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Bibliographies for Physical Properties of Asphalt Cement

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Contents

Introduction

The identification of physical properties that are related to pavement performance was the main objective of Subtask 1.2.1, Identification of Physical Properties. To meet this objective, an annotated bibliography was assembled that includes research papers and reports pertaining to this topic. This bibliography includes a comprehensive review of research studies published in many technical journals, books, conference proceedings, and research reports relevant to the properties of asphaltic materials and their performance.

For the reader's convenience, the bibliography has been divided into five separate sections:

I. **Durability Studies:** those related to field and laboratory studies of the oxidative and steric hardening of asphalt cements and their effect on pavement performance.

II. **Characterization Studies:** those related to methods and procedures used to characterize the rheology of asphalt cements, as well as studies related to the colloidal nature and microstructure of asphaltic materials.

III. **Thermal Cracking Studies:** those related to pavement cracking and the influence of asphalt rheology on this type of pavement distress.

IV. **Moisture Damage Studies:** those related to measurement of physicochemical surface properties of asphalt cements (surface energy and interfacial tension) and their role in the phenomenon of pavement moisture damage. This group also includes studies of the effect of asphalt rheology on adhesion and disbonding.

V. **Fracture, Fatigue, and Rutting Studies:** those related to fracture and fatigue properties of asphalt cements and those relating the asphalt cement rheology to fracture, fatigue, and rutting of asphalt concrete mixtures.

The bibliography contains a total of 497 records. In each record are nine headings that identify the author, title, place of publication, volume number, date, pages, publisher, abstractor, and keywords related to the record. These nine headings are followed by an abstract that highlights the main objective, research approach, and main conclusions of the referenced study.

This publication presents a compilation of the most important technical publications on the subject of physical properties of paving asphalt cements. The bibliography was prepared specifically for use by the researchers in identifying asphalt properties that are performance-related, but it should also aid other asphalt pavement researchers and highway engineers in their evaluation and economic use of materials, design, and construction.

Methodology Used in Constructing the Bibliography

The first step in the literature survey was to use the available on-line engineering data bases relevant to the subject. After a comprehensive review of available data bases, two were selected: The Compendex-Plus data base and the National Technical Information Service (NTIS) data base. The first was selected because it provides the broadest coverage of the world's significant engineering and technological literature. The data base corresponds to the printed publication, Engineering Index, and incorporates additional conference records from the Engineering Meetings data base. The Compendex Plus is known for its international coverage and it contains approximately 25 percent of the documents indexed in a language other than English. It is also one of the oldest data bases with coverage that starts from 1970. At the time of the survey, the size of this data base was more than 2.2 million records.

The second data base, NTIS, provides coverage of U.S. government-sponsored research, development, and engineering plus analyses prepared by federal agencies, their contractors, or grantees. This unique feature of being composed of only government-sponsored research reports made this data base the best complimentary data base to the Compendex Plus, which included a limited number of such research reports. At the time when this bibliography was prepared, the NTIS included more than 1.25 million records; its coverage period starts from 1967.

To conduct the on-line literature search, keywords had to be selected. After consultation with the researchers working for the A-002A project, a final list of 54 keywords was complied. Table 1 lists these keywords. The keywords were then divided into 3 major groups; material group, performance criteria group, and physical properties group. Each of these groups was divided into subgroups, resulting in five performance-criteria subgroups and three physical-properties subgroups. In the on-line search, four different groups were intersected according to a specially designed matrix, as shown in Table 2.

The result of the on-line search yielded 407 records from the Compendex Plus data base and 357 records from the NTIS data base. Those selected were collected and reviewed, and a total of 114 records were selected for inclusion in the different volumes of the present bibliography. Appropriate headings and keywords were selected by the author.

The records selected by the above procedure can be identified from the "Abstractor" heading; those selected from Compendex Plus have the entry "Comp" under the heading.

Table 1. Classification of keywords used for on-line literature searches.

Group	Subgroup	Keywords	No. of Records Found When Intersecting Material Group with Specific Subgroup	
			Compendex Plus	NTIS
I. Material	A	1. Asphalt 2. Bitumen 3. Tar	7,208	3,865
	B	4. Performance 5. Durability 6. Serviceability 7. Pavement (W) performance	760	838
II. Performance Criteria	C	8. Rutting 9. Deformation 10. Plastic (W) deformation 11. Permanent (W) deformation	236	161
	D	12. Stripping 13. Adhesion 14. Disbonding 15. Cohesion 16. Wetting 17. Surface (W) tension	160	142

Table 1. Classification of keywords used for on-line literature searches (continued).

Group	Subgroup	Keywords	No. of Records Found When Intersecting Material Group with Specific Subgroup: Compendex Plus	NTIS
	E	18. Aging		
		19. Age (W) hardening		
		20. Embrittlement or hardening		
		21. Steric (W) hardening	364	217
		22. Oxidation		
		23. Oxygen (W) absorption		
		24. Aging (W) index		
	F	25. Cracking	346	259
		26. Thermal (W) cracking		
III. Physical Properties	G	27. Penetration		
		28. Viscosity		
		29. Softening (W) point		
		30. Ductility	531	345
		31. Fraass (W) brittle point		
		32. Temperature susceptibility		
		33. Coefficient of expansion		

Table 1. Classification of keywords used for on-line literature searches (continued).

Group	Subgroup	Keywords	No. of Records Found When Intersecting Material Group with Specific Subgroup: Compendex Plus	NTIS
	H	34. Stiffness 35. Modulus 36. Compliance 37. Creep (W) compliance 38. Complex (W) modulus 39. Loss (W) modulus 40. Storage (W) modulus 41. Viscoelasticity 42. Complex (W) flow 43. Rheology 44. Rheological 45. Thixotropy 46. Dilatancy 47. Master (W) curve 48. Shift (W) factor 49. Tan (W) delta 50. Shear (W) susceptibility 51. Glass transition temperature	459	219
	I	52. Strength 53. Tensile strength 54. Shear strength	326	271

Table 2. **Matrix of intersections between properties and performance groups used for on-line literature searches.**

Performance Criteria Groups	Physical Properties Groups					
	Routine Tests G		Viscoelasticity H		Strength I	
	NTIS	Compendex Plus	NTIS	Compendex Plus	NTIS	Compendex Plus
Performance--B	115	82	80	86	78	50
Rutting--C	24	33	47	77	27	30
Moisture Damage--D	24	19	16	13	35	14
Aging--E	64	62	32	37	24	17
Cracking--F	29	31	28	40	21	23

while those selected from the NTIS data base have the term "NTIS" under the same heading.

The second source of records in this bibliography is the Highway Research Board (HRB) Bibliographies for Characteristics of Bituminous Materials. These bibliographies were found very useful for abstracting the literature published prior to 1966, which is the starting coverage date of the on-line data bases.

In addition to the other HRB bibliographies, three of them--numbers 35, 40, and 56--were reviewed in detail and from about 1,000 abstracts, approximately 250 abstracts were selected for inclusion in the present bibliography. The selected abstracts were reviewed and categorized, and appropriate headings and keywords were selected for them. The records selected from the HRB bibliographies can be identified by the term "HRB" under the "Abstractor" heading.

The third and last source of the records in the bibliography was the manual selection and abstracting of works published in the traditional asphalt pavement literature. This manual search and abstracting process covered a large number of periodicals, conferences, and books that are known to deal with such literature. Among those reviewed are AAPT proceedings, CTAA proceedings, Transportation Research Board publications, ASTM standards, ASTM proceedings, ASTM Special Technical Reports, Proceedings of the Australian Road Research Board, Journal of Institute of Petroleum, Transactions of Society and Rheology, Journal of Society of Chemical Industry, Reports from Transport and Road Research Laboratory of England, and others.

The extent of manual review of the above sources varied according to type. For example, the AAPT proceedings were surveyed thoroughly starting from Volume 19 (1949) and ending with Volume 57 (1988). The CTAA proceedings were covered starting from 1971, and so on. The availability of the publications and the access to them played a major role in the selection of the articles abstracted. Approximately 130 records were selected by this procedure. They may be identified by the term "PTI" (Pennsylvania Transportation Institute) under the "Abstractor" heading.

Undoubtedly the literature search did not uncover all the relevant articles that have been published. The reviewers endeavored to be very selective and to use their experience to identify the best sources of technical research related to physical properties of asphalt cements. The result, given the time and personal resources devoted to this work, is the present annotated bibliography.

The bibliography entries are arranged in reverse-chronological order within each volume. Also, the keywords are supplied to provide a quick reference about the contents of each entry.

I. Durability Studies

RECORD No.: 1.
AUTHOR : Blomberg, T.; Haekkinen, M. R.; Schueller, S.; Berglund, L
TITLE : Laboratory investigation of Bitumen Aging Properties
JOURNAL : Statens Vaeg-och Trafifinstitut
VOLUME No.: VTI/Meddelande-558
PUBLISHER : Linkoeping (Sweden)
YEAR : 1988
PAGES : 29p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt cements, oxidative hardening, TFOT, RTFOT, penetration, dynamic viscosity, weight loss
ABSTRACT :

Comparative laboratory investigations of the aging properties of bitumen using two standardized methods, TFOT (Thin Film Oven Test, ASTM D 1754) and RTFOT (Rolling Thin Film Oven Test, ASTM D 2872), have been performed. Forty-seven samples of bitumen produced at three refineries from six different crude oils have been examined before and after heating in accordance with TFOT and RTFOT respectively. The parameters investigated are penetration at 25 and 10 degrees C respectively, dynamic viscosity at 60 degrees C, kinematic viscosity at 135 degrees C and change in mass in TFOT and RTFOT respectively. The penetration index, retained penetration and viscosity ratio have been calculated.

RECORD No.: 2.
AUTHOR : Barbooti, Mahmood M.; Al-Soufi, Hussein H.; Al-Saleem, Hisham E.; Hassan, Eman B.
TITLE : Thermogravimetric Studies on Paving Asphalts.
JOURNAL : Journal of Petroleum Research
VOLUME No.: 6, No. 1
PUBLISHER : Council of Scientific Research, Iraq
YEAR : 1987
PAGES : 145-155
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cements, thermogravimetry, composition, performance oxidative hardening

ABSTRACT :

The thermal behavior of two asphalts of different origins, employed for paving in Iraq, was studied during mixing and laying conditions using dynamic thermogravimetry under air and nitrogen atmospheres. The asphalts were prepared in such a way that they would have the same penetration value. The main features of the TG curves were explained and correlated with the chemical composition, method of preparation and performance of the asphalts. Thermogravimetry can be used to aid the standard methods of asphalt testing. (Edited author abstract) 16 refs.

RECORD No.: 3.
AUTHOR : Ishai, Ilan
TITLE : SUGGESTED METHODOLOGY FOR THE ANALYSIS OF ASPHALT AGE-HARDENING.
JOURNAL : Journal of Testing & Evaluation
VOLUME No.: 15, No. 3
PUBLISHER : American Society for Testing and Materials, Philadelphia
YEAR : 1987
PAGES : 127-132
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt Cements, oxidative hardening, penetration, time, temperature, field correlation

ABSTRACT :

This paper discusses a suggested approach for utilization of rheological aging curves for prediction of inservice age-hardening of asphalt which can affect pavement durability. The standard 'one point' evaluation of laboratory aging of asphalts is quite limited with regard to a meaningful, rational, and comprehensive evaluation of asphalt aging with respect to pavement durability. On the other hand, the temperature-time domain should be characterized and investigated by aging curves over a wide range of two-parameter coordinates. An interpretation of asphalt-aging curves in the temperature-time domain is presented that can lead to a reliable calibration of laboratory aging on the basis of actual field aging. The suggested approach and methodology are believed to provide the proper correlation (for a certain asphalt) between laboratory and pavement asphalt aging that can be obtained in almost any of the thin-film or microfilm oven tests. (Author abstract) 15 refs.

RECORD No.: 4.
AUTHOR : Ok-Kee Kim, C. A. Bell, J. E. Wilson, G. Boyle
TITLE : Development of Laboratory Oxidative Aging Procedures for Asphalt Cements and Asphalt Mixtures
JOURNAL : Transportation Research Record
VOLUME No.: 1115
PUBLISHER : Transportation Research Board
YEAR : 1987
PAGES : 101-112
ABSTRACTOR: PTI
KEYWORDS : Oxidative aging, asphalt cements, asphalt mixtures, field samples, POB, resilient modulus, Fraass Brittle Point
ABSTRACT :

An evaluation of an oxidative aging procedure for asphalt materials is described. Test results and the effectiveness of the aging device used are presented. The study also involved laboratory tests on field core samples as well as laboratory mixture samples and asphalt cements used in three projects constructed in Oregon. The procedure selected for aging involved the use of a pressure oxidation bomb (POB)- a sealed container in which asphalt mixture or asphalt samples, or both, were subjected to pure oxygen at 100 psi pressure at 60C for periods of up to 5 days. Resilient modulus and fatigue tests were performed to measure the properties of cores and laboratory mixtures (before and after aging). The asphalt samples were aged on a Fraass plaque to achieve minimum disturbance of the sample, and the degree of aging was assessed by changes in the Fraass breaking temperature. The results of this study showed that the POB was an effective means of producing measurable changes in both mixtures and asphalt samples. However, the mixture properties were substantially different from those measured for the field core samples, whereas the asphalt Fraass breaking temperatures were the same. The resilient modulus ratio and the Fraass breaking point are found good indicators of the aging of mixtures and asphalt cements, respectively. The aging ratio of mixtures varies with the air voids content (higher ratio with higher air voids content). Asphalts aged in the POB for 5 days had compositions comparable to those of recovered asphalts that were from 5 to 10 years old. The laboratory aging period that is equivalent to field aging may vary with the grade and source of asphalt cement as well as mixture properties (particularly air voids and asphalt film thickness), and environmental conditions. Higher pressure or temperature, or longer exposure times, or all three, could be applied to accelerate the aging process. To effectively evaluate mixture aging, representative mixtures must be tested, and if possible these should be core samples obtained shortly after construction rather than laboratory-compiled mixtures that may not represent field mixtures.

RECORD No.: 5.
AUTHOR : MacCarrone, S.
TITLE : Flow and Deformation Properties of Bitumens Service Weathered to Near Distress Level
JOURNAL : Research Memorandum, Australian Road Research Board
VOLUME No.: No. 28
PUBLISHER : Australian Road Research Board
YEAR : 1987
PAGES : 34
ABSTRACTOR: TRRL
KEYWORDS : Asphalt cements, oxidative hardening, steric hardening, test roads, rheological properties, master curves, viscosity, dynamic testing
ABSTRACT :

A study was carried out examining the flow and deformation properties of service weathered bitumens and their corresponding road performance. Bitumen from 39 spray seals was recovered from the cover stones and tested for the range of temperatures and stressing rates experienced in pavement service. A viscosity test conducted at 45 C and a creep test conducted at 0 C both gave information on the response of bitumen under very low rates of stressing. The dynamic data, after being superimposed, gave information on the response of bitumen over a large range of frequency and temperature. The hyperbolic equations of Dickinson and Witt successfully described the frequency dependence of the modulus and phase angle. For weathered bitumens the WLF equation with coefficients derived from this study described the variation of viscosity with temperature in the range -10 to 60 C. The viscosity result (45 C) was a very good indicator of bitumen modulus at low temperature (0 C) and low rates of stressing (thermal contraction) but not at fast rates of stressing (fast moving vehicle). Bitumen viscosity at 45 C is adequately correlated with its service performance and as such it is a suitable parameter for evaluating the field performance of bitumens. However, bitumen modulus calculated at conditions representative of lowest site temperatures and traffic stressing was a marginally better indicator of its service performance. Further studies should be undertaken to confirm the conditions critical to bitumen performance.

RECORD No.: 6.
AUTHOR : J. W. Lund, J. E. Wilson
TITLE : Field Verification of Asphalt Aging in Hot Mix Plants
JOURNAL : Proceedings of the Association of Asphalt Paving Technologists
VOLUME No.: 55
PUBLISHER : Association of the Asphalt Paving Technologists
YEAR : 1986
PAGES : 92-119
ABSTRACTOR: PTI
KEYWORDS : Oxidative aging, viscosity, RTFO, tenderness, field samples
ABSTRACT :

As a measure of aging in the mixing and placement process, the following formula was used to determine the percentage of the expected change in asphalt viscosity at the time of aging:

$$C = \frac{R-A}{B-A} \times 100 \text{ percent}$$

where A=absolute viscosity of original asphalt, B=absolute viscosity of the asphalt residue after rolling thin film over aging, and R=absolute viscosity of the asphalt recovered from the mixture. Asphalt concrete pavement tenderness, due to inadequate aging or unexpected soft consistency of asphalt, has caused problems such as rutting, surface flush stripping, ravelling, and segregation on Oregon highways for the past 10 years. In order to identify the causes of pavement tenderness, data were gathered from 29 different projects in Oregon from 1981 through July, 1983. A total of 111 samples were collected for determining "C" based on field observation. Paving problems were not experienced when "C" was above 50 percent, there were some problems when "C" values were 30 to 50 percent, and problems were always experienced when "C" values were less than 30 percent. In 1985, "C" values were analyzed again to see if any changes had occurred. The comparison of results between the 1981-83 data and the 1983-85 data indicated that "C" value still appears to be a good measure of asphalt properties relating to the tenderness of asphalt paving mixes, especially during the initial placement time.

RECORD No.: 7.
AUTHOR : J. L. Goodrich, L. H. Dimpel
TITLE : Performance and Supply Factors to Consider in Paving Asphalt Specifications
JOURNAL : Proceedings of the Association of Asphalt Paving Technologists
VOLUME No.: 55
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1986
PAGES : 57-91
ABSTRACTOR: PTI
KEYWORDS : Asphalt specification, oxidative aging, viscosity, temperature susceptibility, penetration, ductility, asphalt cements, asphalt mixes
ABSTRACT :

The effect of the current proliferation of asphalt specifications on asphalt manufacturing and supply is discussed. Several recommendations for national, uniform, and functional asphalt specifications are offered. The study focused on present asphalt specifications, the physical properties of world-wide asphalts, the effect of specifications on asphalt supply, specification of asphalt with chemical tests, and whether asphalt specifications can be improved. Wide regional variations in asphalt specifications were found - for AC-20 there are 32 distinct state definitions on the books in 1985. There is, however, a common theme in the asphalt grading system. Specifications were keyed into three functional characteristics of asphalt: its resistance to age hardening during hot mixing, its temperature susceptibility, and its internal compatibility. Data is presented on asphalts manufactured from 80 single crudes. The graphical plot of viscosity ratio (140 F RTFC Vis./Original Vis.), considered to be correlated with hot mix hardening versus temperature susceptibility (PVN 77-140 F), was found useful for users to characterize their local asphalt. To improve present specifications by controlling temperature susceptibility, several measures are recommended: (a) a minimum viscosity at 135 C (275 F), (b) a minimum penetration at 25 C (77 F), (c) computation of equiviscous temperature before and after hot mix hardening, and (d) penetration at 4 C (39.2 F). The penetration at 4 C (20 grams 605 C) was found to be reasonably related to the low temperature creep modulus of actual cores. To define oxidative hardening of asphalts, a maximum viscosity ratio measured at 60 C (140 F) after TRO (or RTFC), and the long-term durability (tilt over durability) at 111 C (231.8 F) and (7 days), which was related to the special case of severe desert conditions, are recommended. To control the homogeneity and internal compatibility, a minimum ductility at 25 C (77 F) on the residues was used. Tests conducted on three asphalts, however, indicated that there is little relationship between ductility before or after oven aging and the ductility of asphalt aged in hot mix cores. Therefore, new tests should be developed. The other recommended measure is minimum solubility in trichloroethylene. For environmental and safety reasons a minimum flash point and a maximum TFO weight loss are recommended.

RECORD No.: 8.
AUTHOR : Al-Soufi, Houssain H.; Luzan, Nina; Na'oom, Suha S.; Al-Saleem, Husham I.
TITLE : CHARACTERISTICS OF SOME IRAQI ASPHALTS - COMPARATIVE STUDY.
JOURNAL : Journal of Petroleum Research
VOLUME No.: 4, No. 2
PUBLISHER : Council of Scientific Research, Iraq
YEAR : 1985
PAGES : 47-62
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt Cements, Oxidative Hardening, temperature susceptibility, penetration, composition
ABSTRACT :

In an attempt to provide better understanding of the behavior of Iraqi asphalts during mixing, laying and service condition; the physical properties, temperature susceptibility, oxidative hardening and stiffness of two asphalts of the same penetration grade produced at Daurah and Qaiyarah refineries were evaluated and correlated to the asphalt composition and origin. The results indicate that the properties of Daurah asphalt are within the internationally accepted limits. While Qaiyarah asphalt, due to its high asphaltene content, shows high viscosity, low temperature susceptibility and high oxidative hardening. (Author abstract) 34 refs.

RECORD No.: 9.
AUTHOR : J. W. Button, J. A. Epps
TITLE : Identifying Tender Asphalt Mixtures in the Laboratory
JOURNAL : Transportation Research Board Record
VOLUME No.: 1034
PUBLISHER : Transportation Research Board
YEAR : 1985
PAGES : 20-26
ABSTRACTOR: PTI
KEYWORDS : Steric hardening, tenderness, penetration, viscosity, temperature susceptibility, resilient modulus, chemical analysis, indirect tensile strength

ABSTRACT :

The physical and chemical properties of asphalt comments and the physical properties of paving mixtures were determined in the laboratory. An attempt was made to relate these properties to tender and slow-setting paving mixtures. Several types of asphalt were used. Four asphalts having different temperature susceptibility properties were used to study change in penetration, measured at 77 F under inert conditions, with time. No relation between setting rate (steric hardening) and temperature susceptibility was observed. Two asphalts were used to study the effect of thin film oven aging on setting rate. The resistance of one of the asphalts to oven aging as measured by penetration appeared to be related to the tenderness exhibited during the early life of the pavement. None of these tests indicated a correlation between the structuring of asphalts after 103 days (measured by penetration), and the setting rate in the field (measured by a subjective numerical tenderness scale). The viscosity at 77 F of another 4 asphalts was measured by a sliding glassplate microviscometer at different times under inert conditions. The structuring--increase in viscosity--rates vary considerably for the different asphalts, but they correlate reasonably well with field experiences. However, viscosity measurements also indicate that there is no relation between setting rate and temperature susceptibility. Chemical analysis of nine asphalts was performed using the Rostler-Stombeg procedure. The data indicated that tenderness is somewhat related to the asphaltene content of the asphalt. Tests on asphalt concrete mixes indicated that resilient modulus and indirect tensile tests at 104 F have the potential to identify tender and slow-setting mixes. Guidelines were provided to avoid tender mixes by laboratory testing.

RECORD No.: 10.
AUTHOR : Q. C. Page, K. H. Murphy, B. E. Ruth, R. Rogue
TITLE : Asphalt Binder Hardening - Causes and Effects
JOURNAL : Proceedings of the Associationof Asphalt Paving Technologists
VOLUME No.: 54
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1985
PAGES : 140-167
ABSTRACTOR: PTI
KEYWORDS : Asphalt hardening, oven tests, viscosity, penetration, asphalt concrete mixes, air voids, mixing temperature
ABSTRACT :

To identify the relationships between binder hardening and certain variables, data from hour temperature-reduction projects in Miami were analyzed to evaluate the hardening trends. Each project contained test sections with two different mix temperatures. Penetration, absolute viscosity at 60 C (140 F), and apparent viscosity at 25 C (77 F) were determined for original and TFOT residue. The same test parameters were also obtained for asphalts recovered by the Abson procedure from samples at the pugmill, paver, and at different time intervals from the in-service pavements. Air void contents were also determined for samples (cores) taken from the pavements. Based on results of the analyses and asphalt hardening trends the following conclusions are derived: (a) the TFOT is considered representative of the hardening which occurs in the hot mix plant for the AC-20 grade asphalt cements used in this study. A high degree of correlation was obtained between the difference in asphalt viscosity (TFOT minus original) and the recovered asphalt viscosity after eight years of service. Asphalts that are susceptible to greater TFOT hardening may also produce greater hardening in the plant mixing process as well as greater in-service age hardening; (b) the effects of age and air void content on asphalt binder hardening are not clearly distinguishable because of changes in air void due to traffic densification. However, when considering air void content at some selected age, the recovered asphalt viscosity or penetration usually indicates harder asphalts for high air void content samples; (c) simulation of in-service hardening appears to be feasible by using asphalt in mixtures compacted to different air void contents and then subjected to heating in an oven at 60 C (140 F) for 12 hours; (d) certain asphalts harden substantially at the high plant mix temperatures whereas other asphalts are unaffected by changing plant mix temperature. The value of TROF or RFT tests may be enhanced by altering test procedures to accommodate a series of test temperatures (e.g. 275 F, 300 F, 325 F, 350 F, and 375 F). The viscosity and/or penetration of these residues would aid in identifying the amount of hardening that could occur at a specific plant.

RECORD No.: 11.
AUTHOR : Delfino, F., Pierini, A.
TITLE : Chemical Compatibility Between SBS Thermoplastic Elastomers and Bitumen
JOURNAL : Muanyag Es Gumi
VOLUME No.: 21, No. 6
PUBLISHER :
YEAR : 1984
PAGES : 110-715
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cements, composition, aging, rheological properties, electron microscopy
ABSTRACT :

Journal Announcement: 8503 Bitumens of various chemical composition were modified by introducing SBS thermoplastic elastomer Europrene A. The morphology of the mixed system was examined by optical and electron microscopy concerning aging and rheological and technological properties. In Hungarian with English abstract.

RECORD No.: 12.
AUTHOR : Christensen, Robert J.; Lindberg, William R.; Dorrence, Samuel M.
TITLE : VISCOUS CHARACTERISTICS OF A UTAH TAR SAND BITUMEN.
JOURNAL : Fuel
VOLUME No.: 63, No. 9
PUBLISHER : Butterworths Scientific Publications, London
YEAR : 1984
PAGES : 1312-1317
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cements, oxidative hardening, temperature, nonlinearity, viscosity, composition, shear history
ABSTRACT :

The material studied was from the Asphalt Ridge, Utah area. The viscosity of the bitumen has been determined as a function of temperature (293-422 K), toluene (solvent) content (0-10%), composition (0-14. 6% asphaltenes), oxidation and shear history. In all cases studied, the Arrhenius plots were significantly non-linear at temperatures above 373 K, with viscous behavior becoming less sensitive to toluene content with increasing temperature. Low temperature behavior was strongly dependent on toluene content. The presence of asphaltenes in the bitumen was shown to be a strong viscosity enhancer. Oxidation and shear history were also shown to measurably increase the bitumen viscosity. 10 refs.

RECORD No.: 13.
AUTHOR : Babu, D. Ram; Cormack, Donald E.
TITLE : EFFECT OF OXIDATION ON THE VISCOSITY OF ATHABASCA BITUMEN.
JOURNAL : Canadian Journal of Chemical Engineering
VOLUME No.: 62, No. 4
PUBLISHER : Chemical Institute of Canada
YEAR : 1984
PAGES : 562-564
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cements, oxidative hardening, low temperature, viscosity, temperature susceptibility

ABSTRACT :

The effect of low temperature oxidation on the viscosity of Athabasca bitumen was investigated over the temperature range 320 to 370K, and to extents of oxidation as high as 41.7 X 10^-3 kg-02/kg-bitumen. Even at this relatively low extent of oxidation, the viscosity was observed to be more than two orders of magnitude higher than that of unoxidized bitumen. It was found that the Andrade viscosity model could adequately characterize the temperature dependence of the viscosity at all extents of oxidation. However, the pre-exponential constant in the model was observed to be a strong function of extent of oxidation. 8 refs.

RECORD No.: 14.
AUTHOR : Gun, R. B.; Khramtsova, V. K.
TITLE : INFLUENCE OF DISPERSED-PHASE CONTENT AND NATURE ON ASPHALT PROPERTIES.
JOURNAL : International Chemical Engineering
VOLUME No.: 24, No. 3
PUBLISHER : American Institute of Chemical Engineers, New York
YEAR : 1984
PAGES : 579-581
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cements, oxidative aging, chemical composition, softening point, penetration, ductility
ABSTRACT :
Asphaltenes recovered from a heavy straight-run residue and from this same residue after different degrees of oxidation were blended with the malthenes from the original residue to prepare model asphalts. The softening point, penetration at 25 degree C and 0 degree C, and ductility of the model blends are plotted as functions of the asphaltene content.

RECORD No.: 15.
AUTHOR : Brion, Y.
TITLE : Colloidal Structure of Bitumens, Relationship Between Composition - Structure Behavior
JOURNAL : Laboratoire Central Des Ponts Chaussees, Paris (France)
VOLUME No.: PC-4
PUBLISHER : LCPC
YEAR : 1984
PAGES : 54p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt cements, age hardening, composition, molecular structure, rheological properties

ABSTRACT :

Bitumen manufacturing procedures, chemical composition, and characterization are reviewed. Several structural states can be defined, corresponding to different rheological behaviors. The factors having an influence on bitumen colloidal stability are also studied, including electrolytic dissociation and the chemical composition of the dispersing media. Artificial aging methods highlight the changes of rheological behavior.

RECORD No.: 16.
AUTHOR : Kandhal, P. S. ; Mellott, D. B. ; Basso, H. R.
TITLE : Durability Study of Viscosity Graded AC-20 Asphalts in Pennsylvania
JOURNAL : FHWA report
VOLUME No.: FHWA/PA-84/009
PUBLISHER : Pennsylvania Department of Transportation
YEAR : 1984
PAGES : 79p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt cements, road tests, oxidative hardening, rheological properties, pavement performance, specifications

ABSTRACT :
This long term asphalt durability project was constructed in September 1976 using six AC-20 asphalts from different sources with the following objectives: (a) to study the changing asphalt properties on aging, (b) to determine the effect of rheological properties of asphalts on the pavement performance and durability especially at low temperatures, and (c) to develop suitable specifications for AC-20 asphalt cements to insure durable pavements.

RECORD No.: 17.
AUTHOR : Ramamurti, K.; Jayaprakash, G. P.; Crumpton, C. F.
TITLE : Microbial Biodeterioration of Asphalt and Related Hydrocarbons - A Literature Review
JOURNAL : FHWA report
VOLUME No.: FHWA/KS-84/1
PUBLISHER : Kansas Department of Transportation
YEAR : 1984
PAGES : 51p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt cements, microbial biodeterioration, oxidation, rheological properties, aging
ABSTRACT :

A survey of the literature related to microbial biodeterioration of asphalt and related hydrocarbons revealed European reports as early as 1895. U.S. studies related to microbial utilization of hydrocarbons date back to about 1940. Later many studies demonstrated microbial utilization of asphalt and related hydrocarbons, particularly the petroleum hydrocarbons. These studies show a fairly large number of microorganisms capable of utilizing asphalt and related hydrocarbons. The microorganisms are normal inhabitants of the soil and often belong to the following genera: Pseudomonas, Micrococcus, Flavobacterium, Mycobacterium, Corynebacterium, etc. The intensity of microbial attack depends on the types of microorganisms, moisture, temperature, oxygen, pH, composition of asphalt, etc. Under favorable conditions, microbial activity could cause rapid oxidation of hydrocarbons but usually any effect on roads would take decades. Several investigators gave specificities relating to bacterial types and described the type of asphalt used in the study. There is some indication that microbial activity can cause changes in the rheological characteristics of asphalt. Bacteria are adaptive, hence bacterial infestations are hard to suppress. The literature surveyed did not reveal any universal panacea for suppression.

RECORD No.: 18.
AUTHOR : J. W. H. Oliver
TITLE : An Interim Model for Predicting Bitumen Hardening in Australian Sprayed Seals
JOURNAL : Proceedings of Australian Road Research Board
VOLUME No.: 12, part 2
PUBLISHER : Australian Road Research Board
YEAR : 1984
PAGES : 112-120
ABSTRACTOR: PTI
KEYWORDS : Asphalts, seal coat, aging, viscosity, yearly mean temperature, prediction model
ABSTRACT :

A number of sprayed seal road trials to monitor bitumen hardening has been laid in different areas of Australia over the past 14 years. Previous analyses have been confined to relating the viscosity of bitumens recovered from the seals to single variables such as durability test result. Sufficient data now exist to develop a multi-variable model of bitumen hardening. Analysis has indicated that the equation

$$\log n = 3.34 + .0394\ YMMT\ (t^{0.5}) - .023\ D\ (t^{0.5})$$

explains 93 percent of the observed variance in log viscosity in 152 sets of test results, where n is the viscosity (Pa.s) of the extracted bitumen, YMMT (C) is the yearly mean of the maximum daily air temperature at the site, D (days) is the ARRB durability test result, and t (years) is the period of seal service. There is insufficient data from pavements near the distress condition for an accurate prediction of viscosity in this region. It is important that the trial sections continue to be sampled to obtain this information as well as information on the bitumen viscosity levels associated with distress in different climatic regions. Once this information has been obtained it should be possible to predict maximum seal life based on durability test result and meteorological parameters for the particular site.

RECORD No.: 19.
AUTHOR : J. C. Petersen
TITLE : Chemical Composition of Asphalt as Related to Asphalt Durability: State of the Art
JOURNAL : Transportation Research Record
VOLUME No.: 999
PUBLISHER : Transportation Research Board, National Research Council
YEAR : 1984
PAGES : 13-30
ABSTRACTOR: PTI
KEYWORDS : Asphalt, durability, composition, aging, oxidation, steric hardening, fractionation, performance
ABSTRACT :
The literature on asphalt chemical composition and asphalt durability was reviewed and interpreted relative to the current state of the art. Two major chemical factors affecting asphalt durability are the compatibility of the interacting components of asphalt and the resistance of the asphalt to change from oxidative aging. Historically, studies of the chemical components of asphalt have been facilitated by separation of asphalt into component fractions, sometimes called generic fractions; however, these fractions are still complex mixtures and their composition can vary significantly among asphalts of different sources. The reaction of asphalt with atmospheric oxygen is a major factor leading to the hardening and embrittlement of asphalt. The hardening phenomenon is primarily a result of the formation, in asphalt, of polar oxygen-containing functional groups that increase asphalt consistency through strong molecular interaction forces. The identification and characterization of the chemical functional types that influence molecular interactions and are normally present in asphalt or formed on oxidative aging, afford a fundamental approach to relating asphalt composition with asphalt properties and thus the performance of both asphalts and asphalt-aggregate mixtures. In addition to the polar chemical functional groups formed on oxidation, asphalt properties can also be significantly altered by molecular structuring, sometimes called steric hardening. This potentially reversible phenomenon, although highly elusive and difficult to quantify in asphalt pavement mixtures, may also be a major factor contributing to pavement embrittlement.

RECORD No.: 20.
AUTHOR : Buelt, J. L.; Barnes, S. M.
TITLE : Aging Test Results of an Asphalt Membrane Liner
JOURNAL : Report
VOLUME No.: DOE/UMT-0064; PNL-4752
PUBLISHER : Battele Pacific Northwest Labs, Richland, WA
YEAR : 1983
PAGES : 57p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt cements, oxidative hardening, composition, oxygen pressure, diffusion
ABSTRACT :

The objective of the asphalt aging study described in this report was to determine the expected performance lifetime of a catalytically airblown asphalt membrane as a seepage barrier for inactive uranium mill tailings. The study, conducted by Pacific Northwest Laboratory for the Department of Energy's Uranium Mill Tailings Remedial Action Program, showed through chemical compatibility tests that the asphalt membrane is well suited for this purpose. The chemical compatibility tests were designed to accelerate the aging reactions in the asphalt and to determine the accelerated aging effect. Higher temperatures and oxygen concentrations proved to be effective acceleration parameters. By infrared spectral analysis, the asphalt was determined to have undergone 7 years of equivalent aging in a 3-month period when exposed to 40 exp 0 C and 1.7 atm oxygen pressure. However, the extent of aging was limited to a maximum penetration of 0.5% of the total liner thickness. It was concluded that the liner could be expected to be effective as a seepage barrier for at least 1000 years before the entire thickness of the liner would be degraded. (ERA citation 08:043346)

RECORD No.: 21.
AUTHOR : E. J. Dickinson
TITLE : The Performance of Thin Bituminous Pavement Surfacings in Australia
JOURNAL : Proceedings of Australian Road Research Board
VOLUME No.: 11, Part 3
PUBLISHER : Australian Road Research Board
YEAR : 1982
PAGES : 35-51
ABSTRACTOR: PTI
KEYWORDS : Asphalt, aging, temperature regimes, oxygen absorption, viscosity, performance, regression models, additive
ABSTRACT :

Low-cost pavement consisting of a granular base surfaced with either a sprayed bitumen seal or a thin layer of asphaltic concrete is an economic construction for the greater part of the Australian (all weather) road network. The performance of the bituminous surfacing in these constructions has a very important bearing on their maintenance costs. If a surfacing has been designed and constructed satisfactorily with a durable aggregate, the onset of distress is decided by the rate at which the bitumen hardens. This rate depends on three factors: the intrinsic durability of the bitumen, the degree of exposure of the bitumen in the surfacing to the atmosphere, and the pavement temperature regimes at the site. Observations of a series of road trials around Australia that were laid in co-operation with the SRAs and measurements of pavement temperature regimes at six different sites have enabled the separate effects of these three factors to be evaluated. A method for assessing the intrinsic resistance of a bitumen to hardening in service has been developed, and hydrated lime promises to be a useful additive for retarding this hardening.

RECORD No.: 22.
AUTHOR : G. R. Kemp and N. H. Predoehl
TITLE : A Comparison of Field and Laboratory Environments on Asphalt Durability
JOURNAL : Proceedings of the Association of Asphalt Paving Technologists
VOLUME No.: 50
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1981
PAGES : 492-537
ABSTRACTOR: PTI
KEYWORDS : Asphalts, hardening, field tests, accelerated lab weathering, viscosity, penetration, ductility, specifications

ABSTRACT :

This asphalt durability study involved the weathering of carefully controlled and fabricated briquettes in four distinctly different field environments for four years. The purpose of the study was to compare the effects of various field environments on asphalts in briquettes to the effects produced on the same asphalts by various laboratory accelerated weathering procedures. The controlled variables included three different asphalts representing high, high moderate, and low temperature susceptibilities; three void ranges, 3-5, 7-9, and 10-12 percent voids; and two aggregate sources representing absorbent and nonabsorbent characteristics. All of the briquettes were weathered in identical trays at each weathering site. In addition, a correlating test road was later studied, using one of the study asphalts in a desert site in the vicinity of the briquette desert weathering site. Laboratory testing of the briquettes was programmed to occur on original, 1-, 2-, and 4-yr-old specimens. Recovery of the asphalt was accomplished using the Abson recovery procedure (AASHTO-T170) prior to testing. Some of the briquettes were tested to determine their resilient modulus (MR) when this procedure became available. Also, a portion of some of the briquettes were sawed into slices to determine hardening with depth. The micro-recovery procedure (California Test 365) was used to recover the small samples of asphalt. Tests on asphalts recovered from briquettes included penetration at 77 F (0.1mm), softening point, ductility at 77 F, absolute viscosity at 140 F, kinematic viscosity at 275 F, and micro-viscosity at 77 F at .05 1/sec shear rate. Several laboratory aging procedures were performed on the asphalts used in this study; Rostler finger printing, asphaltenes dispersions (Heithaus Method), and vanadium content are the compositional types of tests used. The accelerated weathering procedures used in this study were: RTF (5 hr at 325 F), RMF-C at 210 F for 48 hr, Ohawa sand mix weathering at 140 F for time periods up to 1200 hr, weathering plate durability test (California test 347) at 210 F for 24 hr, actinic light weathering test 95 F, 18 hr, 1000 MW/CM of 3660 angstrom actinic radiation, and a new California tilt-oven asphalt durability test. Important findings of the study are: (a) high average air temperature (thermal oxidation) is the most significant factor affecting the rate and amount of asphalt hardening in hot climates. Voids and aggregate porosity are also contributing factors but are dependent upon the type of asphalt

and average temperature. The effect of voids is similar among all asphalts while the effect of aggregate porosity varies among the more volatile asphalts; (b) results from the field test road indicated that briquette weathering per unit time is slightly more severe than actual road weathering; (c) testing of the 2-yr sampling of weathered briquettes indicated that with the exception of the California tilt-oven test, none of the laboratory durability tests can adequately predict the effect of asphalt weathering at field sites. The California tilt-oven tests, however, could be used to predict the asphalt hardening with a good level of accuracy. Tests on the residue from this accelerated weathering procedure could be used with a hot climate specification to control asphalt hardening. Minimum penetration at 77 F of 15, a maximum absolute viscosity at 140 F of 100 kilpoise, and a minimum ductility of 20 cm at 77 F (5 cm/min) are the specification limits on residue properties proposed for hot desert areas; (d) it is recommended that to improve asphalt durability, the voids should be reduced, absorbent aggregates should not be used, the softest grade of asphalt consistent with curing and stability should be used, and the insulation of the asphalt concrete mat with a cover such as a reflective chip seal in hot areas is desirable; (e) the minor study of hardening with depth indicated that, generally, the surface slice showed more hardening due to the effect of actinic hardening. Change of hardening with depth was similar for all types of mixes; (f) effects on temperature susceptibility indicates that, except for the site with the highest average temperature, the effects were negligible. For that one site, the temperature susceptibility decreased continuously with time. Softening point measurements showed a general increase with time. Shear susceptibility as measured by (California Test 348) increased continuously with time but at a lower rate at longer lives. Microductility at 77 F decreased with time at varying rates depending on the site. The most dramatic changes in properties were always seen at the site with the highest average temperature, which indicates the importance of this factor.

RECORD No.: 23.
AUTHOR : Glotova, N. A.; Gorshkov, V. S.; Kats, B. I.; Shapiro, T. M.; Yur'eva, G. N.
TITLE : CHANGES IN RHEOLOGICAL PROPERTIES AND CHEMICAL COMPOSITION OF ASPHALTS UPON AGING.
JOURNAL : Chemistry and Technology of Fuels and Oils (English Translation of Khimiya i Tekhnologiya Topliv i Masel)
VOLUME No.: 16, No. 3-4
PUBLISHER : Plenum Consultants Bureau, New York
YEAR : 1980
PAGES : 278-280
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cements, composition, rheological properties, thin-film aging, viscosity
ABSTRACT :

Differences in the chemical composition of asphalts are responsible for differences in their colloidal and physical properties, particularly their rheological properties. The work reported in this paper represents a study of rheological properties to determine the relationship between changes in chemical composition and rheological behavior of asphalt during thin-film aging. Two grade BNK-5 asphalts were investigated, one from Romashkino crude and the other from Ust'-Balyk crude. Asphalt films with a thickness of 40-60 MU m were prepared and subjected to aging from April to October on a roof exposure rack under the climatic conditions of Moscow. The asphalts were investigated by rheological methods, group analysis, and microchromatography. Test results are tabulated and evaluated. It is shown that the increase in concentration of the solid phase as a result of the appearance of new species and the evaporation of the oils leads to an increase in structurization and viscosity of the system. The asphalt viscosity varies directly with the content of asphaltenes, carbenes, and carboids, and inversely with the quantity of malthene components. 10 refs.

RECORD No.: 24.
AUTHOR : E. J. Dickinson
TITLE : The Hardening of Middle East Petroleum Asphalts in Pavement Surfacing
JOURNAL : Proceedings of the Association of Asphalt Paving Technologists
VOLUME No.: 49
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1980
PAGES : 30-63
ABSTRACTOR: PTI
KEYWORDS : Bitumen, durability test, field trials, oxidative hardening, viscosity, additives, refining processes
ABSTRACT :

This study examined the hardening of the bitumen binders that have been used in pavement surfacing in Australia for the last 15 years. These bitumens have been almost wholly derived from Middle East crude petroleums. A durability test based on an aging procedure developed by the California State Highway Department was used to age seven different asphalts used for seal coats and thin dense hot mix surfacing laid down at different time periods. The viscosity at 45 C and 0.005 1/sec of these aged asphalts were compared with the viscosity of recovered asphalts from field samples. Linear regression analysis was used to relate the durability test results to the viscosity of recovered asphalts from seal coats and to the viscosity of asphalts and air voids content of dense surface mixes. Different regression models were obtained for different ages of test sections. Improving the resistance to hardening in service by using antioxidants and lime, and by blending the bitumens or adjusting the refinery processing was also investigated. Analysis of the data and results of the testing indicated the following conclusions: (a) rate of hardening is dependent on the susceptibility of the bitumen to hardening by thermal reaction with oxygen, the degree of exposure to air, and the temperature regime; (b) the level of hardening at which distress will occur in a surfacing is dependent on the pavement temperature regime in the cold season. Although the rate of hardening is higher in a hot climate, the distress level will also be higher because of the warmer conditions in winter; (c) a durability test that determines the time for a thin film of bitumen maintained at 100 C and exposed to air (in the dark) to reach an arbitrary viscosity level (associated with pavement surfacing distress in temperature climates) was developed to assess the susceptibility to hardening by "Hermal" reaction with oxygen. This test correlated with the hardening observed for different bitumens in seal coats; (d) dense hot mix surfacing trial indicates that the rate of hardening depends on the thermal oxidation of a bitumen as indicated by durability test and the degree of exposure to air as indicated by air void ratio; (e) process hardening by blending precipitated asphalt with propane is preferred to high temperature air blowing. The blending process produces a bitumen with better durability but slightly inferior temperature flow properties; (f) antioxidant zinc diethyl dithiocarbonate decomposed after two years in service and was not an effective oxidation inhibitor. Hydrated lime or lime containing fillers

could be effective for reaching the rate of hardening.

RECORD No.: 25.
AUTHOR : Miller, Richard W.; Dodge, Kenneth S.
TITLE : Effects of Heated Storage on Asphalt Concrete
JOURNAL : NYSDOT, FHWA report
VOLUME No.: NYSDOT-ERD-79-SR-65; FHWA/NY/SR-79/65
PUBLISHER : New York State Department of Transportation
YEAR : 1979
PAGES : 19p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt cements, storage temperature, oxidative hardening, inert environment, field aging, penetration, viscosity
ABSTRACT :

Asphalt hardening in three bituminous concrete top-course mixes was studied after storing at elevated temperatures for periods of 18 and 48 hours in inert gas, and 24 hours in a normal atmosphere. Asphalts extracted from loose mixes before and after storage, and from compacted mixes at the time of placement and after up to 7 years of service, were tested for penetration (77 F), absolute viscosity (140 F), and kinematic viscosity (275 F). The consistency of asphalt in the three mixes was not altered by storage, but delayed hardening was measured in one mix after 1 year of service, the second after 3 years, and the third after 6 years. These differences after once appearing have persisted but have not been reflected in pavement performance. The cause of the delayed hardening is unexplained.

RECORD No.: 26.
AUTHOR : Brown, Ronald A.; Miller, Richard W.; Chamberlin, William P.
TITLE : LONG-TERM EFFECTS OF HEATED STORAGE ON ASPHALT CONCRETE.
JOURNAL : International Journal of Hydrogen Energy
VOLUME No.: 54
PUBLISHER : Pregamon, New York
YEAR : 1977
PAGES : 15
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cements, oxidative hardening, penetration, viscosity
ABSTRACT :

Asphalt hardening in five bitumimous concrete mixes was studied after storing at elevated temperatures for periods of 18 to 24 hr in both inert gas and normal atmospheres. Asphalts extracted from the loose mixes before and after storage, and from compacted mixes at the time of placement and after up to 4 years of service, were tested for penetration (77 F), absolute viscosity (140 F) and kinematic viscosity (275 F). 3 refs.

RECORD No.: 27.
AUTHOR : Brown, R. A.; Miller, R. W.; Chamberlin, W. P.
TITLE : Long-Term Effects of Heated Storage on Asphalt Concrete
JOURNAL : NYSDOT; FHWA report
VOLUME No.: NYSDOT-ERD-77-RR-54; FHWA/NY-77-SSN83-1
PUBLISHER : New York State Department of Transportation
YEAR : 1977
PAGES : 21p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt cements, oxidative hardening, storage temperature, loose mixes, penetration viscosity, asphalt concrete mixes
ABSTRACT :

Asphalt hardening in five bituminous concrete mixes was studied after storing at elevated temperatures for periods of 18 to 24 hours in both inert gas and normal atmospheres. Asphalts extracted from the loose mixes before and after storage, and from compacted mixes at the time of placement and after up to 4 years of service, were tested for penetration (77 F), absolute viscosity (140 F) and kinematic viscosity (275 F). Asphalts from the three fine, dense-graded top course mixes (inert gas for 18 hr, inert gas for 48 hr, and normal atmosphere for 24 hr) were not altered by storage, but delayed hardening was measured in one mix after 1 year of service and another after 3 years. No explanation for the hardening was apparent and pavement performance was not affected. Asphalts from the more open-graded base and binder course mixes hardened significantly during storage. These differences persisted through 4 years of service in one of the mixes but disappeared after 3 years in the other.

RECORD No.: 28.
AUTHOR : Shah, S. C.
TITLE : Asphalt Cement Consistency Study: Field Evaluation of Viscosity and Penetration Graded Asphalt Cements
JOURNAL : FHWA report
VOLUME No.: FHWA/LA/RR-107
PUBLISHER : Louisiana Department of Transportation
YEAR : 1977
PAGES : 64p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt cements, oxidative hardening, field performance, temperature susceptibility, voids content
ABSTRACT :

The report is concerned with the comparative evaluation of durability and field performance of penetration and viscosity graded asphalt cements from four suppliers. The principal findings summarized below are based on 60 month service of sections constructed with these asphalts: (1) The hardening of asphalt cements is a hyperbolic function of time; (2) Asphalt cements with original high viscosity tend to harden more and at a rapid rate; (3) There was no significant difference in durability between the two types of asphalts. Likewise, for a given source, there was no recognizable difference in their performance in pavements, (4) by all durability criteria, asphalts one grade softer than the harder viscosity graded asphalts are more durable and sections constructed with these softer grade asphalts are performing better than any other harder grade asphalts after 60 months of service, (5) there was no association between the high temperature susceptible viscosity graded asphalts and pavement performance. Likewise, there was no association between voids in pavement and rate of asphalt hardening.

RECORD No.: 29.
AUTHOR : Mathey, Robert G.; Rossiter, Jr, Walter J.
TITLE : Properties of 21 Year Old Coal-Tar Pitch Roofing Membranes: A Comparison with the NBS Preliminary Performance Criteria
JOURNAL : NBS report
VOLUME No.: NBSIR-77-1256
PUBLISHER : National Bureau of Standards, Washington, DC Center for Building Technology
YEAR : 1977
PAGES : 27p
ABSTRACTOR: NTIS
KEYWORDS : Coal-tar pitch, roofing asphalts, field performance, tensile strength, coefficient of expansion, elongation modulus
ABSTRACT :

The properties of coal-tar pitch roof membranes approximately 21 years old were compared to the properties reported for such membranes in NBS Building Science Series 55, 'Preliminary Performance Criteria for Bituminous Membrane Roofing.' Samples of the old membranes were taken from eight buildings having roof areas that range from 0.5 to 1.5 million square feet (4.6 to 15 sq km). The buildings were located at three sites in or near the state of Kentucky. The roof membranes on these buildings had been subjected to different maintenance procedures. Laboratory tests conducted on 47 membrane samples included tensile strength, modulus of elongation and coefficient of expansion. The thermal shock factor was calculated for each sample. Laboratory observations were made of the membrane samples to determine between-ply bitumen thickness, weight per unit area, ply adhesion, pliability and condition of the membrane.

RECORD No.: 30.
AUTHOR : Green, E. L.; Tolonen, W. J.; Peters, R. J.
TITLE : PREDICTABILITY TECHNIQUES FOR ASPHALT DURABILITY.
JOURNAL : Transportation Research Record
VOLUME No.: 595
PUBLISHER : TRB
YEAR : 1976
PAGES : 1-8
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cements, oxidative hardening, viscosity, composition, RTFOT, vandium content
ABSTRACT :

This study identified testing techniques that are sensitive to changes in asphalt quality by comparing the results of tests of chemical composition, vanadium content, weatherometer exposure, and rolling thin film oven aging to the durability of environmentally aged specimens. Durability is considered to be measured by the combination of viscosity and asphaltene increases with time. Rankings of each of these testing techniques are compared to actual environmental rankings to illustrate the techniques that best identify the durability changes. 12 refs.

RECORD No.: 31.
AUTHOR : Anderson, Douglas I.; Peterson, Dale E.; Wiley, Max
TITLE : Characteristics of Asphalts as Related to the Performance of Flexible Pavements
JOURNAL : UTAH; FHWA report
VOLUME No.: UTAH-RR-500-925-b; FHWA/RD-76-S0541
PUBLISHER : Utah Department of Transportation, Research and Development Unit
YEAR : 1976
PAGES : 84p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt cements, field performance, cracking, air voids, oxidative aging
ABSTRACT :

Pavement cracking and related distress are the major problem with Utah highways. This study was initiated to isolate the causes and propose solutions to this problem. The most significant factor influencing transverse cracking was found to be the source of asphalt crude. This difference in asphalt performance was found to be related to the parameters temperature susceptibility, force ductility, ductility, aging index, chemical composition, and cannon cone viscosity. The viscosity and penetration grading methods were found to be inadequate in controlling pavement cracking. The high level of air voids content was found to cause a more rapid hardening of the asphalt binder than the low level of air voids.

RECORD No.: 32.
AUTHOR : Roberts, James M.; Gotolski, William H.
TITLE : PAVING ASPHALT PROPERTIES AND PAVEMENT DURABILITY.
JOURNAL : Transportation Research Record
VOLUME No.: 544
PUBLISHER : TRB
YEAR : 1975
PAGES : 14-26
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cements, field performance, oxidative hardening, penetration, viscosity, ductility, composition
ABSTRACT :

Thirteen asphalt concrete pavements built in Pennsylvania were studied from September 1961 to March 1973. As a result of an extensive sampling and analysis program, considerable information has been gained on the durability of asphaltic pavement. Based on physical test data (penetration, viscosity, and ductility) and percentage of asphaltenes, all of the asphalts used in the various pavements hardened with time. 23 refs.

RECORD No.: 33.
AUTHOR : Altgelt, Klaus H.; Harle, Oliver L.
TITLE : EFFECT OF ASPHALTENES ON ASPHALT VISCOSITY.
JOURNAL : Industrial & Engineering Chemistry, Product Research and Development
VOLUME No.: 14, No. 4
PUBLISHER : American Chemical Society, Washington, DC
YEAR : 1975
PAGES : 240-246
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cements, steric hardening, oxidative hardening, viscosity
ABSTRACT :

Asphaltenes are shown to aggregate in solution to different degrees depending on structure, molecular weight, concentration, and solvent power. The viscosity of asphaltene solutions is determined primarily by this aggregation. The effects of concentration and solvent power are very large with asphaltenes of high molecular weight (> 20000) and much less with those of molecular weight <10000. Experiments were conducted with a variety of pure solvents and binary mixtures. The results were extended to real asphalts which are considered as solutions of asphaltenes in maltenes. The aggregation effects are used to explain the differing susceptibilities of various asphalts to oxidation and to blending with cutter stocks. Aggregation also contributes strongly to irregularity in the viscosity of asphalt mixtures. 15 refs.

RECORD No.: 34.
AUTHOR : Glozman, E. P.; Akhmetova, R. S.
TITLE : PROPERTIES OF ASPHALTENES AND ASPHALTS FROM VARIOUS SOURCES.
JOURNAL : Chemistry and Technology of Fuels and Oils (English translation of Khimiya i Tekhnologiya Topliv i Masel)
VOLUME No.: 11, No. 1-2
PUBLISHER : Planum Constultants Bureau, New York
YEAR : 1975
PAGES : 107-109
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cements, oxidative hardening, composition, penetration index, IR spectroscopy
ABSTRACT :

In the reported study the authors have investigated the properties of asphaltenes and model asphalts in relation to the degree and method of oxidation. The original materials from which the asphaltenes were recovered were reduced crudes, asphalts with various degrees of oxidation, and a cracked tar. Elemental analysis showed that the asphaltenes recovered from the oxidized products had lower contents of nitrogen and sulfur than the asphaltenes from the unoxidized products. A highly substituted, condensed structure was present in all the asphaltenes, judging by the IR spectra. Methylene and methyl groups were detected. Carbonyl and hydroxyl groups were observed in all spectra. The spectroscopic results show that the asphaltene structure does depend on the manufacturing technology by which the original material was produced. The oxidation processes used in asphalt production bring about changes in the aromaticity and degree of branching of the asphaltenes and in the content of functional groups in these materials. The asphaltene characteristics are tabulated. The influence of oxidation method on asphaltene and asphalt properties was studied in the example of model systems prepared from deasphalted oil A and various asphaltenes, these asphaltenes having been recovered from asphalts produced by oxidizing West Siberian reduced crude, either in a bubbled batch shellstill or in a continuous tubular reactor. The considerably higher values of penetration index for the products derived from the continuously oxidized asphalt are a further indication of the strong influence of oxidation method on the heat resistance of asphalts. 4 refs.

RECORD No.: 35.
AUTHOR : Kandhal, Prithvi S.
TITLE : Asphalt Properties and Performance
JOURNAL : Transportation Research Record
VOLUME No.: 544
PUBLISHER : Transportation Research Board
YEAR : 1975
PAGES : 72p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt cements, oxidative hardening, road tests, stiffness, viscosity, penetration, RTFOT
ABSTRACT :

The papers in this Record include: a description of changes in the physical properties of six recovered asphalt cements as a function of time in service; a report on results of an extended 12-year study of the properties of recovered asphalts taken from 13 pavements in Pennsylvania; a report on asphalt binder hardening in the Michigan Road Test; a correlation of the low-temperature stiffness of asphalt mixes as measured by creep tests with the low-temperature stiffness estimated from ASTM penetration and viscosity measurements on rolling thin film oven residues and asphalts recovered from mixes; a description of laboratory studies of the blending of asphalts to achieve desired aging index and viscosity properties in the resultant blends; and the cataloging and evaluating of the physical properties of 20 AC-20 asphalt cements to assist in the future development of specifications based on fundamental units of measurement.

RECORD No.: 36.
AUTHOR : P. S. Kandhal, and M. E. Wenger
TITLE : Asphalt Properties in Relation to Pavement Performance
JOURNAL : Transportation Research Record
VOLUME No.: 544
PUBLISHER : Transportation Research Board
YEAR : 1975
PAGES : 1-13
ABSTRACTOR: PTI
KEYWORDS : Oxidative aging, field performance, viscosity, temperature susceptibility, shear susceptibility, ductility, penetration

ABSTRACT :

Six asphalt cements from different sources were used during 1964 in the construction of the pavements studied and reported in this paper. These asphalt cements ranged in viscosity at 140 F from 966 to 2649 poises and in penetration from 62 to 149 units. Tests were conducted to determine the properties of the original asphalts, as well as the asphalts recovered from time to time from the pavements. Pavements were evaluated in 1974 by a team of eight evaluators. Data on the percentage of air voids in the test pavements and the rheological properties of the recovered asphalts indicated that changes in the percentage air voids, viscosity at 77 and 140 F, and shear susceptibility at 77 F followed the following hyperbolic model suggested by earlier investigators:

$$T/y = a + b*T$$

where y = change in test property (such as viscosity, penetration, shear susceptibility) with time; T = time; a = intercept of the equation line on the ordinate; b = slope of the equation line; and = ultimate change (limiting value of change) of the property at infinite time. The term a is primarily a measure of the rate of change or degree of curving of the hyperbola. The experimental data, when fitted to the above equation by the least square regression method, gave excellent correlation coefficient for viscosity, shear susceptibility (tangent of the angle of log shear rate versus log viscosity), and the percentage of air voids. Pavement performance as indicated by the rating rank was affected significantly by the extent of air voids in the pavement. The apparent viscosity at 77 F after pug mill mixing seemed to control the ability of pavements to compact further under traffic at ambient temperatures. Therefore, the air voids should be considered a secondary control factor, since they are affected by other primary parameters, including the apparent viscosity at 77 F after mixing. It is interesting to note here that the viscosity at 140 F did not give good correlation with the ability to compact. Viscosity or shear susceptibility of the aging asphalt alone does not necessarily indicate pavement performance. The rate of gain in shear susceptibility relative to increases in viscosity at 77 F seems to be one of the major factors affecting pavement performance. Relatively lower gain in shear susceptibility with the corresponding increase in viscosity is associated with better pavement performance in this study. The fact that asphalt ductility values were determined at 39.2 F before and after pug mill

mixing seems to be consistent with pavement performance observed. Higher ductility values after pug mill mixing indicate better pavement performance.

RECORD No.: 37.
AUTHOR : Lin, Yung-Yi; Anderson, L. L.; Wiser, W. H.
TITLE : COAL TAR AUTOXIDATION--KINETIC STUDIES BY VISCOMETRIC AND REFRACTOMETRIC METHODS.
JOURNAL : Preprints of Papers - American Chemical Society, Division of Fuel Chemistry
VOLUME No.: 19, No. 5
PUBLISHER : American Chemical Society, Washington, DC
YEAR : 1974
PAGES : 2-32
ABSTRACTOR: Compendex Plus
KEYWORDS : Coal-tar, oxidation, viscosity
ABSTRACT :

Results are presented of an experimental program which was carried out to investigate the kinetics of coal-tar autoxidation. The measurement of viscosity and refractive-index change were regarded as the most convenient ways to determine the extent of coal-tar autoxidation; hence, both of these methods were used in this study. Present-day theory of autoxidation is employed to explain the different mechanisms involved in the autoxidation of whole tar, neutral oils, tar acids, and tar bases respectively, under ambient storage conditions. Extensive experimental data are plotted and evaluated. 10 refs.

RECORD No.: 38.
AUTHOR : Anderson, Douglas I.; Peterson, Dale E.; Wiley, Max
TITLE : Evaluation of Viscosity Graded Asphalt Cements in Utah
JOURNAL :
VOLUME No.: UTAH-RR-500-905
PUBLISHER : Utah State Department of Highways, Salt Lake City. Materials and Tests Division
YEAR : 1974
PAGES : 96p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt cements, road tests, viscosity, penetration, ductility, force ductility, temperature susceptibility
ABSTRACT : .

Test sections were constructed to obtain an indication of the effectiveness of grading asphalts by viscosity. Tests indicate that the standard tests such as viscosity, penetration and ductility are of value as indicators of asphalt quality, but Force Ductility, viscosity vs shear rate, and Temperature Susceptibility are more effective. A chemical breakdown also is a good indicator of asphalt quality, and shows a difference in asphalts mainly dependant upon the source of crude. This difference in source has more effect on performance than does the viscosity grade. Generally, the 'softer' asphalts performed better in Utah's climate. Recommendations are made for desired asphalt properties.

RECORD No.: 39.
AUTHOR : Shahin, Mohamed Y.; McCullough, B. Frank
TITLE : STIFFNESS HISTORY OF ASPHALT CONCRETE SURFACES IN ROADS.
JOURNAL : Highway Research Record
VOLUME No.: 466
PUBLISHER : Highway Research Board
YEAR : 1973
PAGES : 96-112
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cements, asphalt concrete pavements, stiffness, temperature effects, oxidative hardening
ABSTRACT :

A system for predicting the stiffness theory of an asphalt concrete pavement layer throughout its design analysis period has been developed. The system uses standard material properties and environmental inputs to predict the daily changes in stiffness due to temperature variations and also the long-term changes in stiffness due to hardening of the asphalt cement binder. 24 refs.

RECORD No.: 40.
AUTHOR : T. R. J. Fabb
TITLE : Discussion of Paper "Shear Susceptibility of Asphalts in Relation to Pavement Performance"
JOURNAL : Proceedings of Association of Asphalt Paving Technologists
VOLUME No.: 42
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1973
PAGES : 116-124
ABSTRACTOR: PTI
KEYWORDS : Asphalts, test roads, viscosity, shear susceptibility, aging, air voids
ABSTRACT :
In this discussion, the author expresses his concerns about the conclusions drawn in the paper by Kandhal et al. regarding the good correlation found between aging indices and shear susceptibility values of aged asphalts. That good correlation led Kandhal et al. to consider that shear susceptibility is one of the important factors affecting the pavement performance, and that the gain in shear susceptibility should be controlled. Some of the important points in the discussion are summarized as follows: (a) the authors have confused causes and effects. The variation in performance was largely governed by the differences in bitumen consistency in the pug mill, and the consequent variation in initial and traffic compaction. The degree of compaction controlled the air voids and permeability and thereby influenced the extent of hardening and associated increases in shear susceptibility. It is known that consistency and shear susceptibility are highly correlated; (b) using data from the paper, the shear susceptibility is plotted against performance rating. The relation is not sufficiently good; (c) using data from a comprehensive study of 110 surfacings laid in Southern France in May 1963, it can be shown that the rate of hardening in dense, impermeable asphalt surfacings and the consequential increase in shear susceptibility are neglible compared with that experienced by the authors in their work; (d) using data from a road trial carried out in Belgium, it was shown that there is a clear trend of increasing skid resistance as shear susceptibility increases. These results are quoted to offset the impression given by the authors that high shear susceptibility is undesirable; (e) from a rheological/mechanical point of view, high shear susceptibility can convey definite advantages, one of which is a reduction of the change of asphalt stiffness with temperature and loading time. This property can be employed to reduce both the tendencies of asphalt to crack at very low temperatures and to deform at high temperatures; (f) attributing differences in road performance to an increase in shear susceptibility is not well justified by the authors.

RECORD No.: 41.
AUTHOR : C. F. Potts, H. E. Schweyer, and L. L. Smith
TITLE : An Analysis of Certain Variables Related to Field Performance of Asphaltic Pavements
JOURNAL : Proceedings of the Association of Asphalt Paving Technologists
VOLUME No.: 42
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1973
PAGES : 564-588
ABSTRACTOR: PTI
KEYWORDS : Asphalt, field aging, viscosity, penetration, temperature susceptibility, shear susceptibility, air voids, asphalt content

ABSTRACT :

The present work is related to studies on Interstate 10 in the northern part of Florida, which has been in service for nine years. The data collected provide quantitative information statistically analyzed on values of six variables that might be considered as precursors of performance. The variables are: percent asphalt, percent voids, percent retained penetration, viscosity, and shear susceptibility of recovered asphalts. Recovered core samples were inspected from pavements that showed good and poor performance as evaluated by cracking area and deflection measurements at ages of 104 to 134 months from a stretch of highway of about 50 mi in length. The Abson method (AASHTO 170) was used for asphalt recovery. Penetration of recovered asphalts was measured and divided by 92.5 as a representative value of original penetration, because original, exact properties of the asphalts were not known. Absolute viscosity at 25 C, shear susceptibility using the Florida capillary method, and viscosities at 60 C and 135 C (ASTM methods) were also measured. Temperature susceptibility was evaluated by the ratio of viscosity at 60 C to viscosity at 135 C. Statistical analysis of the data collected indicates, unlike the results of other investigators, that temperature susceptibility is a critical factor. A definite trend for this variable with considerable scatter is shown by the data. It has been difficult to determine an exact ranking of the importance of all the variables studied because of the interrelation of the primary variables. Percent voids seems to be the most critical consideration. It appears that when the recovered asphalt viscosity at 77 F exceeds 10 megapoises, poor performance can be expected. Percent asphalt content cannot be used as a criterion, since other factors such as soft asphalt and low voids may compensate for low percent asphalt or vice versa. The percent retained penetration is another indicator synonymous with increased viscosity, but it probably is less sensitive than the later. Both the shear susceptibility and temperature susceptibility appear to be less convincing criterion for performance rating, but their importance may be precluded by the strong indications given for the viscosity. The latter variable may actually control these two variables since they both may not be truly independent.

RECORD No.: 42.
AUTHOR : P. S. Kandhal, L. D. Sandvig, W. C. Koehler, M. E. Wenger
TITLE : Asphalt Viscosity - Related Properties of In-Service Pavements in Pennsylvania
JOURNAL : American Society for Testing and Material
VOLUME No.: Special Technical Publication No. 532
PUBLISHER : American Society for Testing and Materials
YEAR : 1973
PAGES : 66-78
ABSTRACTOR: PTI
KEYWORDS : Asphalt cements, asphalt mixes, durability, evaluation, specification, viscosity, shear susceptibility, temperature susceptibility
ABSTRACT :

Research has indicated that absolute viscosity alone cannot specify the complete rheological behavior of paving-grade asphalts, and other parameters such as shear susceptibility or temperature susceptibility or both are needed. Hence, to study these suggested viscosity-related parameters in relation to the performance of the in-service pavements, six viscosity-graded asphalts from different sources were used in the construction of pavements sections. Tests to determine the viscosity-related properties of the original asphalts, as well as the asphalts recovered from time to time for pavements in service, have been conducted. Evaluation of the performance of these test pavements was carried out using a rating method which reflects effect of aging on pavement condition. The aging index based on viscosity at 77 F (25 C) (.05 1/sec shear rate) was rounded to conform to the pavement performance rating and thus seems to be more meaningful to indicate the comparative aging and life expectancy of the test pavements. The viscosity at 77 F (after mixing in the pug mill), measured using the sliding microviscometer designed by Shell, was found related to the capability of pavements to compact under traffic. Viscosity at 140F using the Cannen Manning Vacuum Viscometer did not show such relation. Shear susceptibility at 77 F of the six aged asphalts was determined after 30-, 42-, and 78-month periods. Very good correlation was obtained between aging indexes (based on viscosity at 77 F) and the shear susceptibility values, which indicates that shear susceptibility is one of the major factors affecting the pavement performance. Data on temperature susceptibility of the asphalts in three temperature ranges (39.2-77 F, 77-140 F, and 140-275 F) for the original and aged asphalts were collected. A decreasing trend of temperature susceptibility was observed with aging in the first two temperature ranges, whereas the increase in the 140 to 275 F range is not appreciable. It appears that the temperature susceptibility parameter may have more significance in the case of low viscosity asphalts. There was an absence of any crack pattern on these test pavements, which can be attributed to temperature susceptibility.

RECORD No.: 43.
AUTHOR : R. J. Schmidt
TITLE : Laboratory Measurement of the Durability of Paving Asphalts
JOURNAL : Symposium on Viscosity Testing of Asphalt and Experience with Viscosity Graded Specifications, American Society for Testing and Materials
VOLUME No.: Special Technical Publication No. 532
PUBLISHER : American Society for Testing and Materials
YEAR : 1973
PAGES : 79-99
ABSTRACTOR: PTI
KEYWORDS : Asphalts, durability, microfilm, test roads, specifications, bituminous concrete, viscosity

ABSTRACT :

The objective of this study was to develop a practical laboratory test to measure reliably the relative durability of paving asphalts. An approximate test must harden a wide variety of asphalts in the same order as for field exposure. The studies reported demonstrated that current asphalt durability tests do not properly relate to field hardening because they exaggerate unrealistically the volatile loss to obtain sufficient oxidative hardening. Four asphalts with widely different hardening properties were used in the study. Asphalt concrete (4 C) specimens using the same aggregates were prepared and exposed in a 140 F oven. At appropriate intervals, specimens were removed, asphalt was recovered, and microviscositics (at 77F, under a uniform stress of 167g/CM^2) were measured. These results were assumed to represent field hardening. Asphalt specimens were then used in running durability tests under different conditions, and the results compared to those of the extracted asphalts from the aged AC specimen. The rolling microfilm oven test (RMFO) was conducted on each asphalt to study the effect of the following: (a) mineral filler and temperature, (b) extra air circulation, (c) capillary venting, (d) simulating hot-mix hardening prior to test, and (e) increasing exposure time. Best correlations were found when using exposure of a 20 nm film at asphalt deposited on the walls of an RTFO bottle (vertical through a .04 lid diameter, 2-in long capillary tube) in an RTF circulating oven for 48 hours at 210 F. No effects of fillers were observed. Comparison of the new RMFC test results on asphalts used in the Zaca-Wigmore and the life of the test sections at 10 percent cracking shows a better correlation than that obtained using the RMFO test results. Comparison of RMFC exposure with hardening in recent California Division of Highways field tests also indicated that this test is useful in ranking asphalts in the same order as they harden in the field. The comparison indicated that asphalts will harden differently in each location and in each different kind of mix. Each different field condition would be represented by an individual curve on a log viscosities chart.

RECORD No.: 44.
AUTHOR : Kemp, G. R.
TITLE : ASPHALT DURABILITY TESTS AND THEIR RELATIONSHIP TO FIELD HARDENING.
JOURNAL : ASTM Special Technical Publication
VOLUME No.: 532
PUBLISHER : American Society Testing and Materials
YEAR : 1972
PAGES : 100-122
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cements, test sections, oxidative hardening, composition
ABSTRACT :

A total of 24 asphalts in 8 test sections are being evaluated relative to their change in viscosity with time. The test sections are located in different climatic areas in California. Statistical correlations are presented covering various laboratory test methods for predicting asphalt durability with 30 and 50 months of pavement service life. The laboratory test methods employed for predicting asphalt durability involve the concept whereby the asphalt is weathered by heat and air in a thin film. The amount of heat and thickness of the film varies, but the end result is basically volatization and oxidation to cause hardening of the asphalt. Additonal correlations are presented using original voids and chemical procedures involving the Rostler analysis and Heithaus procedure. This report discusses the findings to date; additional pavement service life will be required before final conclusions can be drawn. 17 refs.

RECORD No.: 45.
AUTHOR : J. Knotnerus
TITLE : Bitumen Durability-Measurement by Oxygen Absorption
JOURNAL : Industrial and Engineering Chemistry - Product and Research Development
VOLUME No.: 11, No. 4
PUBLISHER : American Chemical Society
YEAR : 1972
PAGES : 411-422
ABSTRACTOR: PTI
KEYWORDS : Asphalt, oxygen, absorption, light, oxidation, inhibitors, weather-o-meter experiments

ABSTRACT :

The absorption of oxygen by bitumens in the light and in the dark was measured at ambient temperature with stirred solutions in an indifferent solvent to avoid problems owing to diffusion effects. The rate of absorption was considerably increased by light (fluorescent lighting) and by traces of certain metals. All chemical-type fractions prepared from bitumens by chromatographic separation oxidized in the light, but only the asphaltenes and resins absorbed oxygen in the dark; this reaction was probably initiated by the stable free radicals present in bitumens. The concentration of reactive components in dark-colored bitumens is higher than in light-colored ones, but in practice the dark color acts as a protection against excessive oxidation in the light. Few of the compounds known to inhibit oxidation reactions appeared to affect bitumen oxidation. Those that were active accelerated oxygen absorption in the light but had hardly any effect in the dark. The effects found with these substances in the light experiments were checked with weather-o-meter experiments.

RECORD No.: 46.
AUTHOR : G. R. Kemp
TITLE : Asphalt Durability Tests and Their Relationship to Field Hardening
JOURNAL : Symposium on Viscosity Testing of Asphalts and Experience with Viscosity Graded Specifications, American Society for Testing and Materials
VOLUME No.: Special Technical Publication No. 532
PUBLISHER : American Society for Testing and Materials
YEAR : 1972
PAGES : 100-122
ABSTRACTOR: PTI
KEYWORDS : Asphalts, test section roads, durability test, viscosity, thin films, hardening
ABSTRACT :

A total of 24 asphalts in 8 test sections were evaluated relative to their change in viscosity with time. The test sections were located in different climatic ares in California. Statistical correlations with 30 and 50 months of pavement service life are presented, covering the results of various laboratory test methods for predicting asphalt durability: Ottawa sand mix (140 F, 400 h, 1000 h), weathering plates (210 F, 24 H), extended RTF (325 F, 5 H), field density briquette (140 F, 90 days), Rostler ratio (N+A1)/(P+A2), percent original voids, Heithaus value P, and Cherron research RMFC. The data analysis indicated that the poorest correlation with field weathering, in general, was obtained with the weathering plate test at 210F used in the tentative specification. The best correlation appeared to be with the Cherron RMFC test, at 48 hours. Correlations for the durability tests were in terms of viscosity at 77 F. Initial air voids were observed to be an important factor in controlling early asphalt hardening. Also more field weathering time is called for before final conclusions can be made on the reliability of the various laboratory test methods for predicting asphalt durability.

RECORD No.: 47.
AUTHOR : Skog, J., Sherman, G.
TITLE : Viscosity Grading for Asphalt Cements
JOURNAL : Highway Research Record
VOLUME No.: 350
PUBLISHER : Highway Research Board
YEAR : 1971
PAGES : 26-29
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cements, oxidative hardening, viscosity, setting, steric hardening
ABSTRACT :

Results presented show that a series of asphalts having original viscosities at 140 F within a narrow band has a very wide range in viscosity after a test that simulates hot-mix hardening. Studies on the relation between asphalt consistency and field "setting" properties of the paving mixture.

RECORD No.: 48.
AUTHOR : Chipperfield, E. H., Duthie, J. L., Girdler, R. B.
TITLE : Asphalt Characteristics in Relation to Road Performance
JOURNAL : Proceedings, Association of Asphalt Paving Technologists
VOLUME No.: 39
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1970
PAGES : 535-613
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cements, test sections, oxidative aging, rheological properties, composition

ABSTRACT :
The behavior of the eight bitumens was studied in dense type hot mix wearing courses subjected to medium to heavy traffic in two European areas, one with a hot and dry summer, the other with a continental cold winter with much heavier rainfall. The paper describes the work carried out on both trails during the first 5 to 6 yr in service. Test work included skid-resistance and deflection measurements. Laboratory investigations were conducted to study changes which have occurred in the chemical composition, rheological properties and general aging characteristics of the bitumens. 10 refs.

RECORD No.: 49.
AUTHOR : ANON
TITLE : Reduce Voids to Improve Asphalt Durability
JOURNAL : Roads and Streets
VOLUME No.: 113, No. 8
PUBLISHER : Fillette Publishing Co., Chicago
YEAR : 1970
PAGES : 78-81
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cements, oxidative hardening, test sections, penetration, void content
ABSTRACT :

How reducing the void content of asphalt concrete pavements to less than 3% improves the lifetime durability. Fifty-three projects in 19 states were tested in detail, 38 were still in service as constructed while the other 15 had been resurfaced. There were 29 asphalt sources represented, with some of the asphalts used on more than one project. A summary of results is given. Effect of voids and filled voids, the relation of void content to penetration of recovered asphalt, and test procedures used are discussed.

RECORD No.: 50.
AUTHOR : Bynum, D. Dr., Traxler, R. N.
TITLE : Gel Permeation Chromatography Data on Asphalts Before and AFter Service in Pavements
JOURNAL : Proceedings, Association of Asphalt Paving Technologists
VOLUME No.: 39
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1970
PAGES : 683-702
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cements, test sections, viscosity, oxidative hardening, composition
ABSTRACT :

Gel permeation chromatography was applied to nine asphalts investigated during a cooperative research conducted by the Texas Transportation Institute and the Texas Highway Dept on the serviceability of 1. 5 in. thick hot mix bituminous pavement surfaces. Extracted and recovered asphalts were tested for viscosity in the same way as the original material to establish the extent of hardening developed in each asphalt during the preparation and construction of the hot bituminous pavement and at intervals of service in the pavement. 9 refs.

RECORD No.: 51.
AUTHOR : Marais, C. P., Jamieson, I. L.
TITLE : Performance of 80/100 Penetration Straight-Run and Air-Rectified Bitumens
JOURNAL : Civil Engineer in South Africa
VOLUME No.: 12, No. 9
PUBLISHER : South African Institute of Civil Engineers, South Africa
YEAR : 1970
PAGES : 203-211
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cements, oxidative hardening, ductility, penetration, composition, field performance

ABSTRACT :

The development of the South African bitumen-producing industry and the introduction of air-rectified Middle East bitumens is outlined. Reasons for air-rectification of bitumen and manufacturing procedures used by South African refineries are given. Air-rectified and straight-run 80/1000 penetration grade bitumens used in premix surfacing experiments are critically examined in terms of the specification for bitumen road cements, a ductilitypenetration curve and a chemical component ratio both suggested by the US Bureau of Public Roads. It is shown that the physical and chemical parameters correlate well with road performance data obtained from these road experiments. 14 refs.

RECORD No.: 52.
AUTHOR : Behl, B. A., Scrivner, F. H., Traxler, R. N.
TITLE : Oxidation of Asphalt Films Measured by Light Scattering
JOURNAL : Indus & Eng Chem-Product Research & Development
VOLUME No.: 8, No. 4
PUBLISHER : American Chemical Society, Easton, PA
YEAR : 1969
PAGES : 453-459
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cements, oxidative hardening, light-scattering, viscosity
ABSTRACT :

The light-scattering technique is a reliable measure of the susceptibility of an asphalt to oxidation. The relation among the light-scattering ratio, relative film thickness, and time in minutes of exposure to ozone, is represented with acceptable accuracy by the equation given. There is a well defined relationship between hardening index (relative viscosity) and the light-scattering ratio of an asphalt. 7 refs.

RECORD No.: 53.
AUTHOR : Majidzadeh, K.
TITLE : Rheological Aspects of Aging-2
JOURNAL : Nat Acad Sciences-Nat Research Council-Highway Research Rec
VOLUME No.: 273
PUBLISHER : HRB
YEAR : 1969
PAGES : 28-41
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cements, oxidative hardening, viscoelastic model parameters, creep compliance, asphalt-sand mixes, activation energy
ABSTRACT :

Effect of aging of asphaltic binder on rheological response of sand-asphalt mixtures is studied; experiment and method of analysis follow procedures outlined in earlier report indexed in Engineering Index 1968 p 2651; Creep response of sand-asphalts at various temperatures and aging were analyzed, and viscoelastic model parameter and overall response were related to asphalt aging index; analysis of activation energy was carried out. 14 refs.

RECORD No.: 54.
AUTHOR : Abu-Elgheit, M. A., Hancock, C. K., Traxler, R. N.
TITLE : Effect of Selected Solvents on Viscosities and Oxygen Contents of Asphalts
JOURNAL : Analytical Chemistry
VOLUME No.: 41, No. 6
PUBLISHER : American Chemical Society, Washington, DC
YEAR : 1969
PAGES : 823-826
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cements, oxidative hardening viscosity, oxygen content
ABSTRACT :

Benzene (a), benzene-ethanol mixture (b), trichloroethylene (c), and 1,1,1- trichloroethane (d) were used to determine their effects as solvents on series of six asphalt cements used in construction of bituminous pavements; magnitude of hardening (measured by viscosity at 25 C) increased in order (a) through (d); oxygen content was determined by neutron activation analysis in original and recovered asphalts; in general, recovered asphalts had lower oxygen contents than reference asphalts.

RECORD No.: 55.
AUTHOR : Bissett, J. R.
TITLE : Changes in Physical Properties of Asphalt Cement under Service Conditions
JOURNAL : Arkansas DOT report
VOLUME No.: HPR-1(6), Research Project No. 17
PUBLISHER : Arkansas Highway Department
YEAR : 1969
PAGES : 98p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt cements, asphalt concrete mixtures, oxidative hardening, penetration, ductility, viscosity, effect of mixing, moisture effect

ABSTRACT :
The purpose of this study was to develop information on the hardening characteristics of asphalt cements used by the Arkansas Highway Department during hot plant mixing and during service in pavements. Asphalt cements from three sources within the State were used in thirteen paving contracts. Samples of asphalt and paving mixture were obtained from each job at the time of construction. Pavement samples representing these materials were obtained three to six months after construction and again after 21 to 42 months service. Extraction and recovery tests were made on the mixtures and pavement samples and the recovered asphalts were tested for penetration and ductility at 77F and 60F and viscosity at 140F. Paving mixtures loose and compacted and stored under water in the laboratory were tested to determine asphalt hardening. A laboratory study of the effect of mixing on hardening also was made. (BPR abstract)

RECORD No.: 56.
AUTHOR : Oakes, D. T.
TITLE : Oxidation Cracking of Asphalt Pavement
JOURNAL : Mississippi DOT report
VOLUME No.: RR-3
PUBLISHER : Mississippi State Highway Department
YEAR : 1969
PAGES : 25p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt concrete mixtures, sonic modulus, stiffness modulus, permeability, air, water, temperature
ABSTRACT :

The report presents a study of weathering effects of fluids on a compacted asphalt aggregate mixture and the mechanisms of deterioration in such a system. Deterioration is measured by changes in sonic modulus, 'Young Modulus' (stiffness), and in permeability (as an indicator of pore channel sizes and distribution of asphalt in the system). The weathering variables include air, water, and temperature. (BPR)

RECORD No.: 57.
AUTHOR : Gotolski, William H.; Ciesielski, S. K.; Smith, R. W.
TITLE : Rates of Asphalt Hardening at In-Service Temperatures
JOURNAL : Pennsylvania State Univ., University Park. Coll. of Engineering.
VOLUME No.: Engineering Research B-100
PUBLISHER : Pennsylvania State University
YEAR : 1969
PAGES : 56p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt cements, oxidative hardening, viscosity, composition, sol asphalts, gel asphalts
ABSTRACT :

Rates of asphalt hardening at in-service pavement temperatures were studied in the laboratory to determine the effect of this factor on the durability of asphaltic concrete pavements. Samples of a sol, a sol-gel, and a gel asphalt, all within the penetration range 85 to 100, were tested at temperatures of 60, 100, 140, and 200 F, at four exposure-time intervals increasing from 0 to 28 days. Changes in asphalt consistency were measured by changes in apparent absolute viscosity and changes in percentage of asphaltenes. Tests results indicated that the rate of change of apparent absolute viscosity depends on temperature, regardless of asphalt type, and that the formation of asphaltenes, after a period of four or five days, is independent of asphalt type and temperature. Though the data for rate of change were similar for the three asphalts, a sol asphalt appears to have the best hardening characteristics for pavement durability. (Author)

RECORD No.: 58.
AUTHOR : Morrison, W. R.
TITLE : Laboratory Investigation of Aging Characteristics of Asphalt Cements Used in Membrane Lining Construction
JOURNAL : Report
VOLUME No.: CHE-91
PUBLISHER : Bureau of Reclamation, Denver, CO, Chemical Engineering Branch
YEAR : 1969
PAGES : 47p
ABSTRACTOR: NTIS
KEYWORDS : Oxidative aging, penetration, ductility, softening point
ABSTRACT :

Laboratory test results are given for an oven aging test and thin film oven test for determining the aging characteristics of asphalt cements used in membrane lining construction. Hardening is allied to penetration, ductility, and an increase in softening point. (Author)

RECORD No.: 59.
AUTHOR : R. W. Culley
TITLE : Relationships Between Hardening of Asphalt Cements and Transverse Cracking in Saskatchewan
JOURNAL : Proceedings, Association of Asphalt Paving Technologists
VOLUME No.: 38
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1969
PAGES : 629-646
ABSTRACTOR: PTI
KEYWORDS : Asphalt, hardening, penetration, viscosity, temperature susceptibility, shear susceptibility, cracking, handling procedures, thin film oven test

ABSTRACT :

Transverse cracking and related pavement performance are major problems with flexible pavements in Saskatchewan. An investigation into the causes of these problems was begun in 1963, and the most significant finding was a relationship between asphalt source or refinery and the amount of transverse cracking. This finding led to a new specification based on tighter viscosity limits for asphalt cement and also to an asphalt usage program based on viscosity criteria. To determine if asphalts produced under the new specifications still resulted in significantly different transverse cracking patterns, a second investigation was begun in 1966. This program consisted of measuring penetration (at 77F) and viscosity (at 60 F and shear rate of 0.05 1/sec) changes and temperature and shear susceptibilities of asphalt, which were sampled at various locations in the transition from the storage tank to 12 months service on five projects. The results of this investigation showed three distinct phases in the hardening of all asphalts, namely, the pre-mixing phase, the mixing-laying phase, and the in-service phase. There is not, however, a significant effect on penetration or viscosity from the various handling procedures within any one phase. Different asphalts are not similar in their hardening behavior. Depending on factors such as environmental temperature range and air voids content, some asphalts harden less during pugmilling than during service, whereas the reverse is true for other asphalts. The use of penetration at 77 F as a measure of hardening over the 12 month period does not show as significant a difference between the asphalts as does the use of viscosity at 60 F or 140 F. Also, viscosities at 140 F and 275 F have little meaning with respect to in-service pavement behavior, therefore test data at 60 F is regarded as more meaningful. Little change in temperature susceptibility was observed as each of the asphalts passed from storage to 12 months of service. Data related to shear susceptibility shows two distinct changes, one during transition from tank to final mix and the other over 12 months of service. The increase in shear susceptibility follows trends of viscosity increase measured at 60 F and 0.05 1/sec. Comparison of losses (changes in penetration and viscosity) from this film oven test with losses from actual pugmilling shows no valid relationship for the particular asphalts tested. Comparison of transverse cracking with hardening of asphalt shows no direct relation

and suggests that transverse cracking is a complex phenomena that is probably more affected by the degree of compaction and environmental conditions than by changes in a single variable, such as penetration or viscosity, during handling or mixing.

RECORD No.: 60.
AUTHOR : Jimenez, R. A.
TITLE : Viscosity and Durability of Asphalts for Paving Mixtures
JOURNAL : N Mex Univ, Proc 6th Paving Conf Dec 12-13
VOLUME No.:
PUBLISHER : University of New Mexico
YEAR : 1968
PAGES : 93-106
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cements, oxidative aging, viscosity, field aving
ABSTRACT :

The report is concerned with measurements of viscosity and durability of asphalt cements used in Arizona to relate their values to the production and performance of asphaltic paving mixtures. The data on asphalt durability were obtained by Shell Oil Co Aging Index procedure. The druability measurements show large differences in the resistance of aging by oxidation of the asphalts tested.

RECORD No.: 61.
AUTHOR : Gotolski, W. H.; Smith, R. W.; Roberts, J. M.
TITLE : A Study of Physical Factors Affecting the Durability of Asphaltic Pavement
JOURNAL : Pennsylvania State Univ., University Park. Dept. of Civil Engineering.(report)
VOLUME No.: RR-IR-9
PUBLISHER : Pennsylvania State University
YEAR : 1968
PAGES : 161p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt cements, oxidative aging, field performance, penetration, chemical composition, viscosity, ductility
ABSTRACT :

The report is a summary of the results obtained, as of the reporting date, in a continuing study of the factors affecting in-service asphalt hardening and pavement durability. Among the factors considered are traffic density, mixture composition, aggregate type and gradation, pavement density and air voids, and asphalt consistency and chemical composition as determined by the Rostler method of analysis. Pavement durability is evaluated by periodic inspection. Asphalt hardening is evaluated principally by changes in composition, penetration, viscosity and ductility. The wearing courses in three pavement groups are studied. (BPR Abstract).

RECORD No.: 62.
AUTHOR : Clark, III, William H.; Thomas, J. J.
TITLE : Early Hardening of Asphalt Cement
JOURNAL : New York State DOT report
VOLUME No.: RR-68-5
PUBLISHER : New York State Dept. of Transportation
YEAR : 1968
PAGES : 56p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt cements, oxidative hardening, pavement performance, road tests, penetration
ABSTRACT :

To determine the effect of hardening of asphalt cement on pavement performance the rates and causes were investigated. Hardening of 46 pavements ranging in age up to 16 years was studied by recovering their asphalt cements by the Abson method and performing penetration testing on the recovered material. A brief review of the state of the art is presented in an appendix. (Author)

RECORD No.: 63.
AUTHOR : A. W. Sisko and L. C. Brunstrum
TITLE : The Rheological Properties of Asphalts in Relation to Durability and Pavement Performance
JOURNAL : Proceedings of Association of Asphalt Paving Technologists
VOLUME No.: 37
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1968
PAGES : 448-475
ABSTRACTOR: PTI
KEYWORDS : Asphalts, aging, TFOT, viscoelasticity, Marshall stability, complex modulus, viscosity, glass-transition temperature, routine testing
ABSTRACT :

There have been many studies on the changes in asphalt consistency with aging. However, viscoelastic properties have been neglected. This paper reports on the use of a modified Weissenberg rheogoniometer (cone and plate viscometer) to measure viscoelastic properties of unaged and road-aged versions of the same asphalts. The aged asphalts were recovered from 12 roads that are well distributed around the country and have been in service for 11 years. An additional road-aged asphalt was also included from a 3-yr road. Also, another 10 asphalts were made available from a study that aged Marshall samples in the field for 345, 730, and 1,230 days. Asphalts used for the Marshall specimens were also aged in the thin film oven test for various periods to compare the field with the oven hardening. Original asphalts, and asphalts recovered from roads, from Marshall specimens, and those aged in the TFOT were tested for penetration at 77 F viscosity at 140 F and 275 F. Composition was determined by a combined solubility and chromatographic procedure. Glass transition temperatures (Tg) of several asphalts were determined with a modified dilatometer, and the changes in molecular size distribution were measured with a Mochrolab vapor pressure Osmometer. The viscoelastic properties of several asphalts were determined by measurements of stress and strain and their strain relationship at 1, 20, 40, 60, and 80 F and at frequencies from 0.001 to 3 cps. The frequency range was extended by combining the data at different temperatures to a reference temperature of 20 F using the relation between frequency and temperature given by the WLF equation. Changes in the asphalts were defined by the ratio of the complex moduli before and after the TFOT, called the mix ratio (a measure of the hardening produced in producing the road), and by the ratio of the complex moduli of the asphalt in the road to the TFOT asphalt, called the age ratio (a measure of age hardening in the road). Roads from which asphalts were recovered were surveyed for evaluation of the extent of cracking, amount of plastic deformation, and riding quality. Analysis and study of the large data collected in the study lead to the following conclusions: (a) aging produces changes in consistency that appear to be due to the development of a gel structure. Hetro-atoms introduced by aging may form secondary valence bonds that are involved in the gel. Evidence for the gel structure comes from a number of observations: the aged asphalt does not flow back

into a crater cut into its surface, the penetration-soften point relation changes, the viscosity increases greatly with a small increase in molecular weight, the WLF constants change, and large changes in viscosity occur without a significant change in glass transition temperature; (b) differences in the complex modulus due to TFOT are small compared to the large differences that may occur in roads; (c) large increases, induced by aging, in the hardness of the asphalt binder (as measured by the complex modulus) are associated with road cracking; (d) the age hardening of asphalt in the road does not correlate directly with the amount these asphalts harden in TFOT; (e) at traffic stress frequencies, unaged and aged asphalts have essentially the same mechanical properties at low temperatures (0 to 20 F); differences due to aging appear at higher temperatures (60 F and higher) and are more conveniently determined by confining the tests to higher temperatures; (f) aging does not significantly change the glass transition temperature; (g) the time-temperature superposition principle allows the construction of master curves of asphalt viscoelastic properties. At temperatures of 0 to 80 F, the general WLF constants are 28.6 and 292; (h) aging shifts the distribution of relaxation times toward longer times and reduces the ability of asphalt to conform to applied stresses.

RECORD No.: 64.
AUTHOR : R. F. Coons and P. H. Wright
TITLE : An Investigation of the Hardening of Asphalt Recovered from Pavements of Various Ages
JOURNAL : Proceedings of Association of Asphalt Paving Technologists
VOLUME No.: 37
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1968
PAGES : 510-528
ABSTRACTOR: PTI
KEYWORDS : Asphalts, aging, viscosity, depth variation, field performance
ABSTRACT :

The purpose of this research was to obtain a precise measure of asphalt viscosity taken from various layers in existing pavement surfaces and to study pavement cores of various ages to measure the magnitude of asphalt hardening that occurs within these layers. The asphalt samples were obtained from 14 existing pavements in Georgia by extraction and recovery from cores. These cores are representative of ages from 4 months to 12 years. Viscosity testing was performed with the sliding plate microvisometer developed by Shell. Absolute viscosity was determined at a shear rate of 0.05 1/sec at 77 F in accordance with procedures proposed by Griffin, et al. Viscosity variations with depth were obtained from asphalt viscosity extracted from five 1/4-in layers of each core. The major increase in viscosity was observed to be in the first layer near the surface, and therefore the variation within that sublayer was further studied by thinner slicing. Increase in viscosity with each 1/4-in layer with age was studied. Also the relation between a relative increase in viscosity and the original viscosity was investigated. The data collected was statistically analyzed to determine major factors affecting viscosity changes. The following conclusions were indicated: (a) there is about a 50 percent increase in the viscosity of asphalt extracted from the top 1/4 in of a pavement over asphalt extracted from depths of 1/2 in; (b) within the top 1/4-in layer there is a greater viscosity immediately under the surface than lower in the layer; (c) viscosity in the upper 1/2 in increases with age, while little change with age occurs at greater depths; (d) at a depth of about 1 1/2 in below the pavement surface, there is little change in viscosity with age except for an initial increase during or before placing: (e) at a depth of about 1 1/2 in below the pavement surface, the relative viscosity is independent of original viscosity.

RECORD No.: 65.
AUTHOR : D. Lee
TITLE : Development of a Laboratory Durability Test for Asphalts
JOURNAL : Highway Research Board Record
VOLUME No.: 231
PUBLISHER : Highway Research Board, National Research Council
YEAR : 1968
PAGES : 34-49
ABSTRACTOR: PTI
KEYWORDS : Asphalts, pressure oxygen bomb, TFOT, oxygen diffusion, oxygen absorption, viscosity, film thickness, oxygen pressure
ABSTRACT :

A laboratory test procedure for evaluating the durability of paving asphalts is proposed that recognizes and is intended to simulate the two-stage hardening of asphalt during mixing processes and subsequent pavement service life. The test consists of first subjecting the asphalt to the thin film oven test (TFOT) and then treating the residue in oxygen at high pressures. The TFOT at 325 F is to simulate the changes that may occur in asphalt during hot-mixing and the pressure-oxidation process at 150 F is to simulate the changes that may occur in asphalt during pavement service life. A 1/8-in film thickness is used in both treatments. The effectiveness of the proposed test in accelerating the hardening and other changes of asphalt, the ability of the test to differentiate asphalts with respect to changes (both physical and chemical), and the effects of time and oxidation pressure were demonstrated by the results of the proposed durability test on five 85 to 100 penetration grade asphalt cements and one of 120 to 150 penetration grade. The properties measured to indicate changes include penetration, softening point, absolute viscosity, asphaltene content, and percent oxygen. The major conclusions from this study are that (a) the approach of the proposed durability test is sound, and the procedure is reproducible; (b) the procedure is capable of accelerating the hardening of asphalt in a relatively short period of time; (c) differences exist among asphalts in hardening during the pressure-oxidation procedure, and therefore the procedure can distinguish between asphalts that are susceptible to hardening and those that are not; (d) the hardening in the pressure-oxidation process is a hyperbolic function of time, which suggests that a definite correlation can be established between field hardening and the proposed laboratory durability test; and (e) continued study into the next phase of the durability test investigation is necessary and warranted so that the information obtained can be put into useful and applied form in asphalt paving design and quality control.

RECORD No.: 66.
AUTHOR : Vind, Harold P.
TITLE : Oxidative Degradation of Asphalt
JOURNAL : NCEL report
VOLUME No.: NCEL-TN-929
PUBLISHER : Naval Civil Engineering Lab Port Hueneme California
YEAR : 1967
PAGES : 20p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt cements, oxidative hardening, modifiers, oxygen, diffusion
ABSTRACT :

Knowledge that the deterioration of asphalt is primarily an oxidative process leads to three general approaches for preventing the deterioration of asphaltic construction mixtures: (1) Agents might be added or other measures might be employed to lower the intrinsic reactivity of asphalt with oxygen, even when the availability of oxygen is not limited; (2) Sacrifical oxygen-consuming agents might be added to the construction mixtures to limit the amount of oxygen available for reacting with the asphalt; (3) Impermeable surface coatings might be applied or fine particles might be added to clog or seal the pores, thereby retarding the diffusion of oxygen through the asphaltic mixtures. The three proposed approaches are applicable irrespective of the involvement of bacteria in the degradation of the asphaltic construction mixtures. Other measures for prolonging the service life of special asphaltic compositions might be the application of heat reflective white coatings to prevent solar heating, or the incorporation of water-absorbing additives to prevent penetration by water.

RECORD No.: 67.
AUTHOR : J. Skog
TITLE : Setting and Durability Studies on Paving Grade Asphalts
JOURNAL : Proceedings of the Association of Asphalt Paving Technologists
VOLUME No.: 36
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1967
PAGES : 387-420
ABSTRACTOR: PTI
KEYWORDS : Asphalts, aging, field performance, durability, setting, viscosity, shear susceptibility, temperature susceptibility, ductility, penetration

ABSTRACT :

This report presents the results of tests that appear to provide necessary measurements for the evaluation of mixing and service life durability and "setting" characteristics during and immediately following construction. Two groups of asphalts were used in the test program. The first was composed of forty 85 to 100 grade paving asphalts from the 1954-55 Bureau of Public Roads test series. The second was a group known as the AC series, which were produced to conform to the 1963 tentative grade requirements of the Asphalt Institute. Changes during mixing were studied using the AASHO thin film oven test and the California rolling thin film test. A satisfactory correlation was found for results obtained by both methods in terms of penetration. However, the California rolling test showed a slightly greater hardening when kinematic viscosities at 140 F and 275 F were compared. It was concluded that either method will provide a test for determining change in consistency during mixing. Specification requirements to provide proper "setting" are presented. These requirements were based on controlling grade and the setting property by specifying viscosity ranges in absolute units at 140 F and 275 F on the residue from the California thin film test. These requirements are expected to ensure an asphalt or more uniform consistency in the paving mixture than is now attained by present or other proposed specification. Results showed that a series of asphalts having original viscosity at 140 F within a narrow band had a very wide range in viscosity after the rolling thin film test. The proposed specifications may control such differences. Tests simulating pavement service life were performed on the two groups of asphalts. The forty 85 to 100 grade paving asphalts were subjected to infrared weathering in an oven for 1,000 hours, which was found to be equivalent to at least 5 years of service life, and in a modified thin film oven test for durability requirements in our tentative specification. Measurements of changes in properties during and at the conclusion of these tests were performed by determining abrasion resistance, viscosities at two different shear rates, and ductility. Studies of property changes indicate that the asphalts may be divided into five groups. Some of the asphalts weather very rapidly from volatilization and chemical change while others weather quite slowly as measured by change in consistency, but the shear susceptibility changes very rapidly with a rapid drop in ductile properties. The results indicated that the asphalts weather in different

ways and could present different forms of pavement failure. This study indicates that an important problem in asphalt specification requirements is the determination of the maximum amount of shear susceptibility that may develop in a paving grade asphalt prior to pavement failure. A good relation between durability residue shear index and micro-ductility for moderate weathering rate asphalts was found. It seems apparent that the development of a high shear index during weathering may have been the cause of failures previously reported in the literature as concerned with a decrease in ductility values. Both factors, shear index and ductility, related to the internal phase relationship of the asphaltic constituents.

RECORD No.: 68.
AUTHOR : F. Moavenzaden and R. R. Stander, Jr.
TITLE : Effect of Aging on Flow Properties of Asphalts
JOURNAL : Highway Research Board Record
VOLUME No.: 178
PUBLISHER : Highway Research Board, National Research Council
YEAR : 1967
PAGES : 1-29
ABSTRACTOR: PTI
KEYWORDS : Asphalts, aging, temperature susceptibility, shear susceptibility, viscosity, energy of activation, asphaltenes content

ABSTRACT :

The effect of aging on the flow properties of three asphalts of different origins was studied at different temperatures. The variables considered included the type of asphalt, the degree of aging, the temperature, and the shear rate. The flow of asphalts was measured by three different viscometers: a sliding plate microviscometer that covered a shear rate change of 0.00001 to 1 reciprocal seconds and a temperature range of 5 to 60 C, capillary viscometers, and a coaxial cylinder type of viscometer. Aging was done with a modified thin film oven with rotating tilted shelves. A limited study was performed to determine the change in the average molecular weights of asphalts and their asphaltene and maltene components. The results of this study showed that for the three asphalts studied and for the method of aging used, aging may result in the following changes: (a) aging increases the degree of non-Newtonian flow behavior. The change in the free energy of activation may be used as a measure of this influence; (b) aging increases the maximum temperature at which non-Newtonian flow behavior is exhibited; (c) as the aging progresses, the asphalt becomes more strongly bonded and less temperature susceptible in the low temperature region (below the softening point temperature); (d) in the higher temperature ranges, however, the situation is quite different. The aging process reduces the size of the large molecules, and their ability to trap the small oily molecules is restricted so that they are more loosely held. Increasing the test temperature can more easily release these molecules, and therefore the asphalt is more susceptible in the higher temperature range after it is aged; (e) the softening point increases with aging. A significant change takes place in the asphalt flow behavior within a narrow range of temperature, and the ring and ball softening point is within this range; (f) the aging of the asphalt to any significant degree does not seem to change the average molecular weight of the asphalt substantially; (g) flow data obtained by different viscometers are consistent, and different viscometers can be used to obtain shear data over a wide range of shear rate or shear stress. The principle of reduced variables can be used to further extend this range by reducing the data obtained at different temperatures to an arbitrary base temperature; (h) aging increases the proportion of asphaltenes in each asphalt. Some breakdown of the complex asphaltene units may be taking place.

RECORD No.: 69.
AUTHOR : E. H. Chipperfield and T. R. Welch
TITLE : Studies on the Relationships Between the Properties of Road Bitumens and Their Service Performance
JOURNAL : Proceedings of Association of Asphalt Paving Technologists
VOLUME No.: 36
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1967
PAGES : 421-488
ABSTRACTOR: PTI
KEYWORDS : Asphalts, age-hardening, viscoelastic properties, loading time, constant stress viscosity, field trials, shear susceptibility

ABSTRACT : .

To assist in the development of significant specifications for road bitumens, two large-scale road trails have been laid in Europe involving eight bitumens of different physical characteristics within the 70/100 penetration grade range. The first trial was constructed in France in 1963 and the second in South Germany in 1964. One area chosen has a largely hot and dry climate, the other has a cold winter. In each trial, two types of mix design, three binder contents for each type of mix, and two types of aggregate were used with each bitumen. Together with control sections, a total of 110 test sections were constructed for each road trial. To measure the extent of deterioration, inspections of the roads were made twice a year by panels of observers. The inspections indicated that there is only slight deterioration that cannot be attributed to bitumen types. Viscosity data on bitumens recovered from samples taken at different stages of construction indicate that much of the initial hardening really occurs during the laying/compaction operation. The different mix designs, in spite of widely different filler contents, did not have much influence on bitumen hardening during mixing. Chemical composition data show that the most significant change during the mixing/laying operation was an increase of n-heptane asphaltenes. After 20 months of service, there were no differences in viscosity increase between coarse- and dense-graded mixes. Viscoelastic properties of the recovered bitumens at loading times representative of traffic stresses were studied using a double cone microelastometer. At short loading times the loss tangent (tan/delta) was shown to be a good measure of the amount of structure of "gel character" in the bitumen as it is aged. A decrease in tan at a particular value of complex modulus will result in an increase of shear susceptibility. Plots of tan versus complex modulus are suggested to study the influence of aging on short time viscoelastic behavior of bitumens. At long loading times it was shown that an aging index based on viscosities before and after aging should be based on viscosities at constant shear stress, rather than at constant shear rate. It was shown that aging index based on viscosities at constant shear rate will vary with shear rate while an aging index calculated from constant shear stress data is reasonably independent on shear stress. Aging indices based on viscosities at constant arbitrary shear rates will tend to decrease with increasing shear rate. The validity of this concept will be fully tested by results emerging from the trials.

RECORD No.: 70.
AUTHOR : R. N. Traxler
TITLE : Changes in Asphalt Cements During Preparation, Laying and Service of Bituminous Pavement
JOURNAL : Proceedings of Association of Asphalt Paving Technologists
VOLUME No.: 38
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1967
PAGES : 541-561
ABSTRACTOR: PTI
KEYWORDS : Asphalts, aging, viscosity, penetration, microductility, asphaltene content, petrolenes viscosity
ABSTRACT :

This paper presents data on the hardening of 85 to 100 penetration asphalt cements (based on viscosity measurements) from the time they entered the hot-mix plant through the laying of the pavement surfacing and two years of service. Thirteen asphalts (made at nine different refineries), employed by the Texas Highway Department in their maintenance program at 13 locations in the state, were used in the study. Density and permeability of mixes, mineralogical properties of aggregates, and viscosity at 77, 95, 140, and 275 F of the asphalt cements (original and recovered) were measured. Ductilities using the California microductility machine at 77 F were also measured. Susceptibility for hardening of the asphalt cements was tested (15 micron films heated in a dark air oven for 2 hr at 225 F). Asphaltene contents were determined on original and 1- and 2-yr-old asphalts. Recovered petrolenes were tested for viscosity at 77 F. Viscosities at 77 and 95 F were made in the thin film (sliding plate) Hallikanien viscometer at .05 1/sec rate of shear. Penetration at 77 F, 100 grams, 5 sec were determined on each original and recovered asphalt. Results indicated that relatively slow hardening occurs during the preparation of a paving mixture at temperature of 250 to 325 F, laying the surfacing and during the first 2 weeks of service. However, from then up to 2 yr the hardening of asphalts is much more. This hardening varies among the different asphalts combined with different aggregates under various service conditions. Asphaltene content increases during the preparation and laying of the pavement and up to 1 yr of service. Between 1 and 2 yr of service the asphaltene content usually increases, but in a few situations an unexplained decrease is noted. This decrease may be related to absorption and absorption of different asphalt components at the surface of the different aggregates. Viscosities of the petrolens, over the 2-year period increased from 1.05 to 20.1 fold. This increase and the increase in asphaltene content with time do not explain the hardening of the films of asphalt cement during service in every case.

RECORD No.: 71.
AUTHOR : Bright, Richard; Justice, Alan; Steele, John
TITLE : The Effect of Viscosity of Asphalt on the Properties of Bituminous Paving Mixtures. Part II. Early Hardening of Asphalt in Hot Bituminous Paving Mixtures
JOURNAL : North Carolina State Univ., Raleigh. Highway Research Program.
VOLUME No.: ERD-100-L
PUBLISHER : North Carolina State University, Raleigh, Highway Research Program
YEAR : 1966
PAGES : 82p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt cements, oxidative hardening, penetration, storage, water, field aging
ABSTRACT :
The investigation was a study of the hardening of the asphaltic binder that occurs in the early life of hot bituminous concrete pavements and in compacted samples cut from the pavements. The rate of hardening was established in hot bituminous wearing surfaces during the first 30 to 60 days of the pavement life. Asphalt of 85-100 penetration grade from four different supply sources and one 170 penetration grade asphalt was used. The hardening of the asphalt in compacted pavement samples was determined when stored at 9F, room temperature, and 140F. The effect of sealing the samples from the air and storing under water was investigated. The effect on the hardening of the rate of cooling of the hot samples was studied. The hardening in the road and in compacted samples varied with the different asphalts used. Hardening occurring in the first 10 days of service was often greater than that occurring in the mixing operation. The hardening of the compacted pavement samples during laboratory storage was very much dependent on temperature. For some of asphalts a sample stored for 20 days at room temperature lost 13% of its penetration. Storing samples under water or at 9F maintained samples close to their original hardness. Sealing samples from the air with thin asphalt layers was not effective in retarding hardening. Rate of cooling had measurable effects on the hardening that occurred. Hardening that had occurred in a few old roads was determined. The asphalt in surface courses of two pavements 15 to 17 years of age showed recovered penetrations of 15 to 18. For other pavements 5 years of age the penetrations of the asphalt varied from 18 to 24. (Author)

RECORD No.: 72.
AUTHOR : Bright, Richard; Steele, John; Justice, Alan
TITLE : The Effect of Viscosity of Asphalt on the Properties of Bituminous Paving Mixtures. Part I. Hardening of Asphalt in Hot Bituminous Base, Binder, and Sand Mixtures
JOURNAL : North Carolina State Univ., Raleigh. Highway Research Program.
VOLUME No.: ERD-110-L "Final Report"
PUBLISHER : North Carolina State University
YEAR : 1966
PAGES : 95p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt cements, viscosity, asphalt concrete mixtures, raod tests, penetration,- density
ABSTRACT :

The purpose of this investigation was to study the effect of the viscosity of the asphaltic binder on the mixing, laying, and compaction of hot bituminous base, binder, and sand asphalt mixes, and to observe the performance under traffic of test strips laid from these mixes. Four test strips were laid for each of the above mixes in which the mix viscosity of the asphaltic binder was varied from approximately 930 to 40 Saybolt Furol Seconds. Temperatures were measured in the pavement at four different elevations during rolling operations. Ross counts were made on the base and binder mixes as they left the mix box, laying characteristics of the mixes were observed, and densities were measured on the finished pavements. Samples of pavement were taken immediately after laying, after 10 months and after 21 or 22 months, and the asphalt extracted and recovered. Penetrations and viscosities were determined on the recovered asphalts. Ross counts and visual inspection showed incomplete coating of the aggregate for all mixes at the high mix viscosities. Base and binder mixes laid satisfactory at all mix temperatures but the sand asphalt showed some tearing at the higher mix viscosities. There was a slight tendency toward higher densities with higher mix temperatures. There was definitely greater hardening in the mix box with increased mix temperature. However, as the strips aged this relationship showed some change. The base and binder mixes made at 250F showed the least hardening after 10 months and 22 months service. Sand asphalt strips showed similar hardness after 21 months. The thicker pavement layers hardened more slowly than thin layers. (Author)

RECORD No.: 73.
AUTHOR : Maine State Highway Commission.
TITLE : Newburgh-Hamp den an Experimental Paving Project Containing 13 Combinations of Fillers and Grades of Asphalt Prepared in cooperation with Bureau of Public Roads, Washington, D. C.
JOURNAL :
VOLUME No.: 210 (507)
PUBLISHER : Maine State Highway Commission
YEAR : 1966
PAGES : 97p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt cements, test roads, oxidative hardening, fillers, modifiers
ABSTRACT :

This study consisted of the design and construction of 13 bituminous concrete test sections on 8 miles of pavement and observation of these over a period of time. The main variables were three grades of asphalt cement and four types of mineral filler. An additional section contained a polymer blended asphalt. Samples of mixture were obtained from construction and the pavement was sampled at two subsequent periods. Samples were tested for density and hardening of the asphalt cement. Generally, the mixtures densified with time and traffic although it was found that densification continued during winter months which was not expected. The filler had more influence on densification than did the asphalt grade. The trends for hardening of the asphalt were inconclusive in that most of the results showed softening following construction. Visual observations indicated little difference in the performance of the mixtures during construction and after four years of service.

RECORD No.: 74.
AUTHOR : Skog, J.
TITLE : Durability of Paving Asphalt. Part I. A Study of the Durability and 'Setting' Properties of Paving Grade Asphalts Manufactured in the United States
JOURNAL : California State Div. of Highways. Materials and Research Dept.
VOLUME No.: M/R-633134-1
PUBLISHER : California State Division of Highways, Materials and Research Department
YEAR : 1966
PAGES : 65p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt cements, temperature susceptibility, oxidative hardening, microductility, viscosity, shear susceptibility

ABSTRACT :

The authors present comprehensive information on the properties of asphalt cements that are associated with essential engineering requirements. Data are included for a series of penetration grades of asphalt cements representing nationwide production in 1954-1955 and a special series of asphalt cements graded by viscosity at 140F also representing nationwide sources. Data are reported to show the rheological properties of the original asphalt and the changes in these properties as a result of weathering by the Shot abrasion test and measurements of viscosity, shear susceptibility and microductility. The authors classify the asphalts into 5 groups, depending upon the changes in the properties induced by weathering.

RECORD No.: 75.
AUTHOR : Lottman, Robert P.; Rao, Anandha M.
TITLE : Durability Characteristics of Asphaltic Materials
JOURNAL : Ohio State Univ., Columbus. Engineering Experiment Station.
VOLUME No.: EES-259-2
PUBLISHER : Ohio State University
YEAR : 1966
PAGES : 89p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt cements, oxidative hardening, viscosity, constnat power, non-Newtonian behavior, composition, intrinsic viscosity, glass-transition temperature, master curves
ABSTRACT :

The conclusions are: (1) The constant-power calculated viscosities of the oven aged asphalts increased more rapidly with increasing oven temperature than with oven time; (2) The aging index values of the asphalt differed at a given viscosity test temperature and for a given asphalt and aging, the aging index increased with decreasing test temperature; (3) Using viscosity-shear plots, the asphalts were shown to have different degrees of non-Newtonian characteristics. Generally, non-Newtonianism increased as aging increased and as test temperature decreased; (4) The percent asphaltene content increased with oven aging, being highest for the most non-Newtonian asphalt and lowest for the least non-Newtonian asphalt; (5) As aging increased, the change in intrinsic viscosity of aged asphalt solutions in benzene increased. Excepting asphaltenes from the least non-Newtonian asphalt, the asphaltene intrinsic viscosity increased at a greater rate beyond a 'critical degree' of aging for each asphalt, indicating that the asphaltenes increase in size weight rapidly above some aging severity; (6) Molecular weights of asphaltenes were determined indirectly by calculations using Staudinger's equation with the intrinsic data. Due to the equation, molecular weights increased with aging in the same manner as intrinsic viscosity did, weights ranged from 900 to 1400 grams per mole; (7) Limited glass transition temperature data were obtained. It was found that by using the glass transition temperatures and log viscosity versus reciprical temperature plots obtained for the asphalt, plots of the unaged and aged asphalt samples could be shifted by use of the Williams-Landel-Ferry equation to a 'reference' plot. (Author)

RECORD No.: 76.
AUTHOR : Wright, Paul H.; Paquette, Radnor J.
TITLE : The Hardening of Asphalt in Hot Bituminous Mixes During the Hauling Process
JOURNAL : Report
VOLUME No.: A-711; 0605
PUBLISHER : Georgia Institute of Technology, Atlanta, Engineering Experiment Station
YEAR : 1966
PAGES : 77p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt cements, oxidative aging, field performance, mixing, hauling

ABSTRACT :
The research reported herein was performed at Georgia Tech under the sponsorship of Georgia Highway Department and the Bureau of Public Roads to determine the significance and seriousness of asphalt hardening during the period of haul. Samples of hot bituminous mix were taken from trucks traveling enroute from the mixing plant to the paving site at times of one, two, and four hours after preparation of the mix. In addition, mix samples were taken immediately after mixing, and after the material had been placed on the roadway. A total of about 100 field samples were taken from ten trucks, including asphalts manufactured from four sources of crude. (Author)

RECORD No.: 77.
AUTHOR : Moavenzadeh, Fred; Stander Jr, Richard R.
TITLE : Durability Characteristics of Asphaltic Materials
JOURNAL : OSU report
VOLUME No.: EES-259-1; 0573
PUBLISHER : Ohio State University, Columbus. Transportation Engineering Center
YEAR : 1966
PAGES : 247p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt cements, rheological properties, viscosity, master curves, oxidative hardening, composition, model, glass transition temperature
ABSTRACT :

The work included: (a) The rheologic analysis of the flow behavior of three asphalts under different shear rates and at various temperatures. (b) The use of three viscosity measuring instruments to obtain rheologic properties over a wide range of temperature and shear rate. (c) The aging of the asphalts to different levels and the determination of their flow behavior. (d) The application of various rheologic models, including especially the hyperbolic sine model, to the flow of asphalt. (e) The chemical separation of the asphalts into asphaltene and maltene components and the determination of aging effects on these components. (f) The measurement of intrinsic viscosity of the aged and unaged asphalts and their components to determine the effects of aging on composition and molecular weight. (g) A limited study of tests such as glass transition and direct molecular weight. (Author)

RECORD No.: 78.
AUTHOR : F. Moavenzadeh, and R. R. Stander
TITLE : Durability Characteristics of Asphaltic Materials
JOURNAL : Research Report EES-259
VOLUME No.: 259-1
PUBLISHER : Ohio State University, Department of Civil Engineering
YEAR : 1966
PAGES : 236
ABSTRACTOR: HRB
KEYWORDS : Oxidative aging, asphalt cement, rheological properties, critical shear stresses, free energy of activation
ABSTRACT :

Relations between the mechanical variables and the degree of aging of asphaltic materials were studied to determine the effect of aging on such a relationship. Rheologic analysis was made of the flow behavior of three asphalts under different shear rates and at various temperatures using three viscosity measuring instruments. Asphalts were aged to different levels and their flow behavior determined using various rheologic models, including the hyperbolic sine model. The intrinsic viscosity was measured of the aged and unaged asphalts and their components to determine the effects of aging on composition and molecular weight. Glass transition and direct molecular weight tests were studied. It is concluded that flow data obtained by different viscometers are consistent when adjusted for errors of the geometry of the instruments, and the temperature dependency of viscosity requires that viscosity variation with temperature at fixed shear be larger than that at fixed shear rate. An examination of the applicability of Eyrings hyperbolic sine relation to the analysis of the flow of the three asphalts used reveals that: 1. For these three asphalts there exist critical shear stresses, beyond which the hyperbolic sine relations fails to represent the flow behavior of each material, and 2. When these critical shear stresses are within the experimental range, the flow results cannot be represented by such a relationship. The degree of aging influences the non-Newtonian response of the material, and the change in the free energy of activation may be used as a measure of this influence. The aging of the asphalt to any particular degree does not seem to change the average molecular weight of the asphalt substantially.

RECORD No.: 79.
AUTHOR : K. G. Martin
TITLE : Influence of Stabilizers on Bitumen Durability
JOURNAL : Journal of Applied Chemistry
VOLUME No.: 16
PUBLISHER : Society of Chemical Industry, London
YEAR : 1966
PAGES : 197-202
ABSTRACTOR: PTI
KEYWORDS : Asphalt, aging oxidation, viscosity, hardening, antioxidants, solar radiation, P.O.B.

ABSTRACT :

Combinations of 8 asphaltic bitumens and 12 selected antioxidants have been examined for susceptibility to oxidative hardening. Bitumen films 40 microns thick were oxidized at 300 psi in the dark and by simple exposure to solar radiation. Subsequent changes were determined with the sliding plate microviscometer. Many combinations exhibited improving stability and their behavior is discussed in relation to the current theory of autoxidation of hydrocarbons.

RECORD No.: 80.
AUTHOR : Pagen, Charles A.
TITLE : Effect of the Viscosity of Asphalt on the Rheological Properties of Bituminous Mixtures
JOURNAL : OSU report
VOLUME No.: EES-191-4; 0303
PUBLISHER : Ohio State University, Columbus. Department of Civil Engineering
YEAR : 1965
PAGES : 91p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt cements, viscosity, mixtures, linear viscoelasticity, oxidative aging, field performance
ABSTRACT :

To analyze the effects of asphalt viscosity or temperature on the mechanical properties of bituminous concrete, constant load compressive tests were employed. Using a standard creep testing program, the instantaneous elastic, retarded elastic, and viscous deformation were recorded and analyzed. Correlations were developed between original and recovered binder viscosity, mixture rheological strength moduli, and mixture deformations for a wide range of loading times and temperatures. The applications of linear viscoelastic theory, apparent activation energy concepts, and time-temperature superposition principle were investigated and validated. Equations of state relating stress, strain, time, and temperature-dependent behavior were developed and evaluated. These can be used to evaluate mechanical properties which cannot be obtained experimentally and to reduce the number of experiments needed to define the response of bituminous mixtures. (Author)

RECORD No.: 81.
AUTHOR : C. Mack
TITLE : An Appraisal of Failure in Bituminous Pavement
JOURNAL : Proceedings of Association of Asphalt Paving Technologists
VOLUME No.: 34
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1965
PAGES : 234-247
ABSTRACTOR: PTI
KEYWORDS : Asphalts, asphalt concrete, aging, complex flow, viscosity, penetration, ductility, aggregate, coefficient of expansion

ABSTRACT :

Failure in bituminous pavements consists, in general, of the formation of cracks that result from external forces being greater than the cohesive forces of the asphalt. Based partly on experimental evidence, it has become customary to relate loss in cohesive forces of weathered asphalts with an increase in consistency as determined by viscosity, penetration, and ductility tests. Weathered asphalts at constant temperature have flow properties that vary with the magnitude of shearing stress. At low stresses up to a certain limit, the viscosity is constant and the shear stress is proportional to the shear rate. Beyond this stress limit, the flow in non-Newtonian and the shear stress is proportional to the shear rate raised to the power of b. It requires, therefore, three constants to characterize the flow properties of non-Newtonian asphalts in the described stress range. It is suggested to compare the viscosities at a given shear rate of an asphalt before and after weathering as a measurement of durability without taking the flow properties into consideration. It is shown that this disregard can lead to wrong interpretations of the tests and can lead, under certain circumstances, to lower viscosities and higher penetrations of the weathered asphalts than those of the originals. Flow properties at low stresses are difficult to measure, but based on the behavior of asphalts in pavements, a large amount of weathering is accompanied by a large decrease in the value of the parameter b, which can be easily obtained from viscosity as well as penetration measurements. The significance of ductility is discussed in the light of present knowledge, and it is shown that a decrease in the ductility of an asphalt after weathering is also accompanied by a decrease in the value of the parameter b. A great change in the flow properties of a weathered asphalt is not the cause but the effect of failure in a pavement. Failure is due to the presence of large residual stresses in the asphalt film, which are mainly caused by the considerable difference in the coefficients of expansion of mineral aggregate and asphalt. This phase is discussed on the basis of the total energy present. It is demonstrated that residual stresses can be reduced and the durability of the pavement improved by proper selection of the mineral aggregate.

RECORD No.: 82.
AUTHOR : Joseph F. Goode and L. A. Lufsey
TITLE : Voids, Permeability, Film Thickness vs. Asphalt Hardening
JOURNAL : Proceedings, Association of Asphalt Paving Technologists
VOLUME No.: 34
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1965
PAGES : 430-463
ABSTRACTOR: PTI
KEYWORDS : Oxidative aging, asphalt mixes, Marshall stability, penetration, softening point, ductility, air permeability

ABSTRACT :

Five different combinations of aggregate containing crushed stone, natural sand, and limestone dust were used along with an 85 to 100 penetration grade asphalt for the mixtures of this study. Test specimens were molded by means of a motorized gyratory compactor employing a procedure that simulates the 50-blow Marshall density. At least three specimens of each mixture were prepared and tested for each of four aging conditions. Upon completion of aging, the specimens were tested for Marshall stability and extracted for tests on recovered asphalt, which included penetration, softening point, and ductility. Prior to the Marshall tests, and in a few cases prior to aging, selected groups of specimens were tested for air permeability using a new device developed by the Bureau of Public Roads. Additional determinations included the surface area for each aggregate combination, an index of asphalt film thickness for each mixture, and the density, air voids, and mineral voids for each set of specimens as molded. As was the case in an earlier study where gravel was used as the coarse aggregate, the results of this study indicate that 0.435 might be a better exponent for indicating maximum density than the 0.45 exponent used in setting up the Bureau of Public Roads gradation chart (1962 AAPT paper by the authors). Air permeability was found to be a function of aggregate gradation as well as air voids. The air permeability of mixes designed at about 4 percent air voids was a very low value regardless of gradation, and does not appear to be needed as a mix design criterion for dense-graded mixtures. Air permeability or air void content, per se, do not appear to be factors affecting the rate of asphalt hardening. Air voids combined with asphalt film thickness, or with an asphalt coating index that is related to film thickness, does appear to be an important factor affecting the rate of asphalt hardening.

RECORD No.: 83.
AUTHOR : F. Moavenzadeh and E. B. B. Sendze
TITLE : Effect of Degree of Aging on Creep and Relaxation Behavior of Sand-Asphalt Mixtures
JOURNAL : Highway Research Board Record
VOLUME No.: 104
PUBLISHER : Highway Research Board
YEAR : 1965
PAGES : 102-123
ABSTRACTOR: HRB
KEYWORDS : Oxidative aging, creep parameters, asphalt cements, asphalt concrete mixes, viscosity, modulus of recovery
ABSTRACT :

Previous work on the study of aging was reviewed. The creep parameters of mixture viscosity and modulus of recovery developed by Wood and Goetz were selected for comparing creep characteristics of aged and unaged mixes. Mixes comprised (by wt of aggregate) 9, 12, and 15 percent asphalt content (60-70 penetration grade) and Ottawa sand (maximum size, No. 16) with gradation corresponding to ASTM D 1663-59T. Mixes were aged at 77 (unaged), 140, and 225 F for 1 week. Specimens, 3.5 cm in diameter, 7 cm high, were tested in creep and relaxation. Maximum creep strain was limited to 1.2 percent and the relaxation strain was 1.4 percent. The rate of creep generally showed a decrease with the increase in aging. With higher asphalt content, the difference in the creep rates was less marked. Maximum relaxation load increased with aging. Semilog relations were developed showing the variation of mixture viscosity with degree of aging and the relation of maximum relaxation load to degree of aging.

RECORD No.: 84.
AUTHOR : Thomas, Jerome J. ; Dixon, William C. ; Clark, William H.
TITLE : Additional Study of Asphalt Concrete Mixing Time
JOURNAL : NY DOT report
VOLUME No.: (Final rept)
PUBLISHER : New York State Department of Public Works
YEAR : 1965
PAGES : 47p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt cements, oxidative aging, mixing practices, penetration viscosity, aggregate properties
ABSTRACT :

The investigation was to obtain further information regarding the reduction of specified mixing time requirements for hot bituminous concrete mixtures. The report presents the results of tests on the percentage of coarse particles coated, as determined by the Ross Count Method. Other tests conducted included aggregate gradation and asphalt content to determine mixture uniformity; and penetration or viscosity tests on recovered asphalt to determine the degree of hardening of asphalt during mixing. It was found that (1) batch plants should be evaluated individually to establish minimum mixing times for specific mixtures, (2) for three-ton capacity plants, aggregates in top and binder mixtures were adequately distributed and coated with about 10 seconds dry-mixing and 25 seconds wet-mixing, and for base course mixtures, 10 seconds dry-mixing and 35 seconds wet-mixing; (3) plants of larger capacity may require longer mixing times; and (4) equipment in many batch plants would prevent a reduction in mixing time below that needed for adequate coating and distribution. Asphalt hardening occurred during the first 15 seconds of wet-mixing but no additional hardening could be attributed to continued mixing. The report includes new specification requirements which will permit reductions in mixing time below a minimum of 15 seconds dry-mixing and 45 seconds wet-mixing.

RECORD No.: 85.
AUTHOR : Bishop, J. A.
TITLE : Surveillance of NAS Alameda Runway Pavement
JOURNAL : NCEL report
VOLUME No.: NCEL-N600
PUBLISHER : Naval Civil Engineering Lab Port Hueneme California
YEAR : 1964
PAGES : 20p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt cement, asphalt concrete mixtures, penetration, compressive strength, field performance

ABSTRACT :
A high type asphaltic concrete overlay of a badly deteriorated runway at NAS Alameda, California, is being monitored to determine changes in properties with time. Changes in the compressive strength of cores taken from the pavement and changes in the penetration of the asphalt cement binder taken from these cores during the first three years following construction are presented. Though the data are somewhat scattered, it is apparent that the compressive strength is increasing and the penetration is decreasing. A prediction is made of values of these quentities expected seven years after onstruction. Similar tests were made on cores and on asphalt taken from the underlying pavement. No trends are apparent from these data, indicating that the older pavement is in a terminal condition. That is, it is not expected that substantial changes in the pavement properties will take place in the future. (Author)

RECORD No.: 86.
AUTHOR : K. G. Martin
TITLE : Evaluation of the Durability of Roofing Bitumens
JOURNAL : Journal of Applied Chemistry
VOLUME No.: 14
PUBLISHER : Society of Chemical Indsutry, London
YEAR : 1964
PAGES : 423-435
ABSTRACTOR: PTI
KEYWORDS : Roofing asphalts, oxidative aging, pressure oxygen bomb, light, water, rheological properties, performance

ABSTRACT :
A wide range of types and grades of roofing bitumen were subjected to bulk heating, pressure oxidation, solar exposure, and water immersion separately, and the resulting changes in rheological properties determined. Particular attention was given to the use of a sliding plate microviscometer and the means of overcoming the complexities of non-Newtonian behavior and shear rupture to develop evaluations, oxidation resistance and solar exposure resistance, involving initial viscosity, rate of increase of viscosity and a critical viscosity at rupture. Results of these tests are discussed in relation to the performance of the bitumens when exposed outdoors for 2 years as model roofs with various surfacings and evaluated by visual rating, microviscometry, and solvent analysis. Agreement is good, and the advantage in durability by using as low a softening point bitumen as possible is indicated, except for aluminum-painted coatings.

RECORD No.: 87.
AUTHOR : Woodrow J. Halstead
TITLE : The Relation of Asphalt Ductility to Pavement Performance
JOURNAL : Proceedings, Association of Asphalt Paving Technologists
VOLUME No.: 32
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1963
PAGES : 247-270
ABSTRACTOR: HRB
KEYWORDS : Ductility test, pavement performance, ductility-penetration relation

ABSTRACT :
Since its introduction in 1903 the ductility test for asphalts has been, and still is, controversial. Some asphalt technologists believe that the test is an indication of a necessary property of asphalt related somewhat to its adhesive properties or stickiness, while others consider the present laboratory test for ductility of no value for indicating the potential quality of an asphalt as a paving material. A review of the literature offers support for both of these divergent views. These contradictions suggest a need for a careful evaluation of the significance of the ductility test and its relation to other properties of the asphalt cement and a restudy of some of the available data to determine if there is a satisfactory explanation for the opposing viewpoints. This report, which is part of a general symposium on the properties of asphalt that affect pavement performance, emphasizes the advantages of considering the ductility-penetration relationship of an asphalt in evaluating the effect of the asphalt characteristics on pavement performance. When available data are analyzed on this bases, there is a strong indication that the consistency at which the asphalt begins to lose ductility rapidly and the temperature at which such consistency occurs is a significant relationship. It is also indicated that for some asphalts this point occurs at a sufficiently low penetration (or temperature) so that factors other than ductility, as measured in the laboratory test, control pavement performance. Hence, the conclusion is often reached that ductility is unimportant.

RECORD No.: 88.
AUTHOR : K. A. Lammiman, T. Les and W. J. Way
TITLE : Field and Laboratory Studies on the Durability of Road Bitumen
JOURNAL : Journal of Applied Chemistry
VOLUME No.: 12, No. 11
PUBLISHER : Society of Chemical Industry, London
YEAR : 1962
PAGES : 510
ABSTRACTOR: HRB
KEYWORDS : Road performance, asphalt hardening, stripping, penetration, field hardening rates
ABSTRACT :

Study showed only small differences in the road performance by seven asphalts from Middle East, Mexican and Venezuelan crudes used on dolertite or quartzite aggregates, although asphalts from one of the Middle East sources had the best combination of properties. Stripping and binder hardening were the major causes of failure of the quartzite and dolertite road sections, respectively. A broad relationship was observed between hardening and road performance. The original asphalts had different hardening tendencies in the Accelerated Weathering and Thin-Film Oven tests, the results of which correlated well with the relatively great changes in penetration occurring during mixing and laying, and in the early life of the road, After a year or so, penetration differences between the weathered binders become small. The road hardening rates were similar in all cases, and followed a hyperbolic equation.

RECORD No.: 89.
AUTHOR : Paul G. Campbell, James R. Wright, and Phil B. Bowman
TITLE : The Effect of Temperature and Humidity on the Oxidation of Airblown Asphalts
JOURNAL : American Chemical Society, Division of Petroleum Chemistry
VOLUME No.: Preprints 7, No. 3
PUBLISHER : American Chemical Society
YEAR : 1962
PAGES : 123
ABSTRACTOR: HRB
KEYWORDS : Oxidative aging, temperature, relative humidity, outdoor exposure, irradiation
ABSTRACT :

A direct comparison based on carbonyl index, of the effects of temperature and relative humidity on asphalts exposed in accelerated weathering machines for a fixed period of time is not possible because the oxidation rate of each asphalt varies with exposure time. The effect of temperature and relative humidity on asphalt oxidation as a function of exposure time showed that the rate of oxidation is dependent on both of these environmental factors. However, the effect may be shown during the induction period, in the slope of the oxidation-rate curve, or in the time required to produce film failure due to cracking. In general, asphalt durability varied inversely with the temperature and relative humidity, respectively. It is proposed that the effect of temperature and humidity on asphalt oxidation rates may be due to the formation and subsequent decomposition of an asphalt-oxygen-water complex. The outdoor exposure of a series of asphalts caused oxidation of about the same relative amount as that obtained indoors by exposure to carbon-arc irradiation.

RECORD No.: 90.
AUTHOR : J. J. Heithaus
TITLE : Physical Factors Affecting the Weather Resistance of Asphalt Coatings
JOURNAL : Industrial and Engineering Chemistry, Product Research and Development
VOLUME No.: 1, No. 3
PUBLISHER : American Chemical Soceity, Easton, PA
YEAR : 1962
PAGES : 149
ABSTRACTOR: HRB
KEYWORDS : Oxidative aging, viscosity, temperature susceptibility, elastic modulus, composition
ABSTRACT :

Rheological measurements and accelerated weathering tests were made on a number of coating-grade asphalts. Performance in the weathering test did not correlate with viscosity, viscosity-temperature susceptibility, or elastic modulus measured on the original material. However, there was excellent correlation between weather resistance and the viscosity of the maltene phase of the asphalt. Asphalts with maltenes of high viscosity were most weather resistant. It is postulated that the rates of the reactions involved in the hardening of an asphalt coating are largely diffusion-controlled. A high-viscosity intermicellar liquid provides greater hindrance to diffusion, slowing down the hardening process.

RECORD No.: 91.
AUTHOR : J. R. Bissett
TITLE : Changes in Physical Properties of Asphalt Pavement with Time
JOURNAL : Proceedings, Highway Research Board
VOLUME No.: 41
PUBLISHER : Highway Research Board
YEAR : 1962
PAGES : 211
ABSTRACTOR: HRB
KEYWORDS : Field performance, asphalt cements, penetration ductility, softening point, ash content, TFOT, Marshall stability
ABSTRACT :

This paper reports the study of approximately 60 mi of asphaltic concrete pavement under actual traffic conditions. The pavements vary from 3 to 8 years of age and represent seven construction projects. Recovery of the asphalt cement was accomplished by a simplified Abson method. Check tests were made on this method to determine any effect it might have on Arkansas asphalts. Density, asphalt content, and gradation of aggregate of the pavements were determined. The asphalt cement recovered from the pavements were subjected to penetration, ductility, softening point, and ash content tests. In some cases the thin-film oven tests was also made. Generally, the results indicate a rapid reduction in the ductility of the asphalt with time. There is also a decided but less rapid reduction in the penetration of the asphalt. Samples of the pavement were heated, remolded, and tested by the Marshall method. Usually, the stabilities were quite high.

RECORD No.: 92.
AUTHOR : J. R. Wright and P. G. Campbell
TITLE : Determination of Oxidation Rates of Airblown-Asphalts by Infra-red Spectroscopy
JOURNAL : Journal of Applied Chemistry
VOLUME No.: 12
PUBLISHER : Society of Chemical Industry, London
YEAR : 1962
PAGES : 256
ABSTRACTOR: PTI
KEYWORDS : Asphalt cements, oxidative aging, light, film cracking
ABSTRACT :

Oxidation rates for eight airblown asphalts were determined by measuring the change in infra-red absorption at 5.88 v-mu with time of exposure to the radiant energy of a carbon arc. While all the asphalts oxidized at different rates, those from the same geographical areas had similar rates; those from different areas varied considerably. The pattern of oxidation was generally the same for each of the eight asphalts, in that there was an induction period followed by a steady oxidation rate until near the failure point, beyond which time the oxidation rate accelerated until film failure as denoted by asphalt film cracking. An inverse relationship was found between the rate of oxidation and the accelerated weathering durability of each asphalt.

RECORD No.: 93.
AUTHOR : F. S. Rostler and R. M. White
TITLE : Composition and Changes in Composition of Highway Asphalts, 85-100 Penetration Grade
JOURNAL : Proceedings of the Association of Asphalt Paving Technologists
VOLUME No.: 31
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1962
PAGES : 35-89
ABSTRACTOR: PTI
KEYWORDS : Asphalt cements, oxidative aging, chemical composition, abrasion resistance, field performance
ABSTRACT :

Comprehensive data on physical characteristics of 119 specimens representative of this grade of asphalt available in various regions of the country were presented and discussed. The present paper is an attempt to enlarge on the information made available by Welborn and Halstead by providing data on chemical composition and changes of composition during aging for the same asphalts. The 119 asphalts, investigated by Welborn and Halstead, were analyzed at three states: (1) as received, (2) after mixing with Ottawa sand, (3) after aging of the asphalt-Ottawa sand mixtures. Abrasion resistance of the asphalt-Ottawa sand mixtures before and after aging was used as an indication of quality and criterion for durability. The first part of the paper is devoted to explaining the fractional chemical analysis used in defining asphalts and to demonstrating the specific influence of the fractions on asphalt performance. The second part of the paper demonstrates the value of complementing data for physical characteristics of asphalts with those for chemical composition on the asphalt specimens previously investigated by Welborn and Halstead. The results obtained in the investigation and presented in the form of a progress report reveal a significant trend for the relationship between composition and performance of the asphalts, which relationship appears to be valid for a wide variety of asphalts. The analytical method employed holds promise as a means of predicting the performance of highway asphalts from their chemical composition.

RECORD No.: 94.
AUTHOR : Burgh, A. J. P., Van Der, Bouwman, J. P. and Steffelaar, G. M. A.
TITLE : The Aging of Asphaltic Bitumen
JOURNAL : Rijkswaterstaat Communications
VOLUME No.: 3
PUBLISHER :
YEAR : 1962
PAGES :
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, oxidative hardening, pressure oxygen bomb, penetration, softening point, composition, light effects
ABSTRACT :

The aging in the course of the years of asphaltic bitumen used in bituminous construction has various causes. One of these, the action of oxygen, is the subject of this publication, although in particular the investigation relates to the rate and intensity of aging caused by the action of oxygen under pressure and without the presence of light. The chemical reactions involved, however, are not dealt with. The investigations showed that of the various factors which could serve as the most suitable basis for a quantitative examination of the phenomena of aging, the penetration was preferable to the ring and ball softening point, the ether asphaltenes content, of the increase of weight. In evaluating the general results, attention is paid to the shape of the aging curves, and an attempt is also made to explain what happens when the aging procedure is interrupted and then resumed after remixing the batch. From the study it has been inferred that asphalts may be prepared which are must less liable to aging than normal ones of the same grade. The probability of parallelism between natural and artificial aging has also been shown by the results of some of the experiments. The experimental part of the investigation consisted of keeping thin layers of various types of asphaltic bitumen in oxygen at 60 C and 20 atm for a varying number of days, and then measuring the changes in the penetration figure, the softening point and other similar characteristics. In addition, several practical experiments relating to the influence of the atmosphere were carried out (natural aging). The materials used were asphaltic bitumens, either as such or mixed with filler, oil or rubber. The results have shown that the characteristics measured, such as the penetration figure and the softening point, altered most quickly at the beginning of the experiments, but that those changes, and therefore the aging rates of the asphaltic bitumens, subsequently became slower and slower. Although the number of available data relating to experiments with natural aging is fairly small, it can be assumed that natural and artificial aging proceed in similar ways.

RECORD No.: 95.
AUTHOR : R. J. Schmidt and L. E. Santucci
TITLE : Influence of Asphalt Type on Pavement Setting
JOURNAL : Highway Research Board Bulletin
VOLUME No.: 333
PUBLISHER : Highway Research Board
YEAR : 1961
PAGES : 10-19
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, steric hardening, viscosity, temperature susceptibility, asphalt-aggregate interaction, moisture, setting rate, mixture toughness
ABSTRACT :

Asphalt concrete mixes which can be scuffed and penetrated readily for prolonged periods after construction are known as slow setting mixes. Sometimes mixes which fail to compact properly because they shove easily from under the roller are also known as slow setting. These problems are caused mostly by the particular mix design, aggregate type and shape, and rolling practice. These factors are discussed in a companion paper. Sometimes when critical mixes are encountered, significant differences in behavior are caused when fast or slow setting asphalts are used. This paper examines the effect of a number of different types and grades of paving asphalt. These are tried in good as well as critical mixes with both rounded gravel and crushed granite at low and high filler levels. All of these variables are examined under different kinds and degrees of full-scale rolling. Extensive physical tests and analyses on the original asphalts used are given. Inspections are also given on the asphalts recovered from the experimental pavements, as well as on thin-film oven residues. A casual relation is indicated between the viscosity and the temperature susceptibility of residues after thin-film oven with the setting rate of pavement toughness. Setting, to the extent controlled by asphalt quality, is indicated to be dependent on how the asphalt components interact with the different types of mineral surface in the mix. These qualities do not appear to be well defined by any of the asphalt properties reported. The varied response by the asphalts to type and amount of mineral surface suggests that the amount of moisture on the mineral surface may have overriding influence on pavement toughness.

RECORD No.: 96.
AUTHOR : K. G. Martin
TITLE : A Review of the Durability of Roofing Bitumens
JOURNAL : Journal of the Institute of Petroleum
VOLUME No.: 47
PUBLISHER : Institute of Petroleum
YEAR : 1961
PAGES : 321
ABSTRACTOR: HRB
KEYWORDS : Oxidative aging, durability prediction tests, asphalt cements, moisture, air
ABSTRACT :

A review has been made of the literature on the durability of bitumens with regard to the performance of bituminous roofs. Oxidation is generally considered to be most important factor, and particular attention has been given to the laboratory study of this reaction and the development of durability prediction tests. It is proposed that three separate oxidation tests simulating conditions of application, exposure to moisture and air in the dark, and exposure to moisture and air in the light may be developed to assess roofing bitumens. Further chemical investigation of the functional groups of the less viscous fractions is required.

RECORD No.: 97.
AUTHOR : R. A. Jimenez and Bob M. Gallaway
TITLE : Laboratory Measurements of Service Connected Changes in Asphaltic Cement
JOURNAL : Proceedings of the Association of Asphalt Paving Technologists
VOLUME No.: 30
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1961
PAGES : 328-358
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, field aging, physical properties, chemical composition
ABSTRACT :

The investigation reported herein concerns the changes which have occurred in asphalt cements recovered from test roads during six years of service. Results of standardized tests and special tests performed on the asphalts are shown to compare the initial properties of the asphalts with subsequent changes in physical and chemical properties. Different testing instruments and methods were used to determine their desirability for evaluating fundamental and empirical properties of the asphalts used in the test roads. The trend of changes in asphalt occurring with age is presented and tentative recommendations are suggested for the specification of asphalts in order to improve or to make better use of certain fundamental properties of asphalts. This constitutes the final report of a cooperative study with the Texas Highway Department. Earlier progress reports on this research have been given before this Association.

RECORD No.: 98.
AUTHOR : Richard Bright and E. T. Reynolds
TITLE : Effect of Mixing Temperature on Hardening of Asphaltic Binder in Hot Bituminous Concrete Under Stated Conditions
JOURNAL : Highway Research Board Abstracts
VOLUME No.: 31
PUBLISHER : Highway Research Board
YEAR : 1961
PAGES : 21
ABSTRACTOR: HRB
KEYWORDS : Asphalt cement, mixtures, viscosity, oxidative aging, penetration, mixing practices, cooling rate, storage
ABSTRACT :

Plant mixes of hot bituminous concrete were made in the mixing temperature range of 250 to 400 F, corresponding to viscosity limits of approximately 400 to 15 Saybolt Furol seconds. The asphalt from samples of these mixes was recovered by the modified Abson method, and changes in the penetration, ductility, softening point, and absolute viscosity were measured. Asphalts from Venezuelan and East Texas crudes were used. The mixes used were base courses, binder courses, wearing surface, and certain city street mixes. The aggregates were varied and were either all granite or mixtures of granite, sand and mineral filler, mixtures of sandy limestone, sand and mineral filler, or mixtures of siliceous gravels, sand, and mineral filler. Some of the samples were cooled slowly, whereas others were cooled rapidly by quenching in water. The samples cooled slowly showed 65 to 75 percent penetration retained at 250 F with an additional 10 percent drop in percent penetration retained for each 50 F increase in mixing temperature. The samples quenched in water showed essentially no difference in hardening at 250 F from slowly cooled. No definite difference in hardening was found for different asphalts, different mixes, different aggregates or different type pugmills. Samples of paving mixture were found to harden appreciably on storage during the first 15 days; but thereafter the rate of hardening was very slow.

RECORD No.: 99.
AUTHOR : W. J. Halstead and J. A. Zenewitz
TITLE : Changes in Asphalt Viscosities During the Thin Film Oven and Microfilm Durability Tests
JOURNAL : American Society for Testing and Materials
VOLUME No.: Special Technical Publication NO. 309
PUBLISHER : American Society for Testing and Materials
YEAR : 1961
PAGES : 133
ABSTRACTOR: HRB
KEYWORDS : Oxidative aging tests, asphalt cements, viscosity, penetration, temperature susceptibility, degree of complex flow

ABSTRACT :

The sliding plate microviscometer was used to determine the changes in asphalt properties during the thin film oven test and the microfilm durability test. The data presented include tests on 85 to 100 penetration asphalts from a wide variety of sources and methods of manufacture. Data on two groups of asphalts used in experimental construction are also included. Viscosity measurements for the 85 to 100 asphalts made at several temperature show significant differences in temperature susceptibility and degree of complex flow. Two types of behavior were noted: In one type, apparently typical of the majority of asphalts, the hardening in the microfilm is greater than the hardening in the thin film tests. This difference is not significant for values of aging index approximately 2 or lower but it increases rapidly as the hardening increases. In the second type of behavior, the hardening occurring during the two tests was essentially equal for all levels of resistance. These studies illustrate the value of the sliding plate microviscometer for obtaining rheological information on asphalts not obtainable with the usual empirical methods. The differences in asphalts and the changes in relative rheological characteristics at different temperatures or values of stress emphasize the inadequacy of control of asphalt consistency by means of measurements at only one temperature. The need for further studies is clearly indicated.

RECORD No.: 100.
AUTHOR : R. N. Traxler
TITLE : Relation Between Asphalt Composition and Hardening by Volatilization and Oxidation
JOURNAL : Proceedings of the Association of Asphalt Paving Technologists
VOLUME No.: 30
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1961
PAGES : 369-379
ABSTRACTOR: HRB
KEYWORDS : Oxidative aging, viscosity, asphalt cements, composition, coefficient of dispersion, TFOT
ABSTRACT :

Data are reported on six commercial 85-100 penetration asphalts. The Bureau of Public Roads Thin Film Test was run for 5, 10 and 15 hours. A test similar to that proposed by Griffin, Miles and Penther was made on 15 micron films in air at 225 degrees for 2 and 4 hours. Films of the same thickness were also heated for 2 and 4 hours in an atmosphere of nitrogen. Rheological and strain data are given on a number of synthetic asphalts of essentially the same viscosity at 77 degrees F. A correlation was established between the relative viscosity (extent of hardening of the asphalt) and a coefficient of dispersion calculated from asphaltene, resin and oil contents. A high coefficient indicates superior resistance to hardening by oxidation in the dark.

RECORD No.: 101.
AUTHOR : Robert G. Wurstner, William A. Higgins and Willis G. Craig
TITLE : Laboratory Evaluation of Factors Influencing the Performance of Paving Asphalts
JOURNAL : Proceedings of the Association of Asphalt Paving Technologists
VOLUME No.: 29
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1960
PAGES : 253
ABSTRACTOR: HRB
KEYWORDS : Oxidative aging, asphalt cements, modified asphalts, abrasion resistance
ABSTRACT :

Asphalts age-harden at different rates. This can be shown by both the Thin Film Test and the Hveem Abrasion Test. Oxygen plays a principal role in age hardening of paving asphalts. Chemicals which effectively inhibit oxidation in other hydrocarbon systems do not do so in these asphalts. Certain oxygen-resistant polymers improve the abrasion resistance and reduce the age-hardening of asphalts. Consistency, as indicated by absolute viscosity, is not the only factor which determines the effectiveness of an asphalt in binding aggregates. Adhesivity and cohesivity are equally important properties. Asphalts produced by non-conventional experimental methods show promise of having outstanding resistance to age hardening.

RECORD No.: 102.
AUTHOR : Franklin P. Abbott and Willis G. Craig
TITLE : Determination of Age Hardening Tendencies and Water Susceptibility of Paving Asphalt by the Sonic Method
JOURNAL : Highway Research Board
VOLUME No.: Bulletin No. 270
PUBLISHER : Highway Research Board
YEAR : 1960
PAGES : 20
ABSTRACTOR: HRB
KEYWORDS : Asphalt cement, oxidative aging, moisture susceptibility, sonic testing

ABSTRACT :

This paper presents data on (a) progressive hardening and embrittlement of the asphalt cement with aging; (b) loss of adhesion of the asphalt cement to the aggregate with the resultant lower compressive strengths due to water displacement of the asphalt binder at the asphalt-aggregate interface; (c) progressive loss of water resistance of the asphalt cement as the asphalt hardens; and (d) progressive loss of the ability of the asphalt binder to re-adhere to the aggregate after displacement by water. The action of effective anti-stripping additives in ameliorating these causes of road deterioration is shown to be in the direction of reducing the magnitude of the last three of these deteriorative factors.

RECORD No.: 103.
AUTHOR : W. C. Simpson, R. L. Griffin, T. K. Miles
TITLE : Correlation of the Microfilm Durability Test with Field Hardening Observed in the Zaca-Wigmore Experimental Project
JOURNAL : American Society for Testing and Materials
VOLUME No.: Special Technical Publication No. 277
PUBLISHER : American Society for Testing and Materials
YEAR : 1960
PAGES : 52-63
ABSTRACTOR: PTI
KEYWORDS : Microfilm durability, sliding plate viscosity at 77F, hot mix hardening, long-term hardening
ABSTRACT :

Examination of the asphalts used in the Zaca-Wigmore project by means of the microfilm durability test gave ratings of the relative durability to be expected of asphalts when all are used under the same conditions. The actual order of occurrence of failures in the test road is in agreement with the predictions of this relatively simple and rapid laboratory test. Progressive hardening of the asphalts in the road over a period of several years was found to parallel that found in the microfilm durability test in a few hours (ratio of viscosity at 77 F before and after exposure of a 5 yr film to air at 225 F for 2 hr). In the first road construction, where pavement deflections were about 0.015 in to 0.025 in under a 15,000 lb axle load, failures developed when the asphalt viscosity entered the range of 10^7 to 10^8 poises. In the second test road construction where deflections are about 0.010 in under the same load, the first distress was noted in an asphalt which reached a viscosity at 77 F of about 10 poises. Recovery of asphalt from slices of pavement cores showed that hardening of asphalt is greatest at the top and decreases with increasing depth in the pavement. Pavements with high air void content were found to harden more rapidly than those with low air voids. Hardening during the asphalt aggregate mixing operation was about twice as great during period 1 as this construction as during period 2 and this difference in hardening in the mix plant is still evident after several years in the road. Hardening by loss of voltaic matter is an important fraction of the total hardening observed in these asphalts. It is shown that this can be controlled by proper selection of crude oil or by application of distillation and blending techniques so as to keep the 10 percent distilled point of the asphalt at or above 400 C (converted to atmospheric pressure).

RECORD No.: 104.
AUTHOR : P. C. Blokker, and H. Van Hoorn
TITLE : Durability of Bitumen in the Theory and Practice
JOURNAL : Proceedings, 5th World Petroleum Congress
VOLUME No.: VI
PUBLISHER : World Petroleum Congresses, London
YEAR : 1959
PAGES : 417-432
ABSTRACTOR: PTI
KEYWORDS : Asphalt, aging, oxidation, P.O.B., light, diffusion, pressure, stiffness, temperature
ABSTRACT :

After a brief review of the physical hardening of bitumen, which is caused by a change in structure or by loss of volatiles, the more important phenomenon of chemical hardening, due to oxidation, is dealt with extensively. The rate of oxidation is much higher in the presence of light than in its absence, and the reactions are of a different type. Oxidation in the light is promoted mainly by the ultra-violet part of the spectrum, and hardening is restricted to a depth of about 4 microns. In the dark, hardening may occur down to depths of 3 mm or somewhat more, which is in good agreement with a theoretical interpretation. The consequences of hardening in the dark for road construction are discussed in considerable detail. It is shown that, since the cracking of road carpets is most likely to occur under the impact of moving traffic at low temperatures, the tendency to this type of failure should be judged from the increase in stiffness of bitumens at short times of loading and at low temperatures, rather than from the increase in viscosity. Data on the hardening of a large number of bitumens are given. An accelerated test procedure for assessing the aging characteristics of bitumens was investigated. The acceleration is affected by increasing the oxygen pressure; it is reproducible and fairly constant. Results of this test show a satisfactory correlation with hardening data obtained from road trials. A recently published test method using acceleration by increase of temperature appears to be practically equivalent to the present method except in the case of an experimental bitumen with a large content of volatiles, where the high-temperature test gives too high a value.

RECORD No.: 105.
AUTHOR : S. H. Kuhn and P. J. Rigden
TITLE : The Measurement of Viscosity of Very Small Samples of Bituminous Binders for the Study of Weathering on the Road
JOURNAL : Proceedings, Association of Asphalt Paving Technologists
VOLUME No.: 28
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1959
PAGES : 372-384
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, ball viscometer, field performance, oxidative hardening
ABSTRACT :

A method for measuring the viscosity of small samples (40-80 mgs) of bituminous binders is described. It consists essentially of compressing a small sphere of the binder under a known load and measuring the deflection as a function of time. The instrument used in the work measures viscosities in the range of 107 to 1012 poises. The ball viscometer has been used to follow increases in viscosity produced by weathering of binders on the road and a method for the sampling of weathered binders from a surface treatment and for the preparation of the sample for viscosity measurement is described. The accuracy of this method has been shown to be sufficient for measuring the large changes in viscosity procedure by weathering on the road. The results of tests on a full-scale surface treatment experiment are given as an illustration of the use of this method.

RECORD No.: 106.
AUTHOR : L. R. Kleinschmidt and H. R. Snoke
TITLE : Effect of Light and Water on the Degradation of Asphalt
JOURNAL : Journal of Research
VOLUME No.: 63C
PUBLISHER : National Bureau of Standards
YEAR : 1959
PAGES : 31
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, oxidative hardening, field exposure, moisture effects, light effects
ABSTRACT :

Coatings prepared from two blown petroleum asphalts in a thickness range of 0.002 to 0.04 inches were exposed to accelerated test conditions and outdoors. When exposed to light only, a surface film, insoluble in common asphalt solvents, was formed. The formation of this surface film was accompanied by a gain in weight of the coatings, apparently due to an oxygen pickup. This surface film retarded further degradation of the maltenes during the exposures made to light only. When the coatings were immersed in water after exposure, or sprayed with water during exposure, or exposed outdoors, they lost weight. These decreases in weight were found to be in part due to the extraction of water-soluble, light-degraded material. Their magnitudes were dependent upon the asphalt exposed, the thickness of the exposed coatings, and exposure conditions. The relationship between the losses in weight and water-soluble material, when considered in conjunction with the oxygen content of the asphalts and the water-soluble materials, indicated that volatile degration products were also formed. When the surface skin formed by the action of light was partially removed by washing with water, percentage decreases were noted in the water-white oils, dark oils, and asphaltic resins. Since these decreases were unequal in magnitude and since the losses in weight were dependent on the thickness of the coating, it was concluded that light-degradable components of the asphalt had migrated to the surface to replace degraded materials that had been washed away.

RECORD No.: 107.
AUTHOR : Bob M. Gallaway
TITLE : Factors Relating Chemical Composition and Rheological Properties of Paving Asphalts with Durability
JOURNAL : Proceedings, Association of Asphalt Paving Technologists
VOLUME No.: 28
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1959
PAGES : 280-294
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, oxidative hardening, field performance, penetration, viscosity ductility, softening point, degree of complex flow, composition

ABSTRACT :

This paper presents the second report on a series of surface treatment type pavements built in 1954 in various parts of the State of Texas. Samples of the asphalt cement used in these surfaces have been subjected to selected special tests as well as standard specifications requirement tests in an effort to evaluate durability characteristics. Testing agencies included on this project are: (1) Texas Transportation Institute, (2) The Texas Company, (3) The Bureau of Public Roads, (4) The California Highway Department, Division of Materials and Research, and (5) The Texas Highway Department. A study has been made of the annual changes in the rheological properties of the service aged samples. Also compositional changes as measured on solvent separated components of the asphalt have been investigated. Comparisons have been made of artificially aged samples and service aged samples. It is concluded from this research that:

1. Present standard specification requirements for paving grade asphalt cements do not adequately restrict the quality of this material.
2. Consistency requirements should include true rheological measurements particularly in the range 40 to 140 degrees F.
3. Chemical composition should be restricted even though such a restriction may appreciably increase the cost of asphalt.

RECORD No.: 108.
AUTHOR : J. J. Heithaus and R. W. Johnson
TITLE : A Microviscometer Study of Road Asphalt Hardening in the Field and Laboratory
JOURNAL : Proceedings of the Association of Asphalt Paving Technologists
VOLUME No.: 27
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1958
PAGES : 17-34
ABSTRACTOR: PTI
KEYWORDS : Asphalt aging, field performance, viscosity, microfilm durability test, void content, asphalt content.
ABSTRACT :

A series of asphaltic concrete test sections placed on a refinery entry road at Wood River, Illinois, provided a good opportunity for the study of asphalt hardening. They contained 18 different types of asphalts that represented four groups: vacuum reduced, cracked, semi-blown, and blends containing propane asphalt or lube extract. Two different types of surface course were in the field trails, one is a dense mix, while the other is an open graded mix. The objective of the study was to compare the properties of the asphalts extracted from the test sections with the properties of the same asphalts after aging in the laboratory. A review of tests used for assessing durability of asphalts indicated that several tests use unmixed asphalts. These tests are standard Loss on Heating Lewis Thin Film, Nicholson Blowing, Ebberts Oxidation, Anderson et al. Bomb. Other tests use asphalt-aggregate mix such as Shattuck test, and Shot Abrasion test. However none gave results in terms functionally related to pavement performance and, furthermore, not enough data exists that correlate these tests with actual field hardening. A recently developed Microfilm durability test that gives the results in terms of viscosity of the asphalt before and after aging is possibly the meaningful test so badly needed. Therefore, it was used in the study. The viscosity on the original, recovered, and laboratory aged asphalts was determined with a water bath model, parallel plate microviscometer at a shear rate of 0.05 1/sec. Asphalts were aged in a film 5 micron thick, at 225 F, for 2 hr. The viscosity was measured at 77 F. Analysis of results indicated the following points: (a) hardening during mixing and laying bears no close relationship to asphalt content or aggregate gradation; (b) there appears to be roughly a direct linear relationship between void content and binder hardening rate. Void content is a function of aggregate gradation, binder content and extent of compaction of mix; (c) the average viscosity increase during mixing and laying was found to be 140 percent of the Aging Index (ratio of laboratory-aged to original viscosity at 77 F, .05 1/sec). During 36 months service in addition to mixing and laying, the average viscosity increase amounted to 244 percent of that occurring in the Microfilm test; (d) different asphalts aged differently: times required for different asphalts to be aged in the Microfilm procedure to reach the same degree of field hardening were different; (e) the correlation coefficient between laboratory and field hardening indicated that type of

mix has a significant effect. Asphalt content, open versus dense mix, and application of a prime coat to the base are the major factors. The correlation coefficient ranged between 0.13 and 0.99. Better correlation was obtained where hardening was greater, that is, in leaner, more open mixes and when hardening during both mixing and service are considered. Correlation was improved when the field data were corrected to the same void content. It is expected that an aging procedure of longer duration would give better correlations.

RECORD No.: 109.
AUTHOR : A. B. Brown
TITLE : Possible Effects of Hardening on Pavement Life
JOURNAL : Proceedings of the Association of Asphalt Paving Technologists
VOLUME No.: 27
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1958
PAGES : 171-176
ABSTRACTOR: PTI
KEYWORDS : Asphalt hardening, viscosity, elastic response, adhesion, fracture, temperature susceptibility.
ABSTRACT :

This paper is a purely hypothetical discussion of the possible effects of the changes in composition of asphalt due to aging on several important physical properties of the asphalts. Some of the important points in which the author describes the mechanism of aging effects on properties of asphalts are as follows: (a) as the oxidation changes, the non-polar oils remain substantially constant, while the smaller resin molecules convert to the larger asphaltene molecules. Undoubtedly, asphaltenes further combine with resins or with themselves to form still larger asphaltenes. This size growth of the reactive molecules result in loss of hydrogen, which is converted to water. Such formation of water in the body of the road probably adversely affects the adhesion of the asphalt. Also, because of increase in size, per-se, a greater degree of physical entanglement of these complex species must result with increased resistance to the slippage of layers at the molecular level. Thus decreased freedom of movement shows an increase of consistency signaled by higher softening points and lower penetration; (b) big molecules respond reversibly to biased stress by reorientation of their configuration in space. Because substantial molecular masses and distances are involved, finite times are required for the action. By buildup of large molecules on the expense of smaller and more-mobile molecules, asphalt during aging would be expected to shift both toward higher consistency and toward accentuation of elastic response of the predominantly time-dependent type; (c) conversion of lower molecular weight polar resins to asphaltenes would leave the flow medium relatively richer in non-polar oil constituents with smaller temperature coefficients of viscosity. Thus, even though its over-all viscosity is greater, aged asphalt might be expected to be less susceptible than its unaged precursor; (d) aging of asphalt would be expected to favor failure by cracking under some lower level of maintained stress than for the fresh asphalt. For transient loads of short duration and below some critical load magnitude, aged pavements would be expected to suffer less from distortion, because of better elastic response and higher specific viscosity; (e) aging makes asphalts more vulnerable to fracture. Input energy can only be accumulated in elastic mechanisms, which tend to increase over the aging process, and may provide reservoirs of energy favorable to initiation and propagation of fracture failures. On the other hand, absence of such mechanisms would result in a material of less elasticity and, thus, of less negative shock-absorbing capacity.

RECORD No.: 110.
AUTHOR : D. F. Fink
TITLE : Symposium: Hardening of Paving Asphalts; Research Studies and Procedures
JOURNAL : Proceedings of Association of Asphalt Paving Technologists
VOLUME No.: 27
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1958
PAGES : 176-183
ABSTRACTOR: PTI
KEYWORDS : Asphalts, oxidative aging, temperature, oxygen, pressure, microfilm durability, viscosity, chemical reactions
ABSTRACT :

This article is a review of the research techniques that have evolved over the years for the study of the rate of paving asphalt hardening. The studies on asphalt hardening may be classified into three groups: (a) studies concerned with the mechanism of hardening, which showed that hardening is due to chemical reactions, including oxidation, polymerization, and condensation and/or due to physical processes, including volatile loss and structural change; (b) studies on the rate at which hardening occurs, which indicated that temperature, oxygen pressure, catalysts, and oxygen diffusion are factors affecting rate of hardening; and (c) studies on the effect of hardening on the mechanical properties of either the binder itself or its admixtures, which measured change by conventional consistency, viscosity, elastic modulus, and toughness and brittleness tests. During laboratory hardening, asphalt was exposed to hardening influences (air, temperature, and oxygen) in the bulk, in relatively thick films solution, and more recently in films only a few microns thick. The reasons for the trend of using thin films are because: they correspond to films existing in actual paving mixtures, hardening proceeds to a much greater extent in a given environment, and oxygen diffusion effects are minimized, permitting a closer approximation to actual reaction velocities. Under normal aging conditions, it has been observed before that oxygen diffuses only a few microns into the bitumen surface. Therefore, the desirability of using films a few microns thick seems well established. Simulation of the hot-mix operation is not a problem. Simulation of long-term aging in a procedure short enough in duration for investigation purposes poses more serious problems. Increase of temperature has been widely used, since most oxidation reactions approximately double in rate for each 10 C increase. However, it is not known whether all asphalts have similar temperature coefficients of oxidation rate and release volatiles to a similar degree; furthermore, there is a possibility that the mechanism of chemical reactions changes with temperature, producing changing effects on consistency properties. There is considerable argument as to which measure of consistency is an appropriate physical property that correlates best with actual road performance. Generally, change in response to rapidly applied stresses (such as stiffness at 10 sec) and change in response to slowly applied stresses such as ductility or viscosity measured, are used as a measure of

hardening. Analysis of some field aging data suggests that stiffness at short loading times has a consistent relationship with viscosity (stiffness at long loading times). Since viscosity values are observed to be more sensitive to aging, it is suggested that an aging index based on viscosity values at normal field temperatures should prove a useful indication of overall hardening characteristics of asphalts.

RECORD No.: 111.
AUTHOR : Dickinson, J. H. Nicholas, S. Boas-Traube
TITLE : Physical Factors Affecting the Absorption of Oxygen by Thin Films of Bituminous Road Binders
JOURNAL : Journal of Applied Chemistry
VOLUME No.: 8
PUBLISHER : Society of Chemical Industry, London
YEAR : 1958
PAGES : 673-687
ABSTRACTOR: PTI
KEYWORDS : Asphalt, tar, oxidation, diffusion, oxygen absorption, light, activation energy
ABSTRACT :

The absorption of oxygen by bituminous road binders in the absence of light at temperatures normally encountered on the road was found to be a process controlled by diffusion, with the rate of absorption depending markedly on the viscosity of the binder and the thickness of the binder-film. The acceleration of absorption produced by increasing the temperature corresponded to an activation energy for the process of approximately 10 kcal/mol. Generally speaking, tars showed a higher rate of absorption than straight-run petroleum bitumens. Irradiation of the film with light in the wavelength range 3000-5000A was found to produce a marked acceleration of the reaction, but, because of the high degree of absorption of the light, it was probably effective only to a depth of 10 below the exposed surface. Light had no effect at film depths greater than 60 . When the illumination was sufficiently intense, a relatively hard layer was formed on the surface, which retarded further reaction of oxygen with the underlying layers of binder. This surface skin is always produced by exposure to natural sunlight. With the bitumens examined, light produced a greater acceleration of the reaction than with the tars; the surface skin was also formed more rapidly on the bitumen films.

RECORD No.: 112.
AUTHOR : Richard F. Sparlin
TITLE : Effect of Ultra-Violet Light on Viscosity of Thin Films of Asphalt Cements
JOURNAL : Proceedings, American Society for Testing and Materials
VOLUME No.: 58
PUBLISHER : American Society for Testing and Materials
YEAR : 1958
PAGES : 1316
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, oxidative hardening, light effects, viscosity
ABSTRACT :

The hardening of thin exposed films of asphalt in service is partly due to the effect of ultra-violet energy. Asphalt durability studies by others have indicated that ultra-violet energy acts as a catalyst, accelerating oxidation and consequent hardening of the asphalt. The purpose of this investigation was to determine whether or not ultra-violet energy is capable of hardening asphalt when oxygen is not present. Thin films of two asphalt cements were exposed to ultra-violet energy while held between glass slides. After exposure the asphalt was sheared in a microviscometer and the viscosity computed. The results were compared by statistical methods to viscosities of control samples. Though the number of tests conducted was quite limited, covering only a few samples of the two paving asphalts, the results indicated that ultra-violet energy is capable of producing measurable increases in the viscosity of asphalt films sealed from the atmosphere.

RECORD No.: 113.
AUTHOR : H. Greenfeld
TITLE : Effect of Mineral Fillers On Weather Resistance of Composition Roofing Covering Masses
JOURNAL : Bitumen, Terre, Asphalte, Peche
VOLUME No.: 9
PUBLISHER : Bitumen, Terre, Asphalte, Peche, Isern Hagen, Germany
YEAR : 1958
PAGES : 112
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, mineral fillers, oxidative hardening
ABSTRACT :

Since about 1930, mineral fillers, used in increasing quantities to improve the rheological properties of bituminous materials, are found in some cases to increase the weather resistance of the bituminous protective covering. Extensive investigations since 1947 by the American National Bureau Standard are reported. The investigations cover the influence of high filler additions, layer thickness, particle size distribution, particle shape, mixing, and the bituminous distributing agent. The results are discussed and, in some points, extended by describing individual working methods and references to the related German scientific literature. Mechanical testing is discussed.

RECORD No.: 114.
AUTHOR : Phil C. Doyle
TITLE : Cracking Characteristics of Asphalt Cement
JOURNAL : Proceedings, Association of Asphalt Paving Technologists
VOLUME No.: 27
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1958
PAGES : 581
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, ductility, pavement cracking, thermal expansion
ABSTRACT :

High ductility asphalts, when used in asphalt pavements, appear to reduce the amount of cracking after 2 to 5 yr of service. A procedure is given for measuring the linear thermal expansion of penetration grade asphalt.

RECORD No.: 115.
AUTHOR : A. B. Brown, J. W. Sparks, and O. Larsen
TITLE : Rate of Change of Softening Point, Penetration and Ductility of Asphalt in Bituminous Pavement
JOURNAL : Proceedings, Association of Asphalt Paving Technologists
VOLUME No.: 26
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1957
PAGES : 66
ABSTRACTOR: HRB
KEYWORDS : Asphalt cement, field aging, oxidative hardening, penetration, ductility, softening point, weather conditions, hardening rate

ABSTRACT :

Softening points, penetrations, and ductilities of two markedly different asphalt types, each used in two different roads, were determined periodically over a nine-year testing period. Changes in these properties followed a simple hyperbolic law with time, whereby the rate and ultimate degree of change of the full life may be predicted from the data of the early years of life. Differences in workmanship, traffic, and weather conditions at different sites may cause as great a change in the properties of a given asphalt as occur between those of two different asphalts used at the same site.

RECORD No.: 116.
AUTHOR : B. A. Vallerga, C. L. Monismith and K. Granthem
TITLE : A Study of Some Factors Influencing the Weathering of Paving Asphalts
JOURNAL : Proceedings, Association of Asphalt Paving Technologists
VOLUME No.: 26
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1957
PAGES : 126
ABSTRACTOR: PTI
KEYWORDS : Asphalt cements, oxidative aging, light effects, penetration, softening point, ductility, TFOT

ABSTRACT :

Three asphaltic materials of different weathering resistant characteristics were used to study the influence of variations in weathering conditions on selected asphalt properties. Variations in weathering included: (a) heating in the absence of light, (b) heating with the presence of infrared radiation, and (c) heating with the presence of ultra-violet radiation. For the effect of weathering in the absence of light, the standard BPR thin film oven test and a modification thereof, utilizing a rotating inclined plane principle designed to produce thinner films, were compared. For weathering the infra-red and ultra-violet radiation, the California Division of Highways Infra-Red Weathering Machine was used and also modified to accommodate the inclined rotating plane principle to produce the thinner films of asphalt. The effects of weathering were determined by measuring the changes in penetration, softening point, and ductility of the asphalt residues after various exposure periods. From the results obtained, the following conclusions were drawn: (a) the use of the rotating included (15 degree) shelf principle in which a 5.5-in diameter pan containing 50 ml of asphalt is placed appears to develop film thicknesses more nearly representative of those existing in paving mixtures and to produce more uniform weathering of the asphalt sample with a sufficient amount of asphalt to prepare a specimen for the standard penetration test; (b) weathering in the absence of light at 225 F caused a decrease in penetration and an increase in the softening point temperature of the asphalts with time, the changes being the least for the three weathering conditions used. In this weathering condition, loss in penetration was not generally accompanied by a reduction in ductility. At 325 F, this type of weathering caused substantial reduction in penetration for all three asphalts. At 225 F, however, the reduction was less marked for Samples B and C; (c) weathering in the presence of ultra-violet radiation caused substantial reductions in penetration of asphalts used and increased their softening point temperatures, but caused either an increase or decrease in ductility, depending on the asphalt. The reduction in penetration and the increase in softening point temperature was most marked for this weathering condition; (d) weathering in the presence of infra-red radiation caused a reduction in penetration and an increase in softening point temperatures, the changes being intermediate between those for weathering in the presence of

ultra-violet radiation and in the absence of light. Depending on the material, this condition of weathering caused either a decrease or increase in ductility. For Samples B and C, no appreciable loss in ductility resulted; for the longer periods of weathering an increase in ductility was observed.

RECORD No.: 117.
AUTHOR : Bob M. Gallaway
TITLE : Durability of Asphalt Cements Used in Surface Treatments
JOURNAL : Proceedings
VOLUME No.: 26
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1957
PAGES : 151
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, field aging, oxidative hardening, viscosity, degree of complex flow, composition

ABSTRACT :

Eleven newly constructed roads widely distributed in Texas were surfaced with penetration grade asphalts from seven different producers. Data concerning the roads were obtained, and samples were obtained from each road after 1 and 2 yr service. The aged asphalt was extracted and tested in comparison with the original asphalt. Viscosity and degree of complex flow, component analyses, oxidation, and other special tests were made on the original and aged asphalts. The roads were carefully inspected after 1 and 2 yr and each evaluated for serviceability.

RECORD No.: 118.
AUTHOR : K. Letters
TITLE : Investigations on Artificial Aging of Bituminous Binders and the Relations to the Properties of Their Films
JOURNAL : Bitumen, Tere, Asphalte, Peche
VOLUME No.: 8
PUBLISHER : Bitumen, Tere, Asphalte, Peche, Isernhagen, Germany
YEAR : 1957
PAGES : 37
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, tars, oxidative aging, moisture effects, u.v. irradiation, adhesion to glass, scratch test.
ABSTRACT :

The author's previous work on tar and bitumen films 1 (1.10 cm) thick on H2 O is followed up by tests on films 0.1mm thick on glass. The periodical course of artificial aging is observed on 16 road tar and bitumen samples. Results of the test series in 3 alternating variables--water storage, u.v. irradiation, heating to 50 C and cooling to -20 C--are presented in detail for individual materials with supporting photographs. Visual observation indicates surface changes. Scratch tests give an estimate of crack and pit formation, depth effects, progress of hardening or oil separation, and changes in adhesion to the glass. Road tars show surface changes with crack formation generally earlier than bitumen, especially with longer water stressing, and show generally some contraction tendency. Bitumen-tar mixtures have higher plasticity, better adhesive power, and smaller tendency to crystallization; advantages are only effective in weak solar irradiation. In tar-bitumen mixtures with small tar additions, thick films give retarded aging with low strengths. Results of further experiments--supported by photographs--show that surface changes with crack formation do not occur with bitumen as rapidly as with tar under long water and heat stressing. In the water stage of stressing, the picture is reversed insofar as an intensified surface change with formation of bright hardened islands and broad oily canals, with a decrease of adhesive power after water storage, appear.

RECORD No.: 119.
AUTHOR : S. H. Greenfeld
TITLE : The Effects of Mineral Additives on the Durability of Coating Grade Roofing Asphalts
JOURNAL : Bitumen Material Series
VOLUME No.:
PUBLISHER : National Bureau of Standards
YEAR : 1956
PAGES : 147
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, oxidative aging, mineral additive, filler properties

ABSTRACT :

The effects of 14 mineral additives on the durability of coating made from three asphalts were evaluated in accelerated durability machines. It was found that while the durability of the coating is largely a function of the asphalt used, it increases, generally, with coating thickness and mineral additive concentration. Additives with flat, platelike particles finer than 75 microns in diameter (U.S. Standard Sieve No. 200) were most effective in producing coatings of increased durability. Complete dispersion of the additives in the base asphalts is necessary to produce consistent results.

RECORD No.: 120.
AUTHOR : Robert G. Clark
TITLE : Asphalt Volatility and Weathering Tests
JOURNAL : Proceedings
VOLUME No.: 25
PUBLISHER : Association Asphalt Paving Technologists
YEAR : 1956
PAGES : 417
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, oxidative aging, extraction, penetration, field performance, cracking
ABSTRACT :

Data on a large number of paving asphalts from many sources are presented. Samples of hot mixtures were obtained in the field and brought to the laboratory for extraction of the bitumen and recovery by the Abson method. The recovered asphalt was tested for penetration and compared with the original penetration of the asphalt. These values were compared with the standard loss in weight test. The thesis is proposed that volatilization is the main cause for the initial hardening of an asphalt. It was found, in the cases of pavements showing considerable cracking, that the asphalt used was airblown in the final stages of refining.

RECORD No.: 121.
AUTHOR : W. P. Van Ort
TITLE : Durability of Asphalt: Its Aging in the Dark
JOURNAL : Industrial and Engineering Chemistry
VOLUME No.: 48, No. 7
PUBLISHER : American Chemical Society, Easton, PA
YEAR : 1956
PAGES : 1196-1201
ABSTRACTOR: PTI
KEYWORDS : Asphalts, aging, oxidation, temperature, pressure of oxygen, viscosity, time
ABSTRACT :

According to the literature, the action of oxygen is one of the principal factors responsible for the occurrence of aging phenomena. When asphalt is exposed to atmospheric oxygen, a slow autoxidation occurs, the chemical nature of which depends to a very large extent upon the temperature. At temperatures above 100 C dehydrogenation takes place, as is evident from the water produced. Some carbon dioxide is also formed. At lower temperatures e.g., 25 or 50 C, the oxygen involved in the oxidation is quantitatively bound in the bitumen and no water or carbon dioxide is formed. The overall rate of oxygen absorption was found to be not only determined by the chemical nature of the asphalt, but also by the physical transport of the oxygen from the surrounding atmosphere to the interior of the material. Therefore, it is also a physical problem, one of diffusion in particular. Measurements were made on asphalt in thin films at temperatures between 20 C and 70 C in the absence of light. Seven types of asphalts were studied. Several grams of each asphalt were made into a thin film (5-10 microns) by mixing grains of sand, as nearly as possible of uniform size, with the asphalts in a heated mixer, which could be provided with an inert atmosphere. The oxygen absorbed, as measured by a conventional volumetric method, by the different asphalts at 22 C in the dark for 50 weeks is presented. The change in viscosity after exposure of the asphalt was also measured with a specially developed micro technique. The rate of absorption and the rate of hardening were observed to decrease with time. The absorption process was not complete at the end of one year. Different asphalts showed significantly different rates. A theoretical model of oxygen absorption is proposed. The model permits the calculation of the total oxygen absorbed by whole layer from the knowledge of film thickness, time, a diffusion coefficient, a reaction coefficient, and other constants. Some experiments were carried out to ascertain the assumptions on which the model was based. The experiments indicated that assumptions made are valid. Other experiments to study factors affecting the absorption mechanism indicated that pressure of oxygen, temperature, and film thickness are the major factors affecting absorption. Lower pressure, lower temperature, and increased film thickness result in decreased absorption. Also, as the viscosity of asphalt increases (or penetration decreases), the coefficient of diffusion of oxygen decreases. The diffusion coefficient was found to depend on the concentration of chemically bound oxygen. As the later increases the coefficient decreases.

RECORD No.: 122.
AUTHOR : R. L. Griffin, T. K. Miles, and C. J. Penther
TITLE : Microfilm Durability Test for Asphalt
JOURNAL : Proceedings of Association of Asphalt Paving Technologists
VOLUME No.: 24
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1955
PAGES : 31-62
ABSTRACTOR: PTI
KEYWORDS : Asphalt aging, oxygen reaction, light, temperature microviscosity, thin films, loss of volatiles

ABSTRACT :

Methods used to accelerate the asphalt aging by various investigators were high temperatures, ultraviolet light, chemical oxidation agents and oxidation in solution under oxygen pressure. Many authors have agreed that it is best to work with thin films that approach the film thickness of asphalt in road carpets. Reaction with oxygen has been shown to be one of the principal factors responsible for the hardening of asphalts in the road. Rate of chemical reaction and rate of diffusion of oxygen have been shown to control aging. Therefore, aging may be considered as a chemical as well as a physical problem. Recently, a durability test in which asphalt is aged in films 5 microns thick and tested with a microviscometer has been developed. In this paper, the microdurability test procedure is used to measure the change in viscosity of 5 microns asphalt films aged in air in the dark. The effects of temperature, film thickness, and presence of light were explored. Also, the hardening due to loss of volatiles was determined by aging in an inert gas (nitrogen). Analysis or results of tests on various types of asphalts indicated the following points: (a) most asphalts are non-Newtonian, therefore comparing viscosity before and after aging should be done at the same shear rate; 5x10 sec was chosen in this study. Some asphalts, especially after aging, show a slight yield point, however, at this shear rate the shear susceptibility curves have about the same slope and no correction is needed; (b) measurements of the viscosity of a non-Newtonian asphalt at different shear rates and different film thicknesses showed no effect of film thickness on viscosity measured by the sliding plate microviscometer at 25 C; (c) effect of film thickness on hardening of asphalts was observed to be significant. The ratio of viscosity before and after aging in the dark was observed to increase by about 25 percent when the film thickness was changed from 10 to 5 microns; (d) increasing the temperature increases the chemical reaction as well as the diffusion coefficient of oxygen due to the lowering of the asphalt viscosity. Temperature has great influence on aging rate; the same amount of hardening can be obtained by aging the asphalts 2 to 3 hours at 225 F as by aging 330 hours at 140 F. Increasing temperature does not have the same effect on various asphalts. (i.e. not all asphalts show same response to increased temperatures.); (e) comparing asphalts as aged in air and in nitrogen under the same conditions indicates that a large part of the hardening is due to loss of volatiles, especially for the asphalts that have high aging indexes. The loss in weight after aging correlates

somewhat with the increase in viscosity when aged in nitrogen; (f) aging asphalts in very thin films should be done in the dark, otherwise light will have a significant effect on hardening. In the field, it is not expected that light will effect more than very thin layer surface.

RECORD No.: 123.
AUTHOR : Lee, A. R., and Dickinson, E. J.
TITLE : The Durability of Road Tar with Special Reference to Its Use in Tarmacadam Wearing Surfaces
JOURNAL : Road Research Paper
VOLUME No.: 31
PUBLISHER : Department of Scientific and Industrial Research (England)
YEAR : 1954
PAGES : 35
ABSTRACTOR: HRB
KEYWORDS : Tar, oxidative hardening, modifiers, diffusion rate, aggregates

ABSTRACT :

This paper summarizes the work carried out at the British Road Research Laboratory to determine the reason for the deterioration of open-textured road surfacings and to improve the quality of tars to make them suitable for this type of surfacing. It is shown that resistance to atmospheric oxidation is an important property required by the tar binder used in an open-textured carpet. A laboratory test has been developed with which it is possible to assess this property, and an upper limit has been given, which should not be exceeded if a durable tar is to be ensured. Two methods are suggested for improving the resistance of certain tars to atmospheric oxidation: the phenolic constituents are removed in one method by washing with aqueous caustic soda, and in the other by oxidizing them in the tar before it is used on the road. The practical value of these processes has yet to be proved. Further work is in progress to establish whether some major structural change occurs with time when tar in the form of a very thin film is in contact with a mineral aggregate. Two appendices are included: (a) Experimental Methods for Examining Tars and (b) Theory of the Diffusion-Controlled Reaction of a Gas with a Thin Film of Viscous Liquid.

RECORD No.: 124.
AUTHOR : John M. Shaw
TITLE : Aging Characteristics of Certain 50-60 Penetration Asphalt Cements--An Interim Report
JOURNAL : Proceedings, Association of Asphalt Paving Technologists
VOLUME No.: 22
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1953
PAGES : 21
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, oxidative hardening, penetration, ductility, ball pressure, softening point
ABSTRACT :

Aging of asphalt at room temperature was evaluated by (a) ductility after 7 and 28 days, (b) penetration after 14, 28, and 365 days, (c) a special cavitometer test at 2 hr, 7 days, and 28 days, (d) ball pressure to cause rupture at 3 hr, 7 days, and 28 days, (e) Schweyer stain number, (f) film hardening at 325 F for 1 hr, and (g) an index based on softening point, ductility, and penetration. Data were obtained on airblown and P_2O_5 and $FeCl_3$ catalytically blown asphalts. Results showed definite differences for asphalts from different manufacturers and methods of processing.

RECORD No.: 125.
AUTHOR : J. T. Pauls and J. Y. Welborn
TITLE : Studies of the Hardening Properties of Asphaltic Materials
JOURNAL : Public Roads
VOLUME No.: 27
PUBLISHER : Bureau of Public Works
YEAR : 1953
PAGES : 187
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, oxidative hardening, penetration, abrasion test, TFOT, source of asphalt

ABSTRACT :

Experimental work by the authors led to the following conclusions: (a) bitumens of different crude origin have different hardening properties, (b) hardening properties depend upon method of manufacture, (c) cracked bitumens become hard and brittle more rapidly than distilled bitumens; on weathering, they also develop a higher degree of hardness and brittleness, the rate of hardness increasing with the degree of cracking, (d) increase in hardness, measured by decrease in penetration, is accompanied by increase in softening point and decrease in ductility and solubility. During the course of the work, 2 new methods, the abrasion test and the weathering strength test, were developed, involving the measurement of the change in physical properties on exposure to heat and the atmosphere, of standard sand-asphalt mixtures. The thin-film oven test was found to be a more speedy and simpler test of measuring these hardening properties.

RECORD No.: 126.
AUTHOR : Sideny H. Greenfeld
TITLE : Effects of Thermal Shock on the Durability of Asphalt Coatings Under Accelerated Test
JOURNAL : American Society for Testing and Materials
VOLUME No.: Bulletin No. 193
PUBLISHER : American Society for Testing and Materials
YEAR : 1953
PAGES : 46
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, oxidative hardening, weathering tests, mineral fillers, moisture, thermal cycles
ABSTRACT :

Three asphalts, representative of the major sources of coatings asphalt used in the manufacture of prepared roofings in the United States, were exposed, without stabilizer and with 30 percent and 60 percent of two mineral stabilizers, to accelerated durability tests. Four panels of each coating were subjected daily to 21 hr of exposure to the radiation from an enclosed, low-intensity carbon arc, with the introduction of a chilled water spray (40 F) for 3 min every 20 min (17-3 cycle). Two of the four panels with each coating were also exposed to air at -5 F for 2 hr daily. The use of the 40 F water produced results equivalent to those obtained when both the 40 F water and exposure to air at -5 F were employed. Exposure to air at -5 F had no significant effect on the durability or failure pattern of both stabilized and unstabilized asphalts under an accelerated test if the test included frequency cyclic thermal shocks.

RECORD No.: 127.
AUTHOR : J. T. Pauls and J. Y. Welborn
TITLE : Studies of the Hardening Properties of Asphaltic Materials
JOURNAL : Proceedings, Association of Asphalt Paving Technologists
VOLUME No.: 21
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1952
PAGES : 48
ABSTRACTOR: HRB
KEYWORDS : Asphalt cement, sand mixes, oxidative hardening, TFOT, compressive strength

ABSTRACT :

The rate of hardening of asphaltic mixtures is an important factor in the service life of bituminous pavements. In this study of the hardening properties of a large number of asphaltic materials, a test method was developed in which molded Ottawa-sand asphalt specimens were weathered in an oven at 325 F for different periods of time and then tested for compressive strength without lateral support. The basis for this procedure is the knowledge that the compressive strength of moded mixtures of asphalt and Ottawa sand, when tested without lateral support, is a measure of the hardness of the asphaltic binder. Oven weathering of the compression test specimens produced wide differences in the compressive strength of mixtures containing asphalts from various sources and produced by different methods of refining. Tests on the asphalts recovered from these weathered mixtures showed that the compressive strength was closely related to the consistency of the contained asphalt. Exposure of the asphalts to the thin-film oven test at 325 F produced changes in the asphalt similar to those produced by the oven weathering of sand-asphalt mixtures. It was thus further demonstrated that the thin-film oven test does indicate the relative resistance of asphaltic materials to hardening. Since the test procedure is relatively simple, the thin-film oven test should prove highly useful in evaluating this important property of asphaltic materials.

RECORD No.: 128.
AUTHOR : S. L. Neppe
TITLE : Durability of Asphaltic Bitumen as Related to Rheological Characteristics
JOURNAL : Trans., S. African Institute of Civil Engineers
VOLUME No.: 2
PUBLISHER : S. African Institute of Civil Engineers
YEAR : 1952
PAGES : 103
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, oxidative hardening, viscosity, penetration, softening point, ductility, temperature susceptibility
ABSTRACT :

An extensive study is reported, covering the durability of asphaltic bitumen as related to rheological characteristics. Six new methods for evaluation that have been evolved by the author are described and discussed. These are: (a) viscosity number - relating viscosity at any one of three temperatures 140, 158, and 176 F, to bitumen penetration at 77 F, (b) softening point number - relating R and B softening point to penetration, (c) softening point viscosity number - relating viscosity at 140, 158, 176 F to softening point; (d) fluidity characterization factor - based on absolute viscosity vs. temperature relationships over a wide range of temperatures from 77 to 275 F or higher, (e) penetration susceptibility factor - the temperature range over which penetration changes from 100 to 10, (f) ductility susceptibility factor - the temperature range over which ductility changes from 100 to 1. The data given amply support the author's concept of softening point number as a measure of bitumen stability. Softening point number is a rheological characterization index read directly from a chart and relating standard penetration at 77 F with softening point. It is shown that under identical conditions of exposure, the most drastic changes in characteristics invariably occur in bitumens of low softening point number. The higher this index, the longer is the life of the bitumen under the action of heat and weathering.

RECORD No.: 129.
AUTHOR : Huet, J.
TITLE : Contribution to the Study of the Chemical Aging of Bitumen
JOURNAL : Raport de Recherche
VOLUME No.: No. 57
PUBLISHER : Centre de Rechenrchs Routieres, France
YEAR : 1952
PAGES : 72
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, oxidative hardening, sulfur content, light effects

ABSTRACT :

The aging of bitumen is caused by diffusion of oxygen into the material, accompanied by oxidation and polymerization, which may be induced by peroxides. Laboratory tests of 12 months duration on 4 bitumens in the absence of light at 10 (+-) 5 C showed that most aging occurs in the first 20-30 weeks; then there is a trend towards equilibrium, when the materials is more stable than the original. Aging affects a thinner layer than indicated by accelerated tests. High-sulfur bitumens are more resistant to oxidation than the low sulfur ones. 64 references.

RECORD No.: 130.
AUTHOR : Neppe, S. L.
TITLE : Durability Properties of Asphaltic Bitumen, A Review of the Literature
JOURNAL : South African Institute of Civil Engineers
VOLUME No.: 1
PUBLISHER : South African Institute of Civil Engineers
YEAR : 1951
PAGES : 195
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, oxidative hardening, penetration, ductility, light effects, true penetration
ABSTRACT :

Literature on the hardening of bitumens is reviewed, with particular reference to critical penetration and ductility limits as affecting the disintegration of road surfaces. A critical survey is given of the methods for the evaluation of binder durability, covering the action of heat on thin films, oxidation, and sunlight, with special emphasis on ultraviolet and infrared radiations. Certain anomalies leading to incorrect interpretation of results in the graphical representations of experimental data by certain other investigators are pointed out, and the author illustrates the practical value of his conception of "true penetration." The term "percentage drop in penetration," as used in most bitumen specifications, is shown to be fundamentally unsound, and should be replaced by the more logical "percentage drop in log true penetration." 107 references are given.

RECORD No.: 131.
AUTHOR : Lee, A. R.
TITLE : Full Scale Experiments in Road Research, with Special Reference to Thin Carpets
JOURNAL : The Institution of Civil Engineers, Road Paper
VOLUME No.: 31
PUBLISHER : The Institution of Civil Engineers (London)
YEAR : 1950
PAGES :
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, test roads, traffic, moisture, oxidative hardening, aggregate gradation
ABSTRACT :

An account is given of some of the full-scale experiments on bituminous road materials that have formed part of the research program of the Road Research Board. Reference is made to many of the problems investigated by these experiments, which include the assessment of the factors that affect the durability of surface dressings, the design of durable non-skid, open- and medium-textured carpets for rural and city roads, and the relative performance of different road bases and surfacings used in the construction of new roads. Consideration is given to the principles involved in the planning and execution of road experiments, the degree of control required in such work, and the relation between road experiments and laboratory investigations. The limitations of circular-track and similar road-testing machines are discussed. As the deterioration of a road surfacing arises from the combined action of weather and traffic, misleading conclusions may easily be drawn from the results of experiments that omit or exaggerate unduly either one of these factors. The great influence of weather on the behavior, in early life, of surface dressings requires that experimental work on this type of road maintenance should consist largely of full-scale road experiments. Recent investigations have been directed to methods of overcoming the destructive action of wet weather, and they have shown how surface-active chemicals may be used successfully for this purpose. The problems raised by the popular demand for open-textured bituminous carpets may be solved with the help of full-scale road experiments in which a series of different surfacing materials are laid, with systematic regular changes being made in the aggregate grading, while with each grading a series of mixtures are laid covering a wide range of binder contents. Quantitative conclusions can be drawn from these experiments only if the limits of composition of each sub-series are so adjusted as to produce premature road failure. A description is given of the Colnbrook bypass experiment carried out in 1939, involving the use of granite and gravel aggregates and tar and bitumen binders. Definite conclusions can be drawn regarding the aggregate gradings and binder contents necessary for producing durable non-skid surfacings. The economic advantages of the successful use of local aggregates and binders has led to the repetition of this type of experiment in different parts of the country. These experiments have demonstrated the predominating influence that the type and quality of bituminous binder have on the life of the surfacing, and have

indicated that adjustments in grading and binder content are required for different aggregates. Further adjustments are required according to the traffic and the climatic conditions. They provide a means of checking the results of laboratory investigations of the weather-resisting and adhesive properties of road tars and bitumens and the properties of aggregates. They also give a basis for the correlation of laboratory tests with road performance. Similar types of road experiments have been carried out with dense, impervious mixtures on city streets, with the object of finding mechanical tests suitable for designing compositions that will successfully resist deformation under heavy traffic. The establishment of laboratory techniques for measuring the weather-resisting properties of road tars and bitumens and the mechanical properties of road mixtures is the outstanding need in the field of bituminous materials. Until these objects have been achieved, the full-scale road experiments offer the only reliable method of investigation.

RECORD No.: 132.
AUTHOR : Fair, W. F., Jr., Beck H. R., and McKee, B. K.
TITLE : Accelerated Weathering of Pitches and Asphalts
JOURNAL : American Society for Testing and Materials, Special Technical Publication
VOLUME No.: No. 94
PUBLISHER : American Society for Testing and Materials
YEAR : 1949
PAGES : 109
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, oxidative hardening, effect of light, heat, pitches, field performance
ABSTRACT :

The present work confirms the findings of Streiter and Snoke regarding the formation of water-soluble products from asphalts by the action of ultraviolet light, heat, and air. Water-soluble materials are extractable to only a small extent from pitches following exposure to ultraviolet light, heat, and air. Both asphalts and pitches exposed in thin films to the action of ultraviolet light, heat, and air in a weather-o-meter with and without water immersion exhibit marked increases in softening points; addition of filler to pitches or use of pitches according to standard built-up roofing procedures greatly reduces this softening point rise. The softening point rise in asphalts is accompanied by the formation of water-soluble compounds supposedly resulting from oxidation. In the case of pitches, the softening point rise is accompanied by the extraction of much smaller amounts of water-soluble compounds. This rise in softening point is probably due mainly to evaporation caused by the high temperature in the weather-o-meter. Thodes and Gillander found evaporation to be the major factor in the weathering of road tar materials. Pitches show little solubility in water following exposure to the action of heat, ultraviolet light, and air and show no change in rate of solubility during the periods studied; the asphalts exhibited considerable solubility for the first several 5-week periods and then exhibited a decrease thereafter. Accelerated aging tests of the kind described cannot be expected to duplicate long-time service performances because materials tested singly in the weather-o-meter behave differently than they do in service, when used in combination with other materials that partially eliminate or greatly retard the aging processes; however, important information may be obtained by accelerated tests if the results are judiciously evaluated and conservatively applied in comparing experimental and standard materials. The importance of the intelligent use of accelerated aging data for practical construction consideration cannot be overstressed.

RECORD No.: 133.
AUTHOR : Hunter, J. B., Gzemski, F. C., and Laskaris, L.
TITLE : A New Method for Evaluating Failure of Bituminous Materials Due to Weathering
JOURNAL : American Society for Testing and Materials, Special Technical Publication
VOLUME No.: No. 94
PUBLISHER : American Society for Testing and Materials
YEAR : 1949
PAGES : 144
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, age hardening, photographic technique, pitches
ABSTRACT :

A photographic technique is described for evaluating the characteristic failure patterns of bituminous coatings undergoing accelerated weathering. This method offers (a) extreme simplicity, (b) a permanent record of the failure pattern, and (c) rate of failure data. This last feature allows a comparison to be made between the weathering characteristics of various asphalts at a higher degree of failure as well as in the initial stages of one percent or less. Reproducibility tests show beyond question that this method of failure detection and evaluation constitutes a useful tool for carrying out investigations where the weathering characteristics of non-conducting coatings is an important factor.

RECORD No.: 134.
AUTHOR : Lewis, R. H.
TITLE : Behavior of Bituminous Road Materials Under Accelerated Exposure Conditions and Laboratory Heat Tests
JOURNAL : American Society for Testing and Materials, Special Technical Publication
VOLUME No.: No. 94
PUBLISHER : American Society for Testing and Materials
YEAR : 1949
PAGES : 14
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, oxidative hardening, tars, light, heat, air flow, penetration
ABSTRACT :

Accelerated weathering tests on various types of bituminous road materials, namely, road tars, liquid asphaltic materials, and asphalt cements, and, in some cases, on bituminous mixtures containing these binders, have been carried on for many years by the bituminous section of the Physical Research Branch of Division of Research, Bureau of Public Roads. When the investigations, which are reviewed briefly in this report, were initiated, the fact that all types of bituminous materials undergo changes upon aging and weathering was well known. However, the extent and character of the alterations that occur were not so well understood, and the first studies or investigations had no other purpose than to determine the kind and extent of the changes that occurred in the various types of bituminous materials when they were exposed to the action of light, air, and solar heat. Accelerated evaporation tests, such as the ASTM Distillation Tests, Methods D20-30(2) and D 402-48(3), as well as the test for so-called "asphalt content" or residue of specified penetration, ASTM Method D 243-36(4), and the test for loss of heating, ASTM Tentative Method D 6-39 T(5), are supposed to show in a relatively short time what will take place when the various materials are exposed to light, heat, air, and the other conditions met in the hot and the cold processing of bituminous surfaces. The adequacy of these tests to predict the probable curing and hardening properties, as well as the relative durability of different materials before embrittlement destroys their usefulness as binders, is often questioned. It was thought that a comparison of the characteristics of the residues developed in service with the characteristics of the residues from accelerated laboratory heat tests might provide a better understanding of the alternations that these materials undergo under both conditions. Such information should lead to the development of better test methods and specification requirements for specific types of road materials. In the majority of the investigations, therefore, the behavior of the materials under exposure has been correlated with the changes that occur in certain laboratory heat tests.

RECORD No.: 135.
AUTHOR : Stanton, T. E., and Hveem, F. N.
TITLE : Test Methods for Performing Accelerated Durability Tests on Asphalts
JOURNAL : American Society for Testing and Materials, Special Technical Publication
VOLUME No.: No. 94
PUBLISHER : American Society for Testing and Materials
YEAR : 1949
PAGES : 84
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, oxidative hardening, temperature effects, mixing, abrasion resistance, light effects

ABSTRACT :

It appears from the evidence thus far obtained that there is a definite difference in the problem of devising significant durability tests for paving asphalts as compared to tests for airblown asphalts. This is thought to be due to the fact that paving asphalts are subjected to two types of deteriorating or weathering influences. The first is the hardening action due to volatilization and oxidation in the mixer when asphalts are speared in thin films over the exterior surface of hot stone particles. A sconed weathering influence develops in the finished pavement exposed to the natural elements. While there may be some relation between hardening in the mixer and on the road, there is also reason to believe that the two processes develop in different order. In other words, an asphalt that can be markedly damaged by high temperatures during mixing may prove to give a satisfactory service life in pavements constructed at lower mixing temperatures. The temperature viscosity relationship of an asphalt should be given at least as much consideration when fixing the mixing temperature as the grade of the asphalt or the climatic conditions at the time of construction. The design of an apparatus for subjecting a sample of asphalt to weathering conditions should establish uniform treatment of all specimens, and the conditions in the weather apparatus should correspond as closely as possible to the destructive influences that operate on highways exposed to sun, wind and moisture. The mixing and preparation of test specimens should be accomplished by mechanical means so far as possible in order to provide uniformity between specimens tested. A quantitative method for testing changes in the abrasion resistance of asphaltic materials has been described. The abrasion test is applied to specimens which have been subjected to the hardening influences of infrared light or heat under conditions permitting the loss of volatiles and oxidation of the asphalt. The test is relatively simple and rapid, and test results are reproducible within a satisfactory range of accuracy.

RECORD No.: 136.
AUTHOR : Swanberg, John H. and Hindermann, W. L.
TITLE : The Use of an Abrasion Test as a Measure of Durability of Bituminous Mixtures
JOURNAL : American Society for Testing and Materials, Special Technical Publication
VOLUME No.: 94
PUBLISHER : American Society for Testing and Materials
YEAR : 1949
PAGES : 67
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, pavements, oxidative hardening, asphalt concrete mixtures, abrasion test, stripping

ABSTRACT :

In an attempt to evaluate the probable field performance of bitumen-aggregate systems, a limited amount of work has been done employing an abrasion test involving the use of the Deval abrasion machine. The specimens are tested in water at 35 F for approximately 1,000 revolutions. The loss in weight is taken as a measure of the resistance of the mixture of the action of water and traffic. Companion tests were made using an immersion-stability test, the Virginia stripping test, and a modification of the Nicholson stripping test. The investigation has involved the testing of a considerable number of gravel and crushed stone aggregates with asphalt cements of different penetration ranges, heavy slow-curing oil and rapid-curing cutback asphalt, with and without the addition of anti-stripping agents. On the basis of the limited data, it is believed that the test has merit. There appears to be reasonable correlation with the immersion-stability test but little or no correlation with the stripping tests. The test seems to evaluate the effect of the addition of anti-stripping agents in varying amounts and is sensitive to changes in bitumen content and changes in the aggregate. In view of its apparent ability to evaluate the performance of different bitumen-aggregate systems, it has been adopted as one yardstick of the suitability of such combinations. Where questionable field performance of a mixture is indicated, the test is further used as a measure of the improvement in a mixture resulting from such modifications in the mixture as may be made.

RECORD No.: 137.
AUTHOR : Zapata, J.
TITLE : Experience with Radiation in Accelerated Durability Tests on Bituminous Materials
JOURNAL : American Society for Testing and Materials
VOLUME No.: 94
PUBLISHER : American Society for Testing and Materials
YEAR : 1949
PAGES : 164
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, oxidative hardening, field aging
ABSTRACT :

A brief summary is made of reports available in the literature. A test conducted by the U. S. Gypsum Co. Research Laboratories is described and the results are analyzed. Some factors involved in the use of weather-o-meters are discussed. Outdoor exposure results are described, and certain recommendations regarding the use of accelerated testing machines are made.

RECORD No.: 138.
AUTHOR : Zapata, J. and von Hazmburg, R. S.
TITLE : The Effect of Fillers on the Durability of Asphalt
JOURNAL : Proceedings, Association of Asphalt Paving Technologists
VOLUME No.: 18
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1949
PAGES : 95
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, oxidative hardening, thin films, visual observations, field aging, fillers, performance
ABSTRACT :

An improved method is given for preparing asphalt films for exposure tests. The difficulty in making vasal inspections is described together with the need for using other methods in order to make the proper evaluation of the performance of asphalt films. The report tabulates observations of film performance on an outdoor exposure test and correlates such performance with particular size of the filler. Data are shown illustrating the effect of the filler on basic characteristics of the filler-asphalt mix. Laboratory tests are correlated to performance in service.

RECORD No.: 139.
AUTHOR : Lewis, R. H., and Welborn, J. Y.
TITLE : The Effect of Characteristics of Asphalts on Physical Properties of Bituminous Mixtures
JOURNAL : Proceedings, Association of Asphalt Paving Technologists
VOLUME No.: 17
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1948
PAGES : 228
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, asphalt concrete mixtures, oxidative hardening
ABSTRACT :

Laboratory tests on a particular bituminous mixture and a review of other investigations of the physical properties of bituminous mixtures indicate that these physical properties can be correlated, before and after accelerated or natural weathering, with the characteristics of the contained binders. Changes occurring in the binders of asphaltic mixtures that influence the durability of pavements under service conditions can be measured directly by tests on the bitumen recovered from the mixtures or indirectly by the changes in the physical properties of the mixtures.

RECORD No.: 140.
AUTHOR : Clark, Robert G.
TITLE : Quality of Asphaltic Road Materials
JOURNAL : Proceedings, Association of Asphalt Paving Technologists
VOLUME No.: 16
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1947
PAGES : 328
ABSTRACTOR: HRB
KEYWORDS : Asphalt cement, oxidative hardening, performance, wax content
ABSTRACT :

A discussion of quality with relation to durability and serviceability is given. New Mexico has found that if a maximum permissible amount of paraffin wax is limited to 4 percent and if the use of cracked materials is not permitted, the resulting asphaltic materials are of improved quality.

RECORD No.: 141.
AUTHOR : White, Oscar A.
TITLE : Durability of Asphalt in Hot-Mixed Asphaltic Concrete Pavement
JOURNAL : Proceedings, Highway Research Board
VOLUME No.: 27
PUBLISHER : Highway Research Board
YEAR : 1947
PAGES : 197-204
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, penetration, oxidative hardening, asphalt content, pavement performance, fillers, mixing time, mixing temperature
ABSTRACT : ·

Results of test indicate that: (a) When other factors are constant, the grade of asphalt has a definite effect in the penetration of asphalt after a period of service; (b) The asphalt content is the greatest single factor that determines the amount of drop in penetration of the asphalt in service; (c) No definite relationship is evident between the filler content and the drop in asphalt penetration after a period of service; (d) The temperature of the mix determines the extent of the asphalt penetration drop during mixing; (e) Mixing time has little or no effect on the amount of drop of penetration during mixing; and (f) The asphalt in cut-back wearing surface hardens in approximately 6 years to the degree that incipient raveling occurs.

RECORD No.: 142.
AUTHOR : Zapata, Joseph
TITLE : Laboratory Accelerated Weathering Tests
JOURNAL : Proceedings, Association of Asphalt Paving Technologists
VOLUME No.: 16
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1947
PAGES : 154
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, oxidative hardening, weathering tests, light effects, field aging

ABSTRACT :

In making accelerated weathering tests it is emphasized that light to which the specimens are exposed should simulate sunlight as nearly as possible. A discussion of cycle of exposure and methods of evaluating end points or failure is given. Photographs of films of bituminous materials exposed outdoors are included.

RECORD No.: 143.
AUTHOR : Lewis, R. H., Halstead, W. J.
TITLE : Behavior of Asphalts in Thin Films
JOURNAL : Public Roads
VOLUME No.: 24, No. 8
PUBLISHER : Bureau of Public Works
YEAR : 1946
PAGES :
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, TFOT, oxidative hardening, penetration, ductility, softening point
ABSTRACT :

This report covers the results of tests on the residues of asphalts from many sources that were obtained in the thin-film oven test (50 gram sample, approximately 1/8 inch thick heated at 325 degrees F for 5 hours in the standard volatilization oven). Ductility, softening point, and penetration tests were made; and, on basis of results obtained, recommendations for specification requirements for the thin-film oven test were suggested.

RECORD No.: 144.
AUTHOR : Zapata, Joseph
TITLE : The Use of Infrared Radiation in the Study of Bituminous Materials
JOURNAL : Proceedings, Association of Asphalt Paving Technologists
VOLUME No.: 15
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1943
PAGES : 197
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, age hardening, ultraviolet radiation, asphalt-sand mixes, field aging

ABSTRACT :

A study of the behavior of bituminous materials when exposed to cycles involving the use of ultraviolet radiation failed to disclose correlations with performance in service and also lacked consistency in duplication. In examining solar radiation, it was found that percentage of total radiation and the power of the short wave lengths were relatively small. However, the percentage and power of the infrared radiation amounted to about 50 percent of the total radiation. Several Ottawa sand-bitumen (MC-3) mixes were prepared and exposed to infrared radiation. Consistency tests were run on the bitumen extracted and recovered from these mixes and on the same bitumen from a pavement mix. The results showed that the bitumen from the laboratory mix had the same consistency after 30 hours exposure as the bitumen from the pavement mix had after 3 months of service.

RECORD No.: 145.
AUTHOR : Gene Abson
TITLE : The Softening of Oxidized Asphalts by Heating at High Temperatures and Its Relationship to Oxidizing Temperatures and Recovery Temperatures
JOURNAL : Proceedings, Association of Asphalt Paving Technologists
VOLUME No.: 13
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1942
PAGES : 182
ABSTRACTOR: PTI
KEYWORDS : Asphalt cements, oxidative hardening, softening point
ABSTRACT :

In observing the physical effects on asphalts recovered at various temperatures from 300 to 572 F, it has been consistently found that, contrary to general belief, softening occurs if the asphalt under observation has previously been oxidized either during manufacture or during the period of incorporation in a paving mixture, that this softening effect increases as the temperature increases, and that the lower the temperature of oxidation, the greater the increase in rate of softening. All of this is not entirely new. In a previous presentation, the subject was touched on by referring to the very marked increase in penetration that results when distilling a cut-back asphalt up to 680 F if the base happens to be an oxidized asphalt. Reference was also made to U. S. Patent 204, 081 issued to Dr. C. P. McNeil of the Standard Oil Company (Indiana), who devised a method of "soaking" at high temperature until the softening effect becomes stabilized. At that time it was not known that this same effect takes place at lower temperatures, albeit to a lesser degree, or that it is confined to blown asphalts, or that it occurs whether or not the asphalt has been previously diluted with a solvent. This paper, therefore, illustrates with specific examples that these effects do occur and that very marked increases in such common tests as penetration and ductility and decrease in softening point are consistently encountered. These are the reasons why it is desirable to use as low a temperature as possible when recovering asphalts from paving mixtures, as otherwise, misleading results are bound to follow since paving asphalts are always in an oxidized state in paving mixtures, due both to the mixing operation and subsequent aging.

RECORD No.: 146.
AUTHOR : Ebberts, L.
TITLE : Oxidation of Asphalts in Thin Films
JOURNAL : Industrial and Engineering Chemistry
VOLUME No.: 34
PUBLISHER : American Chemical Soceity, Easton, PA
YEAR : 1942
PAGES : 1048-1051
ABSTRACTOR: PTI
KEYWORDS : Asphalt, oxidation, pavement performance, cracking, air-blowing
ABSTRACT :

A method for measuring the oxidation of asphalts in thin films by means of potassium permanganate has been devised. It is fast and precise. It requires no special apparatus. Correlation with pavement service was established in several instances. The effect of air blowing on asphalts is still obscure. The method will differentiate between asphalts cracked at different levels and illustrates graphically the long known fact that cracking increases susceptibility to oxidation.

RECORD No.: 147.
AUTHOR : A. P. Anderson, F. H. Struss, and A. Ellings
TITLE : Measurement of Oxidation Stability of Road Asphalts
JOURNAL : Industrial and Engineering Chemistry
VOLUME No.: 14, No. 1
PUBLISHER : American Chemical Society, Easton, PA
YEAR : 1942
PAGES : 45-49
ABSTRACTOR: PTI
KEYWORDS : Asphalts, durability, oxidation, aging, resistance to hardening, pressure oxygen bomb, deterioration index, field performance
ABSTRACT :

The tests used to indicate the service behavior of the asphalt, such as the Oliensis test, and tests determining penetration of residue after heating, fluidity factor, susceptibility factor, etc. are more nearly identification tests for crude source or processing methods than measures of the quality of the bitumen. Thus, the need for a test that measures the durability of asphalts directly is apparent. In this paper, two test methods are described - the first, referred to as resistance to hardening, can be used as a simple routine test, while the second, leading to what is called the deterioration index, gives more accurate results but takes somewhat longer to carry out. Resistance to hardening is determined by heating, in the conventional manner, an asphalt specimen to 163 C for 5 hours in a standard oven after which the penetration of the sample is taken; this process is then repeated. The resistance to hardening may then be calculated as follows:

Resistance to hardening = $5[(Y_1-1)/(Y_1-Y_2)]+5$

where y = log penetration after 5 hr heating y = log penetration after 10 hr heating.

The resistance to hardening of 20 asphalts that differ in source and consistency were measured and compared to the performance of pavement sections constructed using these asphalts. These sections were laid in the San Francisco Bay area under mixing and laying conditions that were as well standardized as possible. Performance was indicated by visual ratings according to the amount of raveling exhibited by the pavements. The ratings were done after the period of one year, during which sections were subjected to uniform light traffic. Resistance to hardening, as calculated from the above equation, represented the time required by the asphalt to drop to "10 penetration" and it gave a fair correlation with service ratings according to the performance of section surveyed. The Deterioration Index is based on the idea that the time necessary for an asphalt to drop to a critical penetration under standardized oxidation conditions that simulate oxidation conditions in service should be the measure of the durability of an asphalt. Since the attainment of this penetration may take too long at the low test temperatures stipulated, it is necessary to develop a method of predicting this time from behavior at shorter times. The solution found was to combine the oxygen-absorption behavior of the asphalt, in amount and rate at a fixed time, with the hardening caused by a given oxygen absorption. This can be done with the Oxygen Bomb Test. The oxidation is carried out in a stainless steel bomb immersed in an oil bath which can be regulated to 0.1 C at the working temperature. 100 g of the warm asphalt are poured into a 240 ml oil sample bottle containing 67 grams of c. p. benzene. After weighing, the bottle is shaken until the solution is homogeneous; when it has reached room temperature it is placed in the bomb, which is at 25 C. The bomb is then sealed and flushed with oxygen by changing it to 100 lb/in^2 gage (6.8 atmospheres above atmospheric pressure). The process of flushing is repeated, the bomb is checked for possible leaks, then the pressure is adjusted to 100 lb/in^2, and the temperature is raised to 50 C. The pressure is recorded from now on continuously or as required. For each asphalt a long run of 40 hr (or longer), a short run in which the pressure drop should be at least 4 lb and an intermediate check run is made. At the end of each run, the oxygen is released, and the asphalt is recovered as soon as possible and the penetration is measured. The pressure drop is plotted against time for the longest run; the other runs should check this plot. From this graph the pressure drop at 40 hr and the slope of the tangent at this point are evaluated. The product of the pressure drop and the slope is called the oxidation rating. Next, the log penetration after oxidation is plotted against pressure drop for the three (or more) runs. The amount of oxygen needed to reduce the penetration to a value of 20 is obtained by extrapolation, and is called the hardening rating. The deterioration index is calculated as follows:

Deterioration index = (Oxidation rating)/(hardening rating) x 100

duplicate or triplicate runs should be made and should check within 1 lb/in^2 of their average. The deterioration indices should check within 10 percent of each other. The correlation found between service rating of section surveyed and deterioration rate was very good. A deterioration index lower than 15 indicates fully satisfactory performance; poor durability can be expected with an index above 20.

RECORD No.: 148.
AUTHOR : V. A. Endersby, F. H. Stroess and T. K. Miles
TITLE : The Durability of Road Asphalts
JOURNAL : Proceedings, Association of Asphalt Paving Technologists
VOLUME No.: 13
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1942
PAGES : 282
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, field tests, oxidative hardening, pavement performance
ABSTRACT :

Several sections of pavement were laid with a lean mix design in order to accelerate failure, using several different asphalt cements, including cracked ones. The performances of the sections were rated by visual examinations. The laboratory test of the asphalt cements that give the best correlation with the performance of the pavements was the Deterioration Index, which consists of determining the amount of and rate of hardening caused by oxygen.

RECORD No.: 149.
AUTHOR : G. H. Fuidge, and J. G. Mitchell
TITLE : Performance Tests for Road Tars -- A Report of the Research (Specifications) Subcommittee of the British Road Tar Association
JOURNAL : Journal of Society of Chemical Industry
VOLUME No.: 61
PUBLISHER : Society of Chemical Industry (London)
YEAR : 1942
PAGES : 133
ABSTRACTOR: HRB
KEYWORDS : Tars, oxidative hardening, road tests, viscosity, distillation test
ABSTRACT :

A large number of tars from various sources and a wide difference in road behavior were subjected to tests that were considered indicative of serviceability and durability. Surface dressing, accelerated carpets (open-graded mixtures) and dense graded carpets were prepared, laid and subjected to the action of traffic. The behavior of the mixtures were correlated with the results of the laboratory tests, such as the Beckton durability test, the rubber strip test, the increase in E.V.T., adhesive temperature test, the distillation test, including the ratio of distillate below and over 270 deg C, and the softening point of the residue over 300 deg C. Data indicate that the durability tests have proved their usefulness in evaluating the probable road behavior of road tars. The conditions of use of a tar are of vital importance in determining its effective life. They conclude that their experiments (field tests) have shown that even unsatisfactory tars can give reasonably good results in correctly applied types of construction, and that it may be that the value of laboratory performance tests will lie in giving an indication of the tolerance of tars to variations in the conditions of use.

RECORD No.: 150.
AUTHOR : R. R. Thurston and E. C. Knowles
TITLE : Asphalt and Its Constituents -- Oxidation at Service Temperatures
JOURNAL : Journal of Industrial Engineering Chemistry
VOLUME No.: 33
PUBLISHER : American Chemical Society, Easton, PA
YEAR : 1941
PAGES : 320
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, oxidative hardening, composition, oxygen environment
ABSTRACT :

Under weathering conditions asphalt surfaces undergo oxidation. This photo oxidation property of asphalt and its constituents have been studied by exposing samples in oxygen-filled sealed Pyrex containers under a sun lamp at temperatures approximating 170 deg F (77 deg C). The constituents identified as asphaltenes, resins, naphtene oil, paraffin oil and wax were obtained from three typical petroleum residues. All constituents absorbed oxygen, the resin and naphthene oil being a little more readily oxidized. Constituent source was also a factor. Part of the used oxygen was eliminated as water and carbon dioxide and all residues showed weight increase. The method is applicable to paving and roofing asphalts.

RECORD No.: 151.
AUTHOR : Emil G. Swanson
TITLE : Discussion of a new Additional Specification for Asphaltic Road Oils
JOURNAL : Roads and Streets
VOLUME No.: 84, No. 12
PUBLISHER : Gillette Publishing Co., Chicago
YEAR : 1941
PAGES : 31
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, oxidative hardening, viscosity of oil phase, ductility, solubility
ABSTRACT :

In a discussion of the specific gravity, flash point, moisture, viscosity, distillation, ductility and solubility, it is concluded that these tests are of no value in predicting the quality of asphalt. Quality is defined as embracing such properties as ease of application, the rapidity and tenacity with which it coats and adheres to the aggregate, its resistance to rupture, cracking or the ability to withstand deformation without failure. It also embraces the ability to retain its original characteristics, to resist stripping, weathering and hardening. The quality test proposed is the determination of the viscosity index of the oily phase of the asphalt.

RECORD No.: 152.
AUTHOR : R. H. Lewis and J. Y. Welborn
TITLE : The Properties of the Residues of 50-60 and 85-100 Penetration Asphalts from Oven Tests and Exposure
JOURNAL : Proceedings, Association of Asphalt Paving Technologists
VOLUME No.: 12
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1940
PAGES : 14
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, oxidative hardening, TFOT, penetration, ductility, field tests
ABSTRACT :

In recent years the value of the standard oven test for the prediction of the probable hardening of asphalts in the mixing and laying operations and under service conditions has been seriously questioned. Many investigators have resorted to oxidation tests to study the hardening and weathering properties of asphalts. Specifications are now in use that limit the loss in penetration and ductility that an asphalt can undergo either in a laboratory mixing text or in a plant-prepared hot-mix surfacing sample immediately after laying. This report presents the results of tests on 50-60 and 85-100 penetration asphalts made on the residues from the standard oven test as well as on the residues from 50-gram samples exposed to the same conditions in films approximately 1/8 inch thick. Changes in the properties of 85-100 penetration asphalts after exposure in 1/8 inch films for 15 weeks during the hot summer months are also shown. Although the residues from the standard oven test are not greatly altered, the residues from the 1/8 inch thin film oven tests, especially in the case of some 50-60 asphalts, are highly altered. Results of tests on the residues of 50-60 asphalts from the thin-film oven tests, when compared with the results of tests on bitumens extracted from both laboratory prepared mixtures and from mixtures from commercial paving plants, indicate that the 1/8 inch film oven test produces alterations in the asphalts similar to the changes in properties that occur during the mixing process. It is believed, therefore, that a thin-film oven test may prove of value in predicting the probable behavior of asphalts under processing and service conditions.

RECORD No.: 153.
AUTHOR : E. G. Swanson
TITLE : Viscosity Index of the Oily constituents of Asphaltic Road Oils
JOURNAL : Roads and Streets
VOLUME No.: 83, No. 5
PUBLISHER : Gilette Publishing Co., Chicago
YEAR : 1940
PAGES : 80
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, oxidative hardening, viscosity of oil portion, viscosity index
ABSTRACT :

It is proposed that the oily constituents be separated from the distillation residue (ASTM Method D 402-36) and the viscosity index of them determined by the method of Dean and Davis for viscosity index of lubricating oils (ASTM method D 567-41). The correlation of the viscosity index values with known service behavior of various oils has been extremely gratifying.

RECORD No.: 154.
AUTHOR : H. W. Skidmore
TITLE : The Effect of Oxidation Upon the Ductility of Asphalt Cements
JOURNAL : Proceedings, Association of Asphalt Paving Technologists
VOLUME No.: 12
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1940
PAGES : 69
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, oxidative hardening, air blowing, ductility
ABSTRACT :

This report describes an oxidation test for the examination of asphalts, to forecast their characteristics in the mixture as laid. It was found that by air blowing 100 grams of asphalt at 350 deg F for two hours, using one liter of air per minute, results were obtained that appeared to duplicate the effect of normal, good plant practice insofar as hardening of the asphalt was concerned. The results of tests before and after blowing for 58 samples of asphalt cement from various sources are given. Ductility tests were determined at 77 deg F at rates of elongation of 5 cm and 60 cm per minute.

RECORD No.: 155.
AUTHOR : C. L. Shattuck
TITLE : Measurement of the Resistance of Oil Asphalts (50-60 Penetration) to Changes in Penetration and Ductility at Plant Mixing Temperatures
JOURNAL : Proceedings, Association of Asphalt Paving Technologists
VOLUME No.: 11
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1940
PAGES : 186
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, oxidative hardening, field tests, ductility, penetration, asphalt-sand mixes, softening point
ABSTRACT :

Results of tests on samples of sheet asphalt taken from Detroit streets showed that for those pavements that were badly cracked, the ductility of the recovered bitumen was below a certain limit. A laboratory mixing test is described which was used to classify asphalt cements with respect to their resistance to oxidation, as measured by drop in penetration and ductility, when subjected to mixing conditions in a well-controlled asphalt plant. Data indicate that there is a wide difference in ductility loss of various asphalts while the penetration loss under the same heat conditions is fairly uniform. The mixing test was made by preparing a two percent asphalt-Ottawa sand mixture in a small laboratory mixer under controller temperatures and time of mixing. The mixture was then heated at 350 deg F for 30 minutes in an electric oven. After cooling, the asphalt was extracted with benzol, recovered by the Abson method and tested for penetration, ductility and softening point.

RECORD No.: 156.
AUTHOR : A. Holmes
TITLE : Investigation of the Shattuck Oxidation Recovery Test
JOURNAL : Proceedings, Association of Asphalt Paving Technologists
VOLUME No.: 12
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1940
PAGES : 167
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, oxidative hardening, asphalt sand mixes, Shattuck test, ductility
ABSTRACT :

This paper presents data showing the effect of certain variables enumerated in the Shattuck test on the properties of the recovered asphalt. The data indicate that: 1. Hardening of the asphalt occurs throughout all the time the sand-asphalt mixture is in a heated condition, but the major portion of asphalt hardening and loss in ductility occurs in the oven treatment. 2. Mixture density and oven temperatures are important factors in oven treating of mixture. 3. Mixing conditions should be standardized to facilitate obtaining uniform results. It is concluded that: 1. There is no positive evidence that the results of Shattuck test will correlate with actual road performance. 2. Lack of assured reproducibility of results indicate the necessity for a shorter and more precise procedure.

RECORD No.: 157.
AUTHOR : Robert G. Clark
TITLE : Quality of Asphaltic Road Materials
JOURNAL : Proceedings, 5th Annual Highway Engineering Conference
VOLUME No.: Series 1, No. 3
PUBLISHER : University of New Mexico
YEAR : 1940
PAGES : 50-60
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, asphalt-sand mixes, oxidative hardening, temperature susceptibility, compressive strength, impact strength
ABSTRACT :

Clark classes the durability of pavement surfaces into two periods: that of "optimum durability", at the end of which cracking of the pavement occurs, and that of "total durability", the time required for total failure, during which period the surface may remain in service by sealing and proper maintenance. By means of evaluation of crude oils in the highway laboratory, Clark claims a better control of the asphalts from accepted sources. Because the refining process is the most important factor in the control of quality of an asphaltic material. Clark investigated asphalts from 4 cracked and 4 uncracked oils of approximately the same consistency by mixing them with well graded sand and molding 1 in. by 1 in. briquettes. At the same time large batches of asphalt-sand mixtures were allowed to weather and at regular intervals briquettes were made from the weathered mixes. Data show that both under compression and impact, cracked road oils aggregate were molded and tested for Hubbard-Field Stability over a range of test temperatures. The stability values obtained were correlated with the asphaltic binders at testing temperature. Report shows that there is a great difference in stability of mixtures prepared with asphalts from various sources; that the bonding strength of asphaltic cement varies; and that for asphalts of the same type, having approximately the same susceptibility to temperature, the stability of the mixtures depended upon the consistency of the asphalt at the temperature of the stability test.

RECORD No.: 158.
AUTHOR : A. H. Benedict
TITLE : Durability of Asphalt Pavements
JOURNAL : University of Colorado Highway Conference
VOLUME No.:
PUBLISHER : University of Colorado
YEAR : 1940
PAGES : 44
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, oxidative hardening, penetration, performance
ABSTRACT :

A discussion of the changes that take place in the weathering of asphalt, namely drop in penetration during mixing and hardening in service. Use of laboratory tests to predict service behavior are also discussed.

RECORD No.: 159.
AUTHOR : E. B. Tucker
TITLE : Factors in the Hardening of Hot-Mix Asphaltic Materials
JOURNAL : Proceedings, Montana National Bituminous Conference
VOLUME No.:
PUBLISHER : Montana Bureau of Mines of Technology
YEAR : 1939
PAGES : 139
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, oxidative hardening, viscosity, age hardening, stripping
ABSTRACT :

Factors affecting the hardening of asphalt cements during plant mixing and placing are the oxidation characteristics of the asphalt, temperature of the mixture and the time the mixture remains at elevated temperatures. The oxidation characteristics of various asphalts shown by hardening and ductility varies widely. Various asphalts differ appreciably in viscosity at mixing and placing temperatures and these temperatures should be adjusted to the viscosity characteristics of the asphalt. The deterioration of paving mixtures after placing appears to be due to the hardening of the asphalt by oxidation and age hardening, or to displacement of the asphalt from the surface of the aggregate by water.

RECORD No.: 160.
AUTHOR : F. C. Land and T. W. Thomas
TITLE : Laboratory Studies of Asphalt Cements
JOURNAL : University of Minnesota Engineering Experiment Station
VOLUME No.: Bulletin 15, XLII, No. 55
PUBLISHER : University of Minnesota
YEAR : 1939
PAGES :
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, stripping, asphalt-sand mixes, tensile strength, abrasion loss, shear strength, field samples, oxidative hardening
ABSTRACT :

Twenty-four asphalts of the 85/100 penetration grade and nineteen asphalts of the 50-60 penetration grade, representing material from the same sources, were tested according to the standard specification tests, as well as many other tests that have been used for the examination of asphalts. The tendency of water to replace asphalt from mixtures of these asphalts and six types of mineral aggregates was investigated and the relative adsorption of asphalts by four types of powdered aggregates in a benzol solution was determined. The relative cementing qualities of the asphalts were determined by testing molded specimens of mixtures of the asphalt and standard Ottawa sand. The tests used included tensile strength and elongation, impact resistance, abrasion loss and shear strength. Mixtures of asphalt and Ottawa sand were exposed to heat and ultraviolet light in order to measure the relative durability of the various asphalts. Additional tests were made on sheet asphalt mixtures. The asphalts were recovered from the exposed specimens and the relative amount of hardening that took place in the various asphalts under the various exposure tests were determined. Sections of pavements (sheet asphalt) that had been in service for many years were extracted and the data obtained on the recovered bitumens were examined for correlation with the laboratory studies and their service behavior and condition at the time of testing. Data show that there are striking differences in the resistance of different asphalts to hardening when exposed under the various test conditions and that the tests ordinarily used in standard specifications for asphalt cements do not distinguish adequately between asphalts having high and low resistance to the exposure conditions of this investigation.

RECORD No.: 161.
AUTHOR : H. C. Bennett and D. W. Parkes
TITLE : A New Laboratory Test for the Durability of Road Binders
JOURNAL : Journal Society of Chemical Industry
VOLUME No.: 58
PUBLISHER : Society of Chemical Industry, London
YEAR : 1939
PAGES : 565
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, oxidative hardening, composite beam, elongation test, fracture, tensile strength, healing

ABSTRACT :

On the premise that retention of ductility within the range of normal temperatures over a long period of time is probably the most important characteristic of a good road binder, the authors describe the development of the rubber strip test to determine this property. Accelerated carpet tests were also installed to correlate the results of the laboratory rubber strip test with service behavior of the tar road binders under actual service condition. The report describes the preparation of the tar coated rubber strips, the instruments developed for making the weathering and elongation tests and the interpretation of the test data in connection with the performance of the binders in service. A film of binder 0.005 inch in thickness is placed on a rubber strip of approximately the same thickness. It is weathered at 40 degrees C for 72 hours and tested at various intervals. The film is elongated at a standard rate and the temperature is lowered until a full crack appears. The effect of quality and quantity of fluxing oil used in preparation of tar binder, the temperature used during the subsequent to fluxing of tar binder, and the healing properties of the binders were investigated and discussed. It is concluded that the rubber strip test is a valuable laboratory tool and the basis of a possible standard durability test. It can also be used to measure the phenomenon of healing of weather binders.

RECORD No.: 162.
AUTHOR : L. V. Garrity
TITLE : Heat-Treatment for Asphalt Cements
JOURNAL : Chemical Abstracts
VOLUME No.: 33
PUBLISHER : American Chemical Society
YEAR : 1939
PAGES : 3990
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, oxidative hardening, asphalt-sand mixes, penetration, ductility
ABSTRACT :

To study the change in ductility and penetration of asphalt cements due to the effects of heat and air, three methods were employed: (1) the 100 penetration asphalt content test, (2) the blowing of air through a material at 200 degrees C for a definite period of time, and (3) graded Ottawa sand-asphalt mixture subjected to an oven temperature of 163 degrees C for different periods of time. There are at least 2 serious objections to the oven method of heating: (a) the operation is laborious, since it involves making the synthetic paving mixture, oven-heating, and then recovering the asphalt by the time-consuming Abson Recovery method; (b) the large temperature difference between the inside of the mix and the surface (60 degrees C at 20 minutes and 30 degrees C at 30 minutes) obviously results in greater changes of the asphalt at the surface of the mix then in the interior. The subsequent blend of the bitumen would then have characteristics different from a bitumen uniformly exposed to the action of heat and air. It was therefore decided to try other methods of heating. The asphalt-content test has certain inherent defects as a method of heat reduction of penetration and ductility. The most serious of these defects are: (a) the temperature range in heating (249 to 260 degrees C) is relatively great, and susceptible materials will give radically different results if heated to the same consistency at extremes of the temperature range allowed (this has been proven many times with road oils); (b) circulation of the material in the test container depends, aside from the occasional stirring, upon convection currents. Samples heated for 4.5 hours showed a variation in penetration from 23 to 32 and in ductility from 16 to 87 cm. These seemingly erratic results can be accounted for only by the differences in the chemical constituents of the asphalts. The physical changes taking place during heating are results of chemical changes involving polymerization, oxidation and condensation. Asphalt is made up of a very complex system composed of several chemical groups and the percentage of each group vary, depending upon the field from which the crude oil was obtained. Since each group has definite characteristics and definite reactions to chemical changes, it follows that any change in the method of heating will affect the results. Thus, an asphalt containing types of hydrocarbon molecules relatively susceptible to oxidation will show greater reduction in penetration and ductility by the air-blowing method. It is thought that oxidation is responsible for most of the changes in asphalt. Proper combination of temperature and quantity of air

in the blowing method is believed to duplicate correctly the reduction in penetration and ductility of the asphalt obtained in asphalt-paving practice.

RECORD No.: 163.
AUTHOR : C. L. McKesson
TITLE : Durability of Asphaltic Binders
JOURNAL : Proceedings, Montana National Bituminous Conference
VOLUME No.:
PUBLISHER : Montana bureau of Mines and Technology
YEAR : 1938
PAGES : 293
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, oxidative hardening, penetration, ductility, additives

ABSTRACT :

This report presents data on the changes that occur in the consistency and ductility of asphalt cements when subjected to laboratory mixing and heating tests as binders in various types of bituminous mixtures. The effect of the admixtures of sulfur and metallic sulfates to asphalt on the penetration and ductility of the resulting asphalt cements was also determined. The effect of air blowing on residual oils and the behavior of the air-blown asphalts resulting therefrom after laboratory hot-mixing tests are also discussed. The characteristics of binders recovered from sheet asphalt and emulsified asphalt penetration pavements are shown. The following conclusions are presented: 1. Asphaltic binders for use, either hot or cold, which lose ductility rapidly in oxidation tests, will similarly oxidize and loss ductility in pavements with resultant brittleness and cracking. 2. The heat treatment of air blowing methods of testing can be applied to liquid asphaltic binders prior to use, as well as to paving asphalt, and can be expected to show whether durable ductile binder will be produced in the pavement when it has aged. 3. Sulfur probably contributes to early hardening the loss of ductility in asphaltic binder. Seventeen references are given in the appended bibliography.

RECORD No.: 164.
AUTHOR : Traxler, R. N., and Coombs, C. E.
TITLE : Structure in Asphalts Indicated by Solvent-Treated Surfaces
JOURNAL : Industrial and Engineering Chemistry
VOLUME No.: 30
PUBLISHER : American Chemical Society, London
YEAR : 1938
PAGES : 440
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, steric hardening, surface observation, solvents, rheological properties
ABSTRACT :

A study of flow characteristics indicates that asphalts possess varying degrees of internal structure, depending upon the source of the material, method of processing, and the temperature at which the rheological test is made. Asphalts which show distinct anomalous flow characteristics as manifested by a high rate of age hardening, marked elastic properties, etc., give surface designs when treated with partial solvents such as ethyl ether and 86 degree Be. naphtha; with asphalts that are essentially viscous no designs are obtained. Consequently, the presence of a surface pattern may be an indication of structure in an asphalt.

RECORD No.: 165.
AUTHOR : R. Vokac
TITLE : Correlation of Physical Tests with Service Behavior of Asphaltic Mixtures--II
JOURNAL : Proceedings, Association of Asphalt Paving Technologists
VOLUME No.: 9
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1937
PAGES : 309-323
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, oxidative hardening, field tests, mixture properties
ABSTRACT :

This paper is an extension of research done earlier the same year by the author. To complete this study he undertook a similar analysis of data obtained from hot sheet asphalt surface mixtures. 79 samples of sheet asphalt were obtained from 17 localities. Included were both oil and native lake asphalt mixtures of various age ranging from 1 to 49 years. The author considered both hot and cold mixtures and concluded that the limits of compressive strength, elastic limit and modulus of permanent deformation were substantially the same for hot and cold mixtures.

RECORD No.: 166.
AUTHOR : R. Vokac
TITLE : Correlation of Physical Tests with Service Behavior of Asphaltic Mixtures
JOURNAL : Proceedings, Association of Asphalt Paving Technologists
VOLUME No.: 9
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1937
PAGES : 309
ABSTRACTOR: HRB
KEYWORDS : Asphalt paving mixture, field tests, oxidative aging, stability, air voids
ABSTRACT :

Data listed in this article concern mixtures that are cold-lay materials and cold-mixes. 106 mixtures were studied for over a year in service and predictions were made for the performance of these mixtures. All mixtures were designed by a method developed in the laboratory of the Barber Company for voids between three and four percent and stabilities between 1000 pounds and 2500 pounds, depending upon the aggregates used. Aggregates were imported from various parts of the Eastern region of the United States. Article well illustrated with many figures.

RECORD No.: 167.
AUTHOR : V. S. Steinbaugh and J. D. Brown
TITLE : A Study of Asphalt Recovery Tests and Their value as a Criterion of Service Behavior
JOURNAL : Proceedings, Association of Asphalt Paving Technologists
VOLUME No.: 9
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1937
PAGES : 138
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, field tests, oxidative hardening, penetration, ductility
ABSTRACT :

A survey of high type bituminous pavements in Michigan showed a prevalence of cracking. Recovery tests showed the asphalts contained in the cracked pavements to have lower penetration and ductility values than in the good pavements. This led to the adoption of a provision in the State specifications for determination of the characteristics of bituminous materials in mixtures after placing. This provision was that the bitumen extracted from pavement samples by the Abson method shall not decrease in penetration by more than 50 percent of the original asphalt and shall not decrease in ductility to less than 40 cm. The effect of recovery methods on the characteristics of the extracted bitumen are given. Laboratory oxidation tests on the asphalts were made in an attempt to produce residues similar to those found in pavements after laying.

RECORD No.: 168.
AUTHOR : H. W. Skidmore and C. Abson
TITLE : The Progressive Hardening of Asphalt Cement in Paving Mixtures
JOURNAL : Proceedings, Association of Asphalt Paving Technologists
VOLUME No.: 9
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1937
PAGES : 195-199
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, oxidative hardening, mixing time, mixing temperature, penetration, ductility, cracking
ABSTRACT :

Results of tests on original asphalts, tests on extracted bitumens from pavements freshly laid, and on uncompressed plant samples after storage under laboratory conditions for various periods of time are given. Authors stress the importance of using softer asphalts, since hardness of asphalt is minor factor in providing stability of mixture.

RECORD No.: 169.
AUTHOR : J. W. Powers
TITLE : Hardening of Asphaltic Cement in Asphaltic Concrete
JOURNAL : Proceedings, Montana National Bituminous Conference
VOLUME No.:
PUBLISHER : Montana Bureau of Mines and Technology
YEAR : 1937
PAGES : 344
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, oxidative hardening, penetration, ductility, softening point, mixing temperature, pavement cracking
ABSTRACT :

Development of cracks and increased roughness of the riding surface led to the investigation of the properties of asphalt in some of the older pavements. While all the records of the original pavements were not available, enough were obtained to give a fair idea of the extent to which the asphalts had hardened. The extraction of the asphalts was done by the Abson method. Results demonstrate that loss in penetration is accompanied by a decrease in ductility and an increase in the melting point. Further tests showed the temperature of mixing over a range at 265 degrees F to 305 degrees F had little effect on the penetration of the recovered asphalt. Samples from an asphaltic concrete job were stored in air-tight containers. The original asphalt had a penetration of 109. At the age of 1 day the penetration of the recovered asphalt was 95. Other samples were extracted from time to time, the final one reported at the age of 106 days had a penetration of 63.5.

RECORD No.: 170.
AUTHOR : Victor Nicholson
TITLE : A Laboratory Oxidation Test for Asphaltic Bitumens
JOURNAL : Proceedings, Association of Asphalt Paving Technologists
VOLUME No.: 9
PUBLISHER :
YEAR : 1937
PAGES : 208-214
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, oxidative hardening, penetration, ductility
ABSTRACT :

The author describes the method and equipment that he employs to show the changes that occur in asphalt cement under oxidation. Two hundred and twenty-five grams of asphalt cement are blown in a glass flask at a temperature of 425 degrees F, with 1/3 cubic feet of air per minute, which treatment simulates the condition at asphalt plant when high temperatures are used. In evaluating asphalts, he states all asphalts alter their properties in the mixing process and in service until the ultimate penetration of 20-25 is reached. The asphalt, which shows the highest ductility at this temperature is considered best. By running the oxidation test until a penetration of 20 is reached, the quality or durability of the asphalt can be predetermined by making ductility tests on the residue. Data are shown on the behavior of typical asphalts subjected to the test.

RECORD No.: 171.
AUTHOR : Hubbard, P., and Gollomb, H.
TITLE : The Hardening of Asphalt with Relation to Development of Cracks in Asphalt Pavements
JOURNAL : Proceedings, Association of Asphalt Paving Technologists
VOLUME No.: 9
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1937
PAGES : 165-194
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, field performance, penetration, pavement cracking, air voids
ABSTRACT :

A review and analysis of published literature dealing with the hardening of asphalts by weathering and during paving plant manipulation is followed by additional data developed by authors' own investigation. They present a table showing the relative resistance of asphalt from eleven different sources and suggest the development of some rapid test on the asphalt alone to indicate its resistance to hardening in paving mixtures. 1. Extreme hardness of asphalt in an asphalt pavement is conducive to cracking. 2. Thin films of all asphaltic products may be expected to harden, if not adequately protected from contact with free air. 3. The expectancy of cracking in temperature climates, but where freezing temperatures are common in winter, is (a) asphalt of less than 20 penetration, bad cracking; (b) asphalt higher than 30 penetration, no cracking; (c) asphalt between 20 and 30 penetration, uncertain. 4. An asphalt of 50 penetration may be reduced to as low as 35 penetration during preparation of hot mix, bringing it dangerously close to the cracking range. 5. Progressive hardening of asphalt film is slow in a dense, thoroughly compacted paving mixture. If readily permeable to air, dangerous hardening may occur quickly. 6. Asphalt in paving mixture should be as soft as consistent with required stability. 7. Film thickness should be as great as consistent with required stability. 8. Mixtures should be prepared at the lowest practicable temperatures and should be thoroughly compressed to make them as impermeable to air as possible. 9. All mixtures permeable to air should be seal coated.

RECORD No.: 172.
AUTHOR : Brannon, T. W.
TITLE : Penetration Tests Being Made on Recovered Asphalt
JOURNAL : Civil Engineering
VOLUME No.: 7
PUBLISHER : American Society of Civil Engineers
YEAR : 1937
PAGES : 291
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, field aging, penetration, temperature of mixing, time of mixing
ABSTRACT :

Tests made on asphalts recovered form hot-mixed, hot laid asphaltic concrete wearing course mixtures, as specified by the Ohio State Highway Department, containing from 6 1/2 to 10 percent of 50-60 penetration asphalts showed, (1) that up to 4 1/3 years the asphalt recovered from fifteen pavements showed a steady drop in penetration; (2) that the asphalts recovered from 17 samples cut from pavement lost approximately 25 percent of their original penetration during the mixing and laying operations (3) that the recovered asphalts recovered that temperature and time of mixing have a direct effect on the penetration of the recovered asphalt.

RECORD No.: 173.
AUTHOR : Traxler, R. N., and Coombs, C. E.
TITLE : Development of Internal Structure in Asphalts with Time
JOURNAL : Proceedings, American Society for Testing Materials
VOLUME No.: 37, Part II
PUBLISHER : American Society for Testing and Materials
YEAR : 1937
PAGES : 549
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, steric hardening, temperature, viscosity, time effects

ABSTRACT :

The increase in consistency of asphalts with time indicates the development of internal structure. This structure is developed more rapidly in air-blown than in steam or vacuum-refined bitumens; it is partially or wholly eliminated by heating or mechanical working. In asphalt-mineral mixtures age-hardening appears to be chiefly dependent on the nature of the bitumen present. It has been indicated that the higher the rate at which internal structure develops, the more marked the deviation from viscous flow. Asphalts with high rates of age-hardening and definite deviation from viscous flow give characteristic microscopic patterns when the surfaces are etched with ethyl ether or 86 degree B. naphtha. Essentially viscous asphalts have low rate of age-hardening and show no surface patterns. The explanation offered for the increase of consistency with time is that a gradual isothermal sol-gel transformation takes place, the magnitude of which depends on the source and method of processing.

RECORD No.: 174.
AUTHOR : Benson, J. R.
TITLE : Microscopic Reactions in Translucent Asphaltic Films
JOURNAL : Proceedings, Association of Asphalt Paving Technologists
VOLUME No.: 9
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1937
PAGES : 102-137
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, oxidative hardening, steric hardening, fillers, thin films, microscopic studies, waxy bodies

ABSTRACT :

A rapid accurate method of obtaining accelerated weathering of asphaltic materials has been desired for many years. In the search for such a test, translucent films approximately 0.001 in. thick have been used. These films present rapid reactions, some within 30 minutes, when exposed to natural and various artificial weathering agencies. Some of these reactions are visible under the microscope. The reactions have been classified as clear, coagulated, flocculated, waxy bodies, checked and hardened. The methods and reactions are described. The coagulative reaction is believed to be a separation of the asphaltic material into two phases, both of which are sometimes observable. Waxy bodies and their possible effect on adhesive and cohesive properties of the asphalt are noted. Hardening may be investigated under conditions closely approaching actual service, or accelerated by various agencies.

RECORD No.: 175.
AUTHOR : Streiter, O. G., and Snoke, H. R.
TITLE : A Modified Accelerated Weathering Test for Asphalts and Other Materials
JOURNAL : Journal of Research
VOLUME No.: 16, No. 5
PUBLISHER : National Bureau of Standards
YEAR : 1936
PAGES :
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, oxidative hardening, oxygen light effects
ABSTRACT :

A modified method for testing asphalts and similar complex materials by accelerated weathering is described. A variety of materials are shown to exhibit the same type of chemical changes when exposed to the accelerated weathering cycle. The experiments show that the weathering process gradually transforms these materials into products that are largely soluble in water, and that these soluble products may be collected quantitatively for examination and identification. The function of light and oxygen in the weathering process is explained, and data are given to show that the products of accelerated weathering are similar to those obtained in outdoors exposures. New applications of accelerated weathering are suggested.

RECORD No.: 176.
AUTHOR : Sabrow, S., and Renaudie, E. M.
TITLE : A Study of the Aging of Coal-Tar Road Binders
JOURNAL : Chemical Abstracts
VOLUME No.: 29
PUBLISHER : American Chemical Society
YEAR : 1935
PAGES : 6389
ABSTRACTOR: HRB
KEYWORDS : Tars, oxidative hardening, viscosity, loss in weight, light effects, fillers

ABSTRACT :

The aging of coal-tar used as a binder in road surfacings is due almost entirely to evaporation of volatile constituents, to a very slight extent to a very slow oxidation and not at all to polymerization. In order to compare the value of tars from the standpoint of their suitability as road binders, it is suggested that, in addition to the usual tests, the determination of the "aging coefficient" can give useful information, particularly as regards the drying properties and the liability to softening in summer. This is defined as C t/v = (Vv - Vp)/Ap, in which C t/v is the aging coefficient at temperature t, Vv is the viscosity after artificial aging at t, Vp is the viscosity of the original tar, and Ap the loss in weight of the tar during the artificial aging. The aging is produced by exposure to ultraviolet light under definite conditions. Considerable experimental work will be required to ascertain the value of this method and to assign numerical values suitable for the practical interpretation of the results. Useful information can also be obtained by spreading the tar on thin aluminum plates and exposing to artificial aging by ultraviolet light. Improvement of the road-making qualities of tar by blowing air through it does not seem to offer any advantages over the ordinary dehydration process; incorporation of carbonaceous fillers seems to hold promising possibilities.

RECORD No.: 177.
AUTHOR : Wasilewski, Ludwik and Maczynski, Maciej
TITLE : Application of a New Method of Laboratory Testing of Mixtures of Stone, Asphalt and Tar
JOURNAL : Chemical Abstracts
VOLUME No.: 26
PUBLISHER : American Chemical Society
YEAR : 1931
PAGES : 276
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, tar,s oxidative hardening, limestone filler, penetrometer, paraffin additive
ABSTRACT :

A limestone of analytically defined properties and crushed to pass 81-225 meshes per sq. cm. served as a standard reference material. It was heated to 120 degrees C and mixed with the asphalt under test brought to the same temperature. The mixture was then briquetted hot (120 degrees C) into fifty gram samples with a pressure of 1,370 kilograms per sq. cm, read on a precision manometer. This rather high pressure was needed to make a clear distinction between the character and behavior of different samples. A needle of 1.4 to 1.5 mm in diameter with a 45 degree point and somewhat similar to the needle of Vicat was made to penetrate slowly into the test briquette by the force of an applied weight while the distance penetrated was recorded on a revolving drum. After a certain depth of penetration, characteristic of the bituminous binder, the briquette very rapidly, in either case showing a distinct break in the curve of time vs distance penetrated. Although in a given series the rate of penetration varied widely the distance of penetration before failure of the briquette always occurred at the same depth. Numerically this might be expressed as the elastic strength of the material. By means of this apparatus it was possible to uncover differences in mixtures produced by the kind and proportion of stone and asphalt, and tar, to show the effect of the addition of paraffins and by changes sometimes produced at various temperatures.

RECORD No.: 178.
AUTHOR : Bateman, J. H., and Delp, C.
TITLE : The Recovery and Examination of the Asphalt in Paving Mixtures
JOURNAL : Proceedings, American Society for Testing and Materials
VOLUME No.: 27, Part II
PUBLISHER : American Society for Testing and Materials
YEAR : 1927
PAGES : 465
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, extraction method, oxidative hardening mineral surfaces
ABSTRACT :

This paper describes a method for extracting and recovering the asphalt in asphaltic paving mixtures by which the physical characteristics of the asphalts were not changed materially. The method makes use of common processes of extracting asphalt but introduces a modification of the usual procedure for distilling off the solvent in the recovery of the asphalt. By the use of a partial vacuum, the distillation of solvent is carried out without greatly affecting the physical characteristics of the asphalt as it exists in the paving mixture. The use of carbon disulfide as solvent caused no appreciable change in the characteristics of the asphalt. Test data on the asphalts before and after admixture with the mineral aggregate show that the process of mixing asphalt with mineral aggregate has an oxidizing effect on the asphalt binder.

RECORD No.: 179.
AUTHOR : Reeve, C. S., and Lewis, R. H.
TITLE : The Effects of Exposure to Some Fluid Bitumens
JOURNAL : Journal of Industrial Engineering Chemistry
VOLUME No.: 9
PUBLISHER : American Chemical Society, Easton, PA
YEAR : 1917
PAGES : 743
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, tars, field exposure, oven test, consistency, solubility
ABSTRACT :

Seven liquid bituminous materials, six asphaltic materials and one water-gas tar were exposed for one year, beginning in January, in thin layers to the action of air, light and solar heat in glass-covered boxes. The report shows the routine tests on the original materials; the changes in weight at the end of each 2 month-exposure period, and the results of consistency, solubility and fixed carbon tests (on asphaltic materials only) on the residues after each exposure period. The original materials were also subjected to the standard oven test for 5, 10, and 15 hours and the residues were tested in the same manner as the residues from exposure. The data obtained corroborated and amplified all previous data that bituminous materials upon exposure undergo changes that are due to something more than mere loss of volatile matter. It was shown that similar changes occur in samples when subjected to the standard volatilization test, although changes are greater when the exposures are made under atmospheric influences. Authors conclude that while oxygen plays its part in the changes which occur, they are led to the conclusion that polymerization and intermolecular reactions induced by heat and possibly increased by the action of light are also very largely responsible for such changes in addition to those which are accounted for by simple evaporation.

II. Characterization Studies

RECORD No.: 1.
AUTHOR : Bell, C. A. ; Kliewer, J. E. ; Kramer, B. W. ; Thenoux, G.
TITLE : Evaluation of Asphalt Properties and Their Relationship to Pavement Performance. Final Report: Part 2. A Microcomputer Inventory for Routine Asphalt Data
JOURNAL : FHWA report
VOLUME No.: FHWA/OR/RD-88/02/2
PUBLISHER : FHWA
YEAR : 1988
PAGES : 143p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt cements, database, laydown temperature, penetration ratio, penetration index, temperature susceptibility
ABSTRACT :

The report is Part 2 of the final report for the research project titled, "Evaluation of Asphalt Properties and Their Relationship to Pavement Performance". Part 1 of the final report presented the results and an evaluation of a laboratory test program. The Oregon State Dept. of Transportation, Highway Division, Materials Section, currently maintains its asphalt sample data manually. A computer database program has been developed and documented to maintain the data efficiently on a microcomputer. The report describes the database management program, applications, operation procedures, examples of data summaries, statistics, and program documentation. The report presents data evaluation examples. The first example considers laydown temperatures, and from an examination of the database, concludes that the current Oregon State Highway Division practice of using a temperature of 280 deg F (138 deg C) is sound practice. The second example attempted to establish a relationship between penetration ratio (PR) and penetration index (PI). No relationship was determined and therefore no ensuing recommendation was made.

RECORD No.: 2.
AUTHOR : Thenoux, G. ; Bell, C. A. ; Wilson, J. E. ; Eakin, D. Schroeder, M.
TITLE : Evaluation of Asphalt Properties and Their Relationship to Pavement Performance. Final Report: Part 1. Presentation and Evaluation of Data
JOURNAL : FHWA report
VOLUME No.: FHWA/OR/RD-88/02/1
PUBLISHER : FHWA
YEAR : 1988
PAGES : 120p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt cements, oxidative hardening, composition, pressure oxygen bomb, rheological properites
ABSTRACT :

The report is Part 1 of the final report for the research project titled "Evaluation of Asphalt Properties and Their Relationship to Pavement Performance". The overall objective of the research was to implement an analytical chemical procedure that could be used to characterize asphalt pavement materials. Results from the chemical analysis were subsequently used for the evaluation of pavement performance. The chemical test procedure used corresponded to that developed by Corbett and Swarbrick. Fractional compositions were statistically related to a number of physical tests and asphalt temperature susceptibility indices. The report also presents an evaluation of four different asphalt extraction/recovery procedures and an evaluation of a pressure oxygen bomb device used for asphalt laboratory aging.

RECORD No.: 3.
AUTHOR : Brule, Bernard; Raymond, Guy; Such, Crhistian
TITLE : Relationships Between the Composition, Structure and Properties of Roadmaking Bitumens: The Progress of Research at the LCPC
JOURNAL : Bulletin de Liaison des Laboratoires des Ponts et Chaussees
VOLUME No.: 148
PUBLISHER : LCPC
YEAR : 1987
PAGES : 69-81
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cements, HPLC, GPC, differential thermal analysis, viscoelasticity, colloidal structure
ABSTRACT :

This article takes stock of research at the Laboratoire Central des Ponts et Chaussees in Paris in the field of bitumens. Where physico-chemical characterization is concerned, this research employs high-performance liquid chromatography, gel permeable chromatography and differential thermal analysis. In the field of rheological behaviour, recourse is had to peeling, viscoelasticity measurement and viscosimetry on thin films. Theoretical considerations have led to a new model of rheological behaviour. Gel permeable chromatography makes it possible to characterize the equilibrium of the colloidal structure of the bitumen and to obtain information on the ability of asphaltenes to interreact to form a developed system which responsible for the gel nature of the rheological behaviour. 26 refs. In French.

RECORD No.: 4.
AUTHOR : Stock, A. F.; Button, Joe
TITLE : Relationship Among Parameters Derived from High-Performance Liquid Chromatography, Physical Properties, and Pavement Performance in Texas
JOURNAL : Transportation Research Record
VOLUME No.: 1115
PUBLISHER : Transportation Research Board
YEAR : 1987
PAGES : 33-46
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cements, asphalt concrete mixes, road tests, oxidative hardening, penetration, voscisoity, chromatography
ABSTRACT :

The performance of asphalt cement in pavement mixes has aroused considerable interest and debate in the past few years. As a result of this, the Texas State Department of Highways and Public Transportation has sponsored studies to compare the performance of asphalt cement from different sources through a series of full-scale trials and associated laboratory studies. The laboratory studies include penetration and viscosity tests on the asphalt cement, from which temperature susceptibility parameters have been derived; mix parameters such as void content and resilient modulus; and state-of-the-art chromatography. This paper makes the results obtained to date available to other researchers and draws some tentative conclusions about the interrelationship among the various tests that have been performed. (Edited author abstract) 5 refs.

RECORD No.: 5.
AUTHOR : Brule, Bernard
TITLE : Bitumens and Standardization
JOURNAL : Bulletin de Liaison des Laboratoires des Ponts et Chaussees
VOLUME No.: 148
PUBLISHER : LCPC
YEAR : 1987
PAGES : 61-68
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cements, specifications, oxidative hardening, consistency

ABSTRACT :
The authors report on the activity of a working group formed by the LCPC whose mission is defined as the preparation of a preliminary investigation concerning modifications in specification standards and test standards for roadmaking bitumens. The evolution of specifications in the USA and in European countries are reviewed. American specifications in the USA first appeared in 1925 and were based on penetration; since then, specifications based on viscosity before or after artificial ageing have been established. In Europe, concern with the prediction of durability has led many countries to include in their specifications a simulation test of the evolution of coating, either the Thin Film Oven Test (TFOT) or the Rolling Thin Film Oven Test (RTFOT). The broad lines of modification seem to lie in the direction of a better prediction of the consistency of bitumens in mixes at high service temperatures. 3 refs. In French.

RECORD No.: 6.
AUTHOR : Webster, William C. (Ed.) (Applications); T; (Theoretical); X; (Experimental)
TITLE : Asphalt Rheology: Relationship to Mixture
JOURNAL : Universtiy of California at Berkeley, Berkeley, CA, USA, Conference Proceedings
VOLUME No.:
PUBLISHER : University of California at Berkeley
YEAR : 1987
PAGES :
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cements, rheology, mixtures
ABSTRACT :

This conference proceedings contains 37 papers. The topics covered include: Ship waves and wakes; large wave problems; real fluid effects; unsteady flow; fluid-structure interactions; and steady flow past bodies. Technical and professional papers from this conference are indexed and abstracted with the conference code no. 11571 in the Ei Engineering Meetings (TM) database produced by Engineering Information, Inc.

RECORD No.: 7.
AUTHOR : Leung, Sui C.; Anderson, Kenneth O.
TITLE : Evaluation of Asphalt Cements for Low-Temperature Performance
JOURNAL : Transportation Research Record
VOLUME No.: 1115
PUBLISHER : Transportation Research Board
YEAR : 1987
PAGES : 23-32
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cements, temperature susceptibility, fracture characteristics, asphalt concrete mixtures, tensile strength
ABSTRACT :

This research project evaluates the temperature susceptibility and low-temperature fracture characteristics of asphalt cements from heavy crude sources in western Canada. Six samples of asphalt of grades 85/100 and 200/300 formulated from crude oils from Cold Lake, Lloydminster, and Redwater sources were tested to determine their physical properties. From the results of the laboratory tests, it is concluded that the Redwater asphalt is the most temperature susceptible of the the three asphalts studied. It was also confirmed that temperature as well as grade and crude source of asphalts have quite marked effects on the tensile properties of asphalt concrete mixtures. The asphalt cements produced from heavy crude sources of the Cold Lake and Lloydminster areas have been found to perform better at low temperature than those produced from the lighter crude source of the Redwater area. The 200/300 asphalt is also expected to perform better than the 85/100 asphalt. (Edited author abstract) 15 refs.

RECORD No.: 8.
AUTHOR : Briscoe, Oliver E. (Ed.)
TITLE : 16th Annual ESD/SMI International Progrommable Proceedings, Conferene and Exposition
JOURNAL :
VOLUME No.:
PUBLISHER : Maryland State Highway Department, Brooklandville, MD, USA
YEAR : 1987
PAGES :
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cements, asphalt concrete mixtures, rheology, modifiers
ABSTRACT :

The proceedings includes nine papers. The main topics presented were asphalt concrete mixtures-properties and performance, rheological properties of asphalt, asphalt pavement design and performance, polymer-modified asphalts, sliding plate rheometer and sulfur asphalt binders. Technical and professional papers from this conference are indexed and abstracted with the conference code no. 11535 in the Ei Engineering Meetings (TM) database produced by Engineering Information, Inc.

RECORD No.: 9.
AUTHOR : Rosengren, A.
TITLE : Bitumens Mekaniska Egenskaper (Mechanical Properties of Bitumen) Text in Swedish.
JOURNAL : Report
VOLUME No.: VTI/MEDDELNANDE-470
PUBLISHER : Statens Vaeg-och Trafikinstitut, Linkoeping (Sweden)
YEAR : 1986
PAGES : 219p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt cements, viscoelastic model, viscosity, penetration, softening point, BTDC, stiffness, tracture, pavement performance, temperature susceptibility
ABSTRACT :

The report is a literature study dealing with the following properties of bitumen: Viscoelasticity - mechanical models; Viscosity, penetration and softening point; Penetration index (PI) and similar parameters; Bitumen Test Data Chart according to Heukelom (BTDC); Stiffness modulus of bitumen; Relation of breaking parameters and stiffness of bitumen; Stiffness and strength of bituminous mixtures; and Low-temperature transverse cracking and prediction of temperature causing it.

RECORD No.: 10.
AUTHOR : J. L. Goodrich, J. E. Goodrich, W. J. Kari
TITLE : Asphalt Compositions Tests: Their Application and Relation to Field Performance
JOURNAL : Transportation Research Record
VOLUME No.: 1096
PUBLISHER : TRB
YEAR : 1986
PAGES : 146-167
ABSTRACTOR: PTI
KEYWORDS : Asphalt cements, oxidative hardening, field performance, composition, rheological properties, test roads, construction practices
ABSTRACT :

Compositional tests of asphalt quality based on chemical fractional separation have not correlated reliably with field performance, nor have ratios based on the fractions. Physical and rheological tests have been shown to correlate with road performance on numerous test roads. These performance-related tests remain the most reliable guide to asphalt quality. Construction practices play a significant role in asphalt durability. High air void content has been shown to override any difference between asphalts. Asphalts from many sources perform well in roads. With this in mind, it appears unlikely that functional specifications based on composition could be devised. The performance-related thin film ovens and viscometers, and possibly new performance-related physical tests, will continue to provide a reasonable way of describing asphalt quality without directly addressing the almost impossible task of describing a most complex chemical material. To evaluate the value of asphalt compositional data as predictors of road performance, 12 test road studies that included composition analysis, rheology, charability, and road performance data were reviewed. The review indicated that similarly performing asphalts (based on road rating and rheology changes) have different compositions. Rheological and aging tests correlated well with road performance while there was no case in which compositional (fractional or GPC) test data added to what was already learned from physical (rheology and aging) tests. Construction practices were found to play a significant role in asphalt durability.

RECORD No.: 11.
AUTHOR : R. Rogue, M. Tia, B. E. Ruth
TITLE : Asphalt Rheology to Define the Properties of Asphalt Concrete Mixtures and the Performance of Pavements
JOURNAL : Asphalt Rheology, Relationship to Mixture, ASTM Special Technical Publication
VOLUME No.: 941
PUBLISHER : ASTM
YEAR : 1985
PAGES :
ABSTRACTOR: PTI
KEYWORDS : Schweyer constant stress rheometer, indirect tension test, temperature effects, asphalt viscosity, low temperature characterization, asphalt concrete mixes, asphalt cement, fracture
ABSTRACT :

The Schweyer Constant Stress Rheometer was used to define the low-temperature rheological properties of asphalts recovered from laboratory-compacted mixtures and field cores. Asphalt viscosity relationships with resilient modulus, mix viscosity, state modulus, stiffness, fracture strains, fracture energy, and fracture stress of the mix were established using dynamic, static, and constant stress-indirect tension testing procedures. Resilient moduli predicted from the viscosity of asphalts recovered from pavements were used in elastic layer analyses to define deflection and strain basins produced by Dynaflect or plate tests. These deflection and strain basins compared favorably with those measured on a test pit pavement and on selected in-service pavements. Relationships between asphalt viscosity and mix parameters are presented to illustrate the importance of asphalt viscosity and to suggest their potential use in the modeling of the thermal behavior of flexible pavements. It is shown that there is no appreciable difference between resilient and static moduli when asphalt viscosity exceeds about 400 MPa's where creep is insignificant. The importance of shear susceptibility for both asphalt and mix viscosity determinations is discussed, and the use of constant power viscosity is recommended to minimize errors induced by extrapolation of viscosity at shear rates outside those obtained in the test. Parameters for thermal and lead-induced fracture include stress, strain, and energy. Laboratory test results were used to develop relationships between these parameters and the constant power viscosity of the asphalt binder. Tests on pavement cores produced fracture corresponding to that obtained in the laboratory tests. A correlation between resilient modulus and the asphalt constant power viscosity (at 100 W/m^3) was developed. A correlation between mix viscosity at constant power of 0.01 Ws/m and asphalt viscosity at 100 Ws/m was also developed. The shear susceptibility of dense graded asphalt concrete mix was found to be approximately equal to that of the asphalt. Although correlations were poor, tests results indicated a fair correlation between static modulus

computed from creep tests and asphalt or mix viscosities. Results of fatigue tests at different temperatures indicated that the failure strain is fairly consistent with asphalt viscosity except in the case of early fatigue failure (<2000 cycles).

RECORD No.: 12.
AUTHOR : Ehrburger, Pierre; Saint-Romain, Jean-Louis; Lahaye, Jacques; Couderc, Pierre
TITLE : Flow Properties and Glass Transition of Coal Tar Pitches
JOURNAL : Extended Abstracts and Program - Biennial Conference on Carbon
VOLUME No.:
PUBLISHER : American Carbon Society, Univeristy Park, PA, USA
YEAR : 1985
PAGES : 168-169
ABSTRACTOR: Compendex Plus
KEYWORDS : Pitches, thermodynamic factors, flow properties, glass transition temperature
ABSTRACT :

The processing of carbon electrodes for the aluminium industry requires pitches having good binding properties. Some binder pitches easily wet the coke particles and rapidly flow into the interparticle voids. In a recent paper, the authors showed that the flow behavior of some pitches is mostly determined by thermodynamic factors, wetting angle and surface energy and a rheological one, viscosity. For other pitch samples however, the flow behavior is more complex and the objective of the present paper is to investigate further the flow properties of molten pitch and to correlate them with the glass transition characteristics of these materials. 3 refs.

RECORD No.: 13.
AUTHOR : Yanovskii, Yu. G.; Vinogradov, G. V.; Zhdanyuk, V. K.; Zolotarev, V. A.
TITLE : Influence of the Composition of Coal Tars on Their Rheological Properties
JOURNAL : Colloid Journal of the USSR (English Translation of Kolloidnyi Zhurnal)
VOLUME No.: 47, No. 6
PUBLISHER :
YEAR : 1985
PAGES : 984-991
ABSTRACTOR: Compendex Plus
KEYWORDS : Coal tars, rheological properties, glass transition temperature thixotropic properties, dynamic testing
ABSTRACT :

Coal tars of different compositions have been investigated in different regimes of shear deformation over a wide range of frequencies, deformation rates, and amplitudes, and at different temperatures. The glass transition temperatures T//g, the activation energies of viscous flow, and the initial viscoelastic constants of these systems have been determined. Analytical expressions have been proposed that describe the concentration dependence of the above parameters. Prestationary and established-flow regimes have been studied at continuous deformation, and the thixotropic characteristics have been evaluated under the joint action of vibrations and continuous deformation. (Author abstract) 16 refs.

RECORD No.: 14.
AUTHOR : Bell, Chris A.; Wilson, James E.
TITLE : Proliferation of Paving Grade Asphalt Cement Specifications in Oregon
JOURNAL : Transportation Research Board Record
VOLUME No.: 1034
PUBLISHER : Transportation Research Board
YEAR : 1985
PAGES : 8-19
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cements, specifications, temperture susceptibility, viscosity
ABSTRACT :

Specifications used by Oregon or adjacent states are now based on three grading systems with four distinct grading requirements, two AR versions, an asphalt concrete (AC) version, and a penetration version. To ensure the maximum number of options for asphalt supply, Oregon presently uses all four alternate specifications. The developments leading to this situation are outlined and some consequences are examined. It is shown that there are significant differences between the existing specifications and that it is possible for asphalts with the same specification grade or with nominally the same specification to have distinctly different properties (e. g., AR-4000 versus AR-4000W). This is primarily due to the way in which each specification controls temperature susceptibility. (Edited author abstract) 12 refs.

RECORD No.: 15.
AUTHOR : Yanovskii, Yu. G.; Vinogradov, C. V.; Zhdanyuk, V. K.; Zolotarev, V. A.
TITLE : Rheological Parameters of Coal Tars in Cyclic and Continuous Deformation
JOURNAL : Journal of Engineering Physics (English Translation of Inzhenerno-Fizicheskii Zhurnal)
VOLUME No.: 48, No. 4
PUBLISHER :
YEAR : 1985
PAGES : 469-473
ABSTRACTOR: Compendex Plus
KEYWORDS : Coal tars, rheological properties, molecular structure
ABSTRACT :
Studies have been made on the prestationary and steady-state modes of flow, and the amplitude and frequency limits to linear behavior have been determined, while it has been shown that there is a structured framework consisting of dispersed-phase particles. (Author abstract) 14 refs.

RECORD No.: 16.
AUTHOR : Vinogradov, G. V.; Zhdanyuk, V. K.; Yanovskii, Yu. G.; Zolotarev, V. A.
TITLE : Rheological Properties of Coal Tars as Disperse Systems
JOURNAL : Colloid Journal of the USSR (English Translation of Kolloidnyi Zhurnal)
VOLUME No.: 47, No. 4
PUBLISHER :
YEAR : 1985
PAGES : 566-571
ABSTRACTOR: Compendex Plus
KEYWORDS : Coal tars, rheolgoical properties, dyanmic testing, temperature, molecular structure
ABSTRACT :

A study has been made of the viscoelastic behavior of paving-grade coal tar in continuous, cyclic, and combined deformation modes over a broad range of deformation frequency and amplitude, shearing rate, and temperature, in regimes of prestationary deformation and steady-state flow. The frequency dependences of the accumulation and loss moduli have been determined with small amplitudes of shear in the linear region. Conditions for the correlation of characteristics obtained in continuous and cyclic deformation have been demonstrated experimentally. It has been shown that the tar contains an internal structural skeleton formed by disperse-phase particles. (Author abstract) 14 refs.

RECORD No.: 17.
AUTHOR : Kolb, K. H., Paulmann, G.
TITLE : Characterization of the Polymer Modified Bitumen on the Bases of the Dynamic Testing
JOURNAL : Bitumen
VOLUME No.: 47, No. 3
PUBLISHER :
YEAR : 1985
PAGES : 97-105
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cements, modifiers, pavement performance, temperature susceptibility, viscosity, dynamic testing, rheological properties
ABSTRACT :

Asphalt pavement performance depends mainly on the temperature-viscosity properties and amount of the binding material. The article presents methods and results of dynamical testing of bitumen and bituminous materials. The results show that dynamic mechanical properties, viscosity-temperature susceptibility and its relation with other rheological characteristics can be improved by polymer addition to asphalt mixtures. 5 refs. In German.

RECORD No.: 18.
AUTHOR : Kari, W. J.
TITLE : Life Cycle of Asphalt
JOURNAL : TRNews
VOLUME No.: 119
PUBLISHER : Transportation Research Board
YEAR : 1985
PAGES : 10-15
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cements, oxidative hardening, viscosity, specifications
ABSTRACT :

Asphalt properties change as soon as the asphalt is added to hot aggregate to form a paving mix. The rate of change is greatest during hot-mix production, followed by a more gradual hardening during its service life in the pavement. These changes in asphalt properties, particularly viscosity, are profoundly affected by the mix design and construction practices used. This article is a producer's view of what has been accomplished in paving asphalt tests and specifications.

RECORD No.: 19.
AUTHOR : Partl, M.; Roesli, A.
TITLE : Approximation of Uniaxial Creep During Alternating Tension-Compression Step Loading at Constant Temperature
JOURNAL : International Journal of Solids and Structures
VOLUME No.: 21, No. 3
PUBLISHER :
YEAR : 1985
PAGES : 235-244
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cements, uniaxial creep behavior, viscoelastic properties, nonlinear behavior
ABSTRACT :

A new simple approximate method is presented and compared with experimental results, which enables the estimation of the uniaxial creep behavior of asphalt or asphalt-like materials under arbitrary alternating tension-compression loading histories with a comparatively small mathematical and experimental effort. The method is based on the assumption that the total creep deformation consists of two independent components: a visco-elastic one and a viscoplastic one. With this new approach the creep behavior of asphalt under arbitrary step loading histories can be predicted with better results than with conventional theories ignoring structural weakening effects. 14 refs.

RECORD No.: 20.
AUTHOR : Nadkarni, Vikas M.; Shenoy, Arun V.; Mathew, Johnson
TITLE : Thermomechanical Behavior of Modified Asphalts
JOURNAL : Industrial & Engineering Chemistry, Product Research and Development
VOLUME No.: 24, No. 3
PUBLISHER : American Chemical Society, Easton, PA
YEAR : 1985
PAGES : 478-484
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cements, modifiers, dynamic testing, viscoelastic properties, cracking resistance
ABSTRACT :

The thermomechanical properties of a variety of modified asphalts have been investigated by using dynamic mechanical characterization, melt viscosity determination, and softening point measurements. The asphalt modifications studied include chemical reaction of the asphalt flux with maleic anhydride, physical blending with styrene-butadiene-styrene rubber, air blowing, and use of inorganic fillers. The results indicate that chemical modification of asphalt flux with maleic anhydride significantly improves both the low-temperature cracking resistance and the high-temperature cohesive strength. The optimum amount of maleic anhydride has been found to be 10% on a weight basis. (Edited author abstract) 14 refs.

RECORD No.: 21.
AUTHOR : Vakili, Jalal
TITLE : Determination of Nonlinear Viscoelastic Properties of Asphalt-Concrete by a Simple Experimental Procedure
JOURNAL : Res Mechanica: International Journal of Structural Mechanics and Materials Science
VOLUME No.: 14, No. 2
PUBLISHER :
YEAR : 1985
PAGES : 145-153
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt concrete mixtures, non-linear viscoelastic properties, permenant deformation
ABSTRACT :
A multiple integral functional relationship has been employed as a constitutive equation of a nonlinear viscoelastic asphalt-concrete. The kernel functions of this representation have been determined from a single ramp loading test. For the loading range used in the test, the multiple integral expansion has been found to be adequately represented by the two-term integral representation. Permanent deformation was observed in the unloading phase of the specimen which was a function of stress level as well as stress rate. 9 refs.

RECORD No.: 22.
AUTHOR : Halstead, W. J.
TITLE : Properties of Asphalt Cements Used in Virginia and Their Effects on Pavement Performance. Task 1. Evaluation of Asphalt Characteristics
JOURNAL : VHTRC; FHWA REPORT
VOLUME No.: VHTRC-84-R48; FHWA/VA-84/48
PUBLISHER : FHWA
YEAR : 1984
PAGES : 18p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt cements, specifications, viscosity, temperature, susceptability, ductility-penetration
ABSTRACT :

Results of usual tests for specification compliance and special tests to show viscosity-temperature susceptibility and ductility-penetration relationships for asphalts supplied for use by the Virginia Department of Highways and Transportation in 1983 are reported.

RECORD No.: 23.
AUTHOR : Cmiljanic, Slobodan; Pap, Imre; Opacic, Dragan
TITLE : Influnce of the Type and Degree of Alteration of Andersite and Dacite on the Quality and Life of Asphaltic Concrete
JOURNAL : Bulletin of the International Association of Engineering Geology
VOLUME No.: 30
PUBLISHER : International Association of Engineering Geology, Paris, France
YEAR : 1984
PAGES : 41-45
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cements, asphalt concrete mixtures, aggregates, rheological properties
ABSTRACT :

This report deals with the influence of alteration processes in andesite and dacite with special reference to those alterations and characteristics of stone having the greatest influence on the quality of asphaltic concrete mixes. Using andesites and dacites with extremely different properties for standard asphaltic mixes has proved that quality of the mixes very much depends on the quality of the stone aggregate used. Properties of stone aggregate of different degree and type of alteration have a significant influence on the rheological characteristics of bitumen. Therefore, special attention has been paid to this influence. (Author abstract) 4 refs.

RECORD No.: 24.
AUTHOR : Zhao-dong, Xu; De-kun, Chen
TITLE : Reserach into Aperature Parameters of Point-Bonded Waterproof Layers
JOURNAL : Journal of Testing & Evaluation
VOLUME No.: 12, No. 6
PUBLISHER : American Society for Testing and Materials
YEAR : 1984
PAGES : 348-352
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cements, rheological model, cracking
ABSTRACT :

In this paper the requirements for resistance to cracking and wind suction of waterproof layers are studied. According to the data obtained by practical measurement, a rheological model of Chinese asphalt felt was constructed. The paper presents a general method to determine aperture parameters of perforated asphalt felt and a feasible way to extend the free deformation length. The value of aperture parameters of Chinese perforated asphalt felt is given. (Author abstract) 3 refs.

RECORD No.: 25.
AUTHOR : Keyser, Joseph Hode; Ruth, Byron E.
TITLE : Analysis of Asphalt Concrete Test Road Sections in the Province of Quebec, Canada
JOURNAL : Transportation Research Board Record
VOLUME No.: 968
PUBLISHER : Transportation Research Board
YEAR : 1984
PAGES : 54-65
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt concrete, test roads, performance, rutting, penetration, viscosity, softening point, cracking
ABSTRACT :

Data were collected from test road sections in the Province of Quebec, Canada, for the purpose of evaluating the effects of materials and in situ conditions on the performance of asphalt concrete pavements. These pavements were tested in 1980 to determine rutting, ride, and deflection characteristics. In situ conditions were determined by sampling and test measurements. Asphalt concrete cores were obtained for indirect tensile strength tests and for recovery of asphalt for conventional consistency tests (penetration, viscosity, and softening point). These data were compiled along with information contained in the original construction records and pavement crack surveys. Statistical analyses were conducted and various relationships were developed that relate to factors that influence asphalt binder properties, tensile strength, and transverse cracking. 9 refs.

RECORD No.: 26.
AUTHOR : Basma, Adnan A.; George, K. P.
TITLE : Environmental Factors in Flexible Pavement Design
JOURNAL : Transportation Research Record
VOLUME No.: 954
PUBLISHER : Transportation Research Board
YEAR : 1984
PAGES : 52-58
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cements, field performance, rutting, cracking, fatigue
ABSTRACT :

The principal objective of this research was to study the influence of the environment on the thickness of flexible pavements. Environmental variables considered include general soil conditions and temperature effects. As identified in previous studies, six climatic zones were recognized. Weather information and soil properties were collected for 175 typical stations covering the continental United States, excluding Alaska. Based on the criteria of rutting of 1. 25 cm (0. 5 in.) and thermal cracking of 115 m/1000 m**2 (35 ft/1000 ft**2), appropriate asphalt-cement grades were selected for each station. To consider the interaction of temperature and modulus with fatigue damage, the concept of effective modulus was introduced. 8 refs.

RECORD No.: 27.
AUTHOR : J. W. Button, D. N. Little, and B. M. Gallaway
TITLE : Influence of Asphalt Temperature Susceptibility on Pavement Construction and Performance
JOURNAL : National Cooperative Highway Research Program Report
VOLUME No.: 268
PUBLISHER : Transportation Research Board
YEAR : 1983
PAGES : 62 pp.
ABSTRACTOR: PTI
KEYWORDS : asphalt cement, temperature susceptibility, aging, asphaltene content, consistency, tenderness, indirect tensile test, resilient modulus
ABSTRACT :

The overall objectives of the NCHRP Project 1-20 research study were to determine the range or extent of variability in temperature susceptibility of asphalt cements currently being used in road construction, to evaluate effects of asphalt cement properties on pavement construction operations and short-term performance of pavements over the full range of service temperatures, to identify the limits of variability in asphalt cement properties that can be accommodated through application of known mixture design techniques, and to determine procedures for accommodating or controlling the variability in temperature susceptibility of asphalt cements that cannot be accommodated by known asphalt technology. The findings of this research are presented in this report. In relation to the effect of properties of asphalts on the performance of paving mixtures in the field, the following conclusions were reached on the basis of data collected and analyzed: 1. Temperature susceptibility of asphalt cements is affected very little by artificial aging in TFOT and RTFOT. Therefore, aging in an asphalt mixing plant is not expected to significantly affect asphalt temperature susceptibility. The effect of TFOT and RTFOT aging on asphalt consistency is nearly identical over a temperature range from -40 to 275 F. 2. Highly temperature-susceptible asphalts and asphalts with high shear susceptibility have been related to tender pavements. These same asphalts exhibit undesirable low-temperature characteristics. 3. Asphalts containing less than 10 percent asphaltenes, particularly the softer grades, appear to have a greater probability of producing slow-setting paving mixtures. However, an asphalt will manifest itself as slow-setting only if the aggregate type and/or gradation is such that a critical paving mixture is produced (even though the aggregate may meet the specifications) or possibly if densification of the pavement is inadequate. 4. There is no correlation between asphalt temperature susceptibility and asphaltene content. There is no relationship between asphalt temperature susceptibility and other chemical constituents of asphalts as determined by the Rostler-Sternberg analysis or the Rostler parameter. 5. Asphalt consistency increases with time when asphalts are left undisturbed at 77 F; furthermore, upon heating to 275 F, the asphalt will return to its original consistency. Although this thixotropic property of asphalt is detectable using the standard penetration test or the sliding glass plate in microviscometer at 77° F, it does not correlate well with the setting rate in the field. 6. On the basis of the results of this study, asphalt properties alone will not cause a tender mixture during construction. Aggregate type and/or gradation coupled with a highly temperature-susceptible asphalt can aggravate the problem at the higher compaction temperatures. 7. The indirect tensile test and the diametral resilient modulus test are much more sensitive to asphalt consistency than either the Hveem or Marshall stability tests. Indirect tensile and resilient modulus tests at 104 F have the potential to identify tender and slow-setting asphalt paving mixtures in the laboratory. Based on the guidelines developed in the course of this study, a specifying agency can develop criteria which can be used in the laboratory to avoid tender paving mixtures. 8. Minus No. 200 mesh aggregate (and possibly other fillers) may be used in gravel-type asphalt paving mixtures to increase tensile strength and resilient modulus which would, in all probability, decrease mixture tenderness. 9. The mixture variables that have the greatest influence on resilient modulus and tensile strength of hot-mixed asphaltic concrete are asphalt viscosity and filler content.

RECORD No.: 28.
AUTHOR : Neumann, H. J.
TITLE : Asphalts: Recent Findings Regarding Their Structure and Properties
JOURNAL : Report
VOLUME No.: NRC-CNR-TT-2048
PUBLISHER : Canada Institute for Scientific and Technical Information, Ohawa (Ontario)
YEAR : 1983
PAGES : 27p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt cements, colloidal structure, composition, rheological properties
ABSTRACT :

Asphalt represents the residue of the vacuum distillation of certain crude oils. It is a naturally occurring multicomponent mixture of high boiling and nonboiling substances. The colloidal constituents of crude oils, i.e., asphaltenes and petroleum resins, are present in high concentrations in these mixtures. Their composition of higher molecular weight hydrocarbons and polar sulfur, oxygen and nitrogen heterocompounds, on the one hand, and their colloidal structure, on the other, determine their performance characteristics. Their position in the consistency diagram and their rheological deformation behavior are of special significance. These qualities are mainly a function of the concentrations of asphaltenes and petroleum resins, which can be modified by distillation and by blowing in a defined manner.

RECORD No.: 29.
AUTHOR : Schweyer, Herbert E.; Ruth, Byron E.; Potts, Charles F.
TITLE : New Approchaes for Studying Rheology Properties of Asphalts
JOURNAL : ASTM Special Technical Publication
VOLUME No.: 807
PUBLISHER : American Society for Testing and Materials
YEAR : 1983
PAGES : 3-4
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cements, viscoelastic model, asphalt concrete mixes, rheolgoical properties
ABSTRACT :

The objectives of this paper is to propose some new thoughts on using more recent 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. 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 discusses 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.

RECORD No.: 30.
AUTHOR : Huschek, S.
TITLE : Deformation Behavior of Aspahlt Concrete under Triaxial Pressure
JOURNAL : Bitumen
VOLUME No.: 45, No. 4
PUBLISHER : Plenum, New York
YEAR : 1983
PAGES : 162-170
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cements, asphalt concrete mixtures, triaxial loading, softening point, grain size distribtuion, deformation resistance
ABSTRACT :

Static and dynamic pressure tests with and without lateral pressure have been carried out on typical asphalt mixtures for pavement, binder, and base layers in a triaxial test apparatus. They confirm qualitatively a formula for calculating the time-dependent deformation. Relative quantification is given regarding the effects of grain size distribution, content of binders, degree of compaction, and softening point of the binder on deformation resistance. 9 refs. In German.

RECORD No.: 31.
AUTHOR : Frolov, A. F.; Egorova, V. V.; Aminov, A. N.; Ovchinnikova, V. N.
TITLE : Strength and Ductility of Asphalts
JOURNAL : Chemistry and Technology of Fuels and Oils (English translation of Khimiya i Tekhnologiya Topliv i Masel)
VOLUME No.: 19, No. 7-8
PUBLISHER :
YEAR : 1983
PAGES : 356-360
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cements, ductility, rubber, molecular structure, tensile deformation
ABSTRACT :

Data are presented on the ductility of asphalt as measured in an RMI-5 tensile tester (GOST 270-75), designed for tests on raw and vulcanized rubbers and rubber mixes; this machine matches up quite well with the requirements placed on the ductility of asphalts. The stress/strain diagrams for rubbers and asphalts have common features. The presence of common features for the two materials is explained by the similarity of internal structures of these materials and the common mechanism of tensile deformation for these structures. 11 refs.

RECORD No.: 32.
AUTHOR : Dark, William A.
TITLE : Asphalt Tests are Correlated
JOURNAL : Hydrocarbon Processing
VOLUME No.: 62, No. 9
PUBLISHER :
YEAR : 1983
PAGES : 104-105
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cements, chromotography, penetration, softening point, composition
ABSTRACT :

This paper presents results of an experimental program which demonstrate that high performance liquid chromatographic techniques can be used to identify the changes in chemical composition of asphalt during the air blowing process. In addition, penetration and softening point tests show how these physical properties are related to the chemical nature of the asphalt. 17 refs.

RECORD No.: 33.
AUTHOR : Marechal, J. Ch.
TITLE : Methods for the Study of Aging of Bitumen-Polymer SBS Materials
JOURNAL : Durability of Building Materials
VOLUME No.: 1, No. 3
PUBLISHER : Cont. Sci. et Tech du Batiment, St. Martin d'Heres, France
YEAR : 1983
PAGES : 201-208
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt roofing material, composition, modifiers, fillers, creep compliance, creep recovery

ABSTRACT :

The perfecting of methods for identification and the laboratory evaluation of the quality and durability of roofing materials made with bitumen-SBS are presented. It is possible to characterize these materials by chemical and rheological analysis. The parameters noted are: the composition of the mixture, polymer, asphaltene, malthene and filler content, and the molecular weight of the polymer. For the rheological parameters, the compliance with stability under creep by traction, the recovery rate after creep and the viscosity of the binding material are determined. 2 refs.

RECORD No.: 34.
AUTHOR : Ros, J.; Pronk, A. C.; Eikelboom, J.
TITLE : Performance of Highway Pavements in the Netherlands and the Applicability of Linear Elasticity Theory to Pavement Design
JOURNAL : Proceedings, 5th International Conference on the Structural Design of Asphalt Pavements
VOLUME No.: 1
PUBLISHER : University of Michigan, Ann Arbor
YEAR : 1982
PAGES : 285-302
ABSTRACTOR: Compendex Plus
KEYWORDS : Pavements, strains, pressure, speed, temperature.
ABSTRACT :

In 1971 the Rijkswaterstaat (National Public Works Department) constructed 9 trial sections, each 200 meters in length, on Highway A15 in the Netherlands. Each section was of a different structure and the range included structures in current use, variants on these and even experimental structures. The strains and pressures were measured at different levels in the structures when subject to the load of a standard lorry at varying speeds and temperatures. This paper presents results of these measurements.

The stiffness properties of the subgrade, sand cement, slag and the various types of asphalt were determined as far as possible both in situ and in the laboratory. The results were then used in the BISAR computer program and the computed strains and soil pressures were compared with the measured values. In general, the correlation was reasonable, particularly at the higher asphalt stiffnesses. Fatigue properties were also determined in the laboratory.

The results were also used to compare the computed relative life and the "actual" life based on a 90% cut-off value for the measured strains; the former proved to be higher than the latter.

The performance of the trial sections under normal traffic conditions was monitored for an 8-year period.

Periodic measurements of skid resistance, evenness, rut depth and deflection as well as visual inspections have been carried out. The evenness of all sections was still good after 8 years. There were differences in the degree of rutting and cracking but these were still acceptable.

An overall assessment revealed some of the design methods to be conservative. The results and findings have been partly responsible for thinner structures being used on highways.

RECORD No.: 35.
AUTHOR : Shook, J. F.; Finn, F. N.; Witczak, M. W.; Monismith, C. L.
TITLE : Thickness Design of Asphalt Pavements - The Asphalt Institute Method. Thickness Design of Asphalt Pavements - The Asphalt Institute Method
JOURNAL : Proceedings, 5th International Conference on the Structural Design of Asphalt Pavements
VOLUME No.: 1
PUBLISHER : Univeristy of Michigan, Ann Arbor
YEAR : 1982
PAGES : 17-44
ABSTRACTOR: Compendex Plus
KEYWORDS : Pavement design, computer program, permanent deformation, fatigue, asphalt cement, asphalt concrete, temperature, Poisson's ration, modulus
ABSTRACT :

Unlike previous editions, the ninth (1981) edition of The Asphalt Institute Thickness Design Manual (MS-1) is based on mechanistic design methodology. Elastic theory and concepts of limiting subgrade strain, to control permanent deformation, and limiting tensile strain in the asphalt layers, to control fatigue cracking, were adopted. Typical material properties, modulus of elasticity and Poisson's ratio, were selected from available test data.

A comprehensive computer program was developed to produce design charts for use in the manul. Design charts were prepared for structural sections consisting of asphalt concrete surface and base placed directly on subgrade, asphalt concrete with emulsified asphalt base and asphalt concrete with untreated granular base. Three environmental conditions, each consisting of a separate 12-month temperature distribution, were used to represent temperature effects on asphalt mixture properties. Untreated aggregate bases were considered to have stress-dependent properties. In addition, subgrade and untreated base properties were made to vary on a monthly basis to account for freezing and thawing effects. Loads were represented by a dual tire, equivalent to the load produced by a standard 80 kN single axle load.

An extensive verification study was made using the design charts prepared for the manual. Comparisons were made to several existing design methods, including previous editions of The Asphalt Institute manual. In general, the comparisons produced similar design thicknesses, except at very high traffic and high subgrade strength levels, particularly, when untreated bases are used.

Comparisons also were made to performance data collected on full-scale test road projects and existing highways. Six separate sources of data, representing 402 individual design comparisons, were used in this study.

Results indicated that the ninth edition of The Asphalt Institute Thickness Design Manual (MS-1) produced design thicknesses that on the average were 41 mm (1.6 in.) greater than the observed thicknesses, but also produced unconservative designs 12.7 percent of the time.

RECORD No.: 36.
AUTHOR : Brown, S. F.; Brunton, J. M.; Pell, P. S.
TITLE : Development and Implementation of Analytical Pavement Design for British Conditions
JOURNAL : Proceedings, 5th International Conference on the Structural Desing of Asphalt Pavements
VOLUME No.: 1
PUBLISHER : University of Michigan, Ann Arbor
YEAR : 1982
PAGES : 3-16
ABSTRACTOR: Compendex Plus
KEYWORDS : Computer program, asphalt mixture properties, permanent deformation, cracking, fatigue damage, design life
ABSTRACT :

A description is given of the computer program ANPAD which provides three basic facilities for using analytical procedures in pavement design calculations. These include the ability to compute the required layer thickness, the design life or asphalt mix proportions for a balanced design, the particular option being selected on the basis of the available data and design constraints. Examples are given to illustrate some applications of the program. Prediction methods for dynamic stiffness and fatigue characteritsitcs of asphalt mixes are used in ANPAD. However, the resistance of a particular mix to permanent deformation requires realistic laboratory testing and the techniques available are reviewed in the light of recent experiments. The implementation of full scale trails in which unconventional asphalt mixes have been used. The paper also provides a description of the computer program CUDAM which includes the consideration of cumulative damage in fatigue when determining the required layer thickness of an asphalt base.

RECORD No.: 37.
AUTHOR : Miller, Richard W.; Brown, Ronald A.; Chamberlin, William P.
TITLE : Effects of Adopting a Viscosity Specification for Asphalt Cement in New York State
JOURNAL : FHWA Report
VOLUME No.: SR-66; FHWA/NY/SR-80/66
PUBLISHER : FHWA
YEAR : 1980
PAGES : 35p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt cements, specifications, viscosity, penetration, pavement construction, performance
ABSTRACT :

In 1972, the New York State Department of Transportation changed from a penetration (77 F) grading specification to a viscosity (140 F) grading specification for asphalt cement. About then, with increasing frequency field engineers reported problems with placement of bituminous concrete and in-service performance that they attributed to changes in asphalt-cement consistency. This report documents the penetration and viscosity properties of asphalt cements supplied to the state during the years 1968 to 1975 inclusive. The changes determined are discussed with reference to the problems reported by field engineers.

RECORD No.: 38.
AUTHOR : Shim-Ton, J.; Kennedy, K. A.; Piggott, M. R.; Woodhams, R. T.
TITLE : Low Temperature Dynamic Properties of Bitumin-Rubber Mixtures
JOURNAL : Rubber Chemistry and Technology
VOLUME No.: 53, No. 1
PUBLISHER :
YEAR : 1980
PAGES : 88-106
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cement, modifiers, low temperature susceptibility, viscosity, dynamic testing, penetration
ABSTRACT :

In the reported experiments, the influence of four different elastomeric materials on the low temperature dynamic properties of bitumen was determined using a Rheovibron Viscoelastometer. The four elastomeric materials included two waste products and two liquid rubbers. The results of the evaluation indicate that liquid polybutadiene is the most efficient low temperature flexibilizer, as might be expected from its low second order transition temperature (minus 85 degree C). A comparison of the penetration of the rubber-bitumen mixtures with the Brookfield viscosity reveals that the addition of rubber markedly reduces the temperature susceptibility. Attempts were also made to follow the thickening behavior of bitumen/CTBN rubber mixtures after the addition of calcium hydroxide. The implications of the low temperature dynamic transitions, viscosity behavior, penetration values and thickening behavior of bitumen/rubber mixtures with respect to road performance are discussed. 41 refs.

RECORD No.: 39.
AUTHOR : V. P. Puzinauskas
TITLE : Properties of Asphalt Cements
JOURNAL : Proceedings of Association of Asphalt Paving Technologists
VOLUME No.: 48
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1979
PAGES : 646-710
ABSTRACTOR: PTI
KEYWORDS : Asphalts, age hardening, temperature susceptibility, shear susceptibility, viscosity, penetration, ductility
ABSTRACT :

This study presents a comprehensive evaluation of the physical properties of currently-produced asphalt cements. A general evaluation of the physical properties of asphalts, with the emphasis on such properties at low temperatures, was the main study objective. A comparison of such properties with asphalts produced in the past was another objective. A group of 68 asphalt cements was selected for comprehensive testing from a total of 211 asphalt cements representing 78 refineries. This group of asphalts represented all major crude oil sources and all currently-in-use manufacturing processes. Besides a general evaluation of physical properties, the effects of heating on asphalts were assessed. Also, various methods for evaluating temperature susceptibility were examined and compared. A substantial effort was placed on the evaluation of the consistency properties at low temperatures. Viscosities, penetrations, and ductilities at temperatures ranging from 25 C to subfreezing were examined and compared. Factors affecting such measurements were also scrutinized. Test data presented in this study led to several important observations and conclusions: 1. Asphalts produced today do not differ substantially from those produced in the past. This applies not only to the conventional properties, utilized in materials specifications, but also to measurements such as temperature-susceptibility, heat effects, and shear sensitivity. 2. Asphalts, within a given grade, differ substantially in their properties. However, the magnitude of these differences appears to be similar for asphalts manufactured during different time periods. 3. Both the source of parent oil and the method of manufacture affect the physical properties of asphalt cements. However, because of the wide variation in manufacturing conditions, it is difficult to single out the separate effects of these two factors. 4. The response of asphalts to heating is highly variable. Generally, viscosity at low temperatures is affected by heating more than viscosity at high temperatures. In most cases, heating increases the temperature-susceptibility of asphalt. Also, the agreement between heating effects as assessed by viscosity and penetration tests is poor. 5. Different methods used to evaluate temperature susceptibility or temperature effects on asphalts correlate rather poorly. Furthermore, it was found that all temperature indexes vary and depend on the temperature range selected for the calculation of such indexes. Temperature-viscosity

susceptibility, because of its universality and fundamental nature, is preferred over the empirical methods--those utilizing either penetration measurements or penetration and viscosity measurements at different temperatures. 6. The low-temperature viscosities of asphalt cements were found to vary extremely over a wide range. This range increases with decreasing temperatures. Generally, poor correlation was registered between consistency properties such as viscosity, penetration, or ductility. Furthermore, measurements at high or moderate temperatures cannot be used to predict behavior of asphalt at subfreezing temperatures. 7. Low-temperature viscosity measurements are sensitive to a variety of factors. Shear rate, the mode of load application and sample conditioning before shear rate are some such factors. Although no specific evaluation was made, it may be assumed that such factors would also affect penetration or ductility measurements. 8. Shear effects become more pronounced with the increasing viscosity of asphalt or with decreasing test temperatures. For a given asphalt and temperature, shear sensitivity, or a slope of apparent viscosity-shear rate curve, is variable. It tends to increase with the increasing shear rate, provided the shear rates of the initial viscosity are exceeded. 9. In paving mixtures, at temperatures of pavement use, the asphalt is admixed in thin films with a variety of mineral substances. With fillers, it forms binders varying greatly in properties from the original in-bulk asphalt. Additionally, the properties of the original asphalt are changed by heating in the hot paving mixture preparation process. Thus, the utility and significance of extensive tests evaluating the properties of the binder at low temperatures, in its original state, are questionable. The measurement of paving mixture properties, rather than the properties of the binder, appears to be a more rational approach.

RECORD No.: 40.
AUTHOR : Transportation Research Board, Washington, DC.
TITLE : Relationship of Asphalt Cement Properties to Pavement Durability
JOURNAL : TRB/NCHRP/Synthesis
VOLUME No.: No. 59
PUBLISHER : Transportation Research Board
YEAR : 1979
PAGES : 51p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt cements, pavement aperformance, test roads, durability, physical properties
ABSTRACT :

This synthesis will be of special interest to materials engineers, construction engineers, designers, and others seeking information on factors affecting the performance of bituminous pavements. Detailed information is presented on how various properties of asphalt cement influence pavement performance. In recent years, apparent changes have evolved in the physical properties of asphalt cements used in pavement construction. Some of these properties are not controlled or are controlled only partially by AASHTO specifications. This report of the Transportation Research Board reviews all available information relating durability and performance of asphaltic concrete mixtures to the properties of asphalt cement. Recommendations for improved test procedures and criteria are included. The report concludes that hardness of the asphalt is the property most important to pavement performance.

RECORD No.: 41.
AUTHOR : Anon
TITLE : Relationship of Asphalt Cement Properties to Pavement Durability
JOURNAL : National Cooperative Highway Research Program, Synthesis of Highway Practice
VOLUME No.: 59
PUBLISHER : Transportation Research Board
YEAR : 1979
PAGES : 43
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cement, pavement performance, penetration, viscosity, stiffnes, ductility, temperature susceptibility, asphalt-aggregate interaction

ABSTRACT :

A comprehensive review of the literature presented that contains detailed information on how various properties of asphalt cement influence pavement performance. A literature search revealed studies of such properties as penetration, viscosity, temperature susceptibility, shear susceptibility, stiffness modulus, ductility, chemical composition, and asphalt-aggregate interactions. 91 refs.

RECORD No.: 42.
AUTHOR : Witczak, Matthew W. ; Bell, Kenneth R.
TITLE : Determination of Remaining Flexible Pavement Life. Volume III. Predicted Flexible Pavement Remaining Life Interpreted from Various Analytical Procedures
JOURNAL : FHWA Report
VOLUME No.: FHWA/MD/R-79/3
PUBLISHER : FHWA
YEAR : 1978
PAGES : 426p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt concrete mixtures, design methods, pavement performance, analysis, fatigue, cracking
ABSTRACT :

The objective of the report was to determine the remaining life of three Maryland highway pavements from various analytical design methods. Remaining pavement life was determined from both a functional (performance) viewpoint and structural (cracking) viewpoint. Extensive laboratory tests were done to determine conventional material properties as well as dynamic elastic responses of each component layer. Crack surveys were made on each pavement to quantify the physical state of distress. Measured laboratory properties were used in a theoretical multilayered analysis to predict fatigue cracking repetitions from cumulative damage theory by the Pell and Brown, Monismith, Kentucky Highway, The Asphalt Institute and Shell Oil fatigue relationships. Remaining damage predictions for each pavement were also made using the AASHTO design method in both a 'conventional' and 'limiting layer' analysis as recommended by NCHRP 128. It was concluded that the best agreement between measured cracking distress and predicted fatigue life occurred with the Monismith criteria. For all pavement sections considered, the critical or controlling design repetitions by the AASHTO procedure was associated with the 'limiting layer analyses'. The relationship developed between structural and functional failure was found to be in excellent agreement with other published values.

RECORD No.: 43.
AUTHOR : Anderson, Douglas I.; Peterson, Dale E.; Wiley, Max L.
TITLE : Prevention of Early Pavement Deterioration
JOURNAL : FHWA REPORT
VOLUME No.: FHWA/RD-79/S0855
PUBLISHER : FHWA
YEAR : 1978
PAGES : 81p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt cements, pavement performance, tenderness, cracking, stripping, temperature susceptibility, composition, mix design
ABSTRACT :

This study was done to identify the major forms and causes of early pavement distress, and to recommend changes in specifications or policies to prevent the distress. Three major forms of distress in Utah were identified as follows: (1) Unstable mixes, (2) Transverse cracking and (3) Stripping. The VESYS IIM rutting model was found adequate in predicting dangerous levels of rutting and shoving of flexible pavements. Higher values of temperature susceptibility, and saturates content in the asphalt binder were found to be related to greater levels of transverse cracking. Use of the COLD program is promising in reducing temperature-associated cracking. Asphalt-aggregate interactions were found to be related to both unstable mixes and stripping. The analysis of more anti-stripping agents along with hydrated lime was recommended for possible use in reducing stripping. It was determined that changes in the marshall mix design method are needed to better represent conditions in the Dryer Drum mixer. A major factor resulting in early pavement deterioration is poor quality control on some highways leading to the pavement not meeting present specifications.

RECORD No.: 44.
AUTHOR : Way, George B.
TITLE : Asphalt Properties and Their Relationship to Pavement Performance in Arizona
JOURNAL : Proceedings, Association of Asphalt Paving Technologists
VOLUME No.: 47
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1978
PAGES : 49-72
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt concrete mixtures, asphalt cement properties, pavement performance
ABSTRACT :

Performance of asphaltic concrete pavements has long been a major concern of highway engineers. Like others, Arizona has recognized need for improved methods of predicting future pavement performance. As such, from 1971, considerable work has been done to relate asphaltic concrete performance to a myriad of factors. The paper reports on laboratory and field investigations, and the analysis of data that these studies produced, all aimed at relating how asphalt properties influence asphaltic concrete properties, which in turn influence pavement performance. 10 refs.

RECORD No.: 45.
AUTHOR : Schweyer, H. E.; Burns, A. M.
TITLE : Low Temperature Rheology of Asphalt Cements - 3. Generalzied Stiffness-Temperature Relations of Different Asphalts
JOURNAL : Proceedings, Association of Asphalt Paving Technol, Tech Sess, Lake Buena Vista, Fla
VOLUME No.: 47
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1978
PAGES : 1-18
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cements, stiffness, shear susceptibility, viscosity, viscoelasticity, generalized model
ABSTRACT :

The paper discusses the variations in stiffness for certain selected asphaltic bitumens at the low ambient temperature ranges. It reports experimental work utilizing a constant stress shear mode tube flow apparatus. In addition, the paper demonstrates a proposed method to generalize the deformation characteristics of a material as a function of time, temperature, shear susceptibility, viscosity and shear modulus.

RECORD No.: 46.
AUTHOR : Jennings, P. W.; Spittler, T. D.; Shane, S.; Pribanic, J.
TITLE : Chemical Composition of Commercial Asphalt Cement as Determined by High Pressure Liquid Chromatography
JOURNAL : FHWA report
VOLUME No.: FHWA/MT-7929
PUBLISHER : FHWA
YEAR : 1977
PAGES : 115p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt cements, composition, pavement performance, penetration, ductility
ABSTRACT :

The chemical composition of asphalt cement will determine its quality, which in turn will ultimately influence the performance of bituminous roadways. This investigation was conducted to determine if the chemical composition of asphalts as measured by high pressure liquid chromatography (HPLC) could be used to determine the significant differences between asphalts from good and bad roads. If so, perhaps this method could be used in a predictive manner for improved asphalt specification requirements. HPLC analysis of asphalt cements from roadways which varied in quality from good to bad showed highly significant differences. Using these differences, these roadways were classified into good, fair, poor and bad. Coupling these data with the relative amounts of asphalt sub-fractions and physical tests such as penetration at 77 degrees F and ductility at 40 degrees F, a reasonable explanation for why a given roadway had reduced performance was established. Using HPLC analysis and sub-fraction quantities, a qualified prediction on the asphalt quality used in two newly constructed roadways has been advanced.

RECORD No.: 47.
AUTHOR : Kalash, Reda Mohieddine
TITLE : Asphalt-Rubber Mixtures for Seepage Control
JOURNAL : Report
VOLUME No.: W77-08195; OWRT-A-075-ARIZ(1)
PUBLISHER : Arizona Univeristy, Tuscon Department of Civil Engineering and Engineering Mechanics
YEAR : 1977
PAGES : 93p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt cements, rubber modifier, viscosity, tension test, ductility, water absorption, permeability

ABSTRACT :
A laboratory investigation was made of asphalt-rubber for use in water seepage control applications. Laboratory testing used for physical property determinations included viscosity, creep (tensile), ductility (ASTM D113-74), water vapor transmission (ASTM E96-72, Procedure Bw), water absorption (ASTM 570-72), and permeability. The results showed that the asphalt-rubber is relatively impermeable as a membrane. Physical properties of the base asphalt that are increased with the addition of rubber include water absorption and viscosity. The test that exhibited lower physical property values was ductility. Compared with plain asphalt, creep (tensile) test results showed that the rate of deformation of asphalt-rubber mixtures depends on the magnitude of the tensile load applied.

RECORD No.: 48.
AUTHOR : Kalash, Reda Mohieddine
TITLE : Asphalt-Rubber Mixtures for Seepage Control
JOURNAL : Report
VOLUME No.: W77-08195; OWRT-A-075-ARIZ(1)
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RECORD No.: 49.
AUTHOR : Schweyer, H. E.; Burns, A. M. Jr.
TITLE : Low Temperature Rheology of Asphalt Cements: Stiffness and Viscosity
JOURNAL : Transportation Research Board Record
VOLUME No.: 659
PUBLISHER : Transportation Research Board
YEAR : 1977
PAGES : 1-11
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cements, stiffness, viscosity, viscoelastic properites, low temperature properties
ABSTRACT :

This paper shows the quantitative relations between viscosity and stiffness and explains how the shear modulus and viscosity found by a constant stress rheometer can be used to evaluate stiffness. Experimental data from creep curve studies are given for a number of asphalt cements. The shear modulus is shown as the limiting asymptote that intersects the viscosity term asymptote at a stiffness limit time. These two asymptotes delineate the complete stiffness curve. Characteristic stiffness is shown to be a material property, but knowledge of the geometry of the system is prerequisite to its use in design, if the absolute deformation is to be considered. Variations in stiffness with shear rate (stress), temperature, and time are illustrated by data on absolute measurements for eight different types of asphalts at temperatures from 25 down to minus 5 degree C. 24 refs.

RECORD No.: 50.
AUTHOR : D. I. Anderson and M. L. Wiley
TITLE : Force Ductility - An Asphalt Performance Indicator
JOURNAL : Proceedings, Association of Asphalt Paving Technologists
VOLUME No.: 45
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1976
PAGES : 25-41
ABSTRACTOR: PTI
KEYWORDS : Asphalts, forced ductility, chemical composition, temperature susceptibility, shear susceptibility, performance aging, cracking
ABSTRACT :
Highway pavements, like any structures, expand and contract with changes in temperature and experience stresses and strains under traffic loadings. If a pavement material cannot withstand these forces or if unusually high forces are generated for a certain material, fracture of the structure occurs. This inevitably results in accelerated pavement deterioration. This paper develops the theory and background of a modified ductility test--Force Ductility Test--and attempts to establish a reasonable case for its routine use in asphalt testing. The test is based on the theory that an asphalt must be able to relax under the applied loads, but posses enough tenacity to maintain a proper matrix. The higher the stress level in the thin film of asphalt between the aggregate, the greater the chance for fracture. The test is a modification of the standard Ductility test at 39.2 F (4 C). It not only measures the elongation of an asphalt sample, but also measures the forces found in the sample at any magnitude of elongation during the test. In the operation of the Force Ductililty test, all parts used in the standard ductility test are used in the same manner and the only modification is the addition of a proving ring mounted in series with the drive mechanism to measure force generated in the sample with elongation. However, many shortcomings of the original ductility test have been eliminated in the new test. The data in the new test are gathered in the first 10 or 15 cm of the test, when the areas are relatively constant thus reducing the change in results due to sample disfiguration. The repeatability of test is therefore much better. Indefinite data such as 100+ are eliminated and fewer shoulder breakages seem to occur, most likely due to the slight give in the added apparatus. Various asphalts have been tested in Utah to observe any correlation with the results of the force ductility tests. The test results were compared with the performance of pavements in controlled test sections, as well as with pavements selected randomly from across the state. Both groups of pavements revealed a significant correlation between the force ductility test and pavement performance (especially the temperature-induced transverse cracking). Tests on asphalts treated for 75 minutes in the Rolling Thin Film Circulating Oven indicated an increase in maximum force and the recovery slopes illustrating the hardening of the asphalts with lab

hardening. Again the values were indicative of field performance. Tests on asphalts extracted from field cores showed similar increases in force and slope after field aging. Chemical breakdown of four asphalts using the Rostler method indicated a significant relationship between the paraffin content of an asphalt, and the force ductility results, thus establishing a link between chemical composition and this physical test result. The paraffin content in turn correlated highly with pavement cracking.
Another physical properly investigated was shear susceptibility, defined as the change in Cannon cone viscosity with changes in shear rate. For the same four asphalts, the slopes of lines plotted on viscosity-log shear rate were found to be an indicator of asphalt performance. The steeper the slope the greater the extent of cracking. A general relationship exists between the force ductility test results, and shear susceptibility.
Further studies were done with viscosities at various temperatures, and a parameter know as temperature susceptibility [(loglogV1 - loglogV2)/(log T1 - log T2)] was investigated. The temperature susceptibility values also correlated with the temperature-associated transverse cracks observed in the field. As an asphalt hardens, its temperature susceptibility decreases. A satisfactory agreement between force ductility results (maximum force) and temperature susceptibility (140 - 275 F) of original, residue, and 66 months aged asphalts was observed.

RECORD No.: 51.
AUTHOR : L. W. Corbett, H. E. Schweyer, and W. A. Lloyd
TITLE : Asphalt Viscosity by the Exxon Rapid Method
JOURNAL : Proceedings Association of Asphalt Paving Technologists
VOLUME No.: 45
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1976
PAGES : 42-52
ABSTRACTOR: PTI
KEYWORDS : Asphalts, viscosity at 140 F, testing time, precision test variability
ABSTRACT :

A rapid method is proposed for determining the viscosity of asphalt cement at 140 F (60 C). This method is capable of turning out a test result in 25 minutes upon receipt of a hot sample, which is one half the time required for the standard ASTM method. The Exxon Rapid Method involves the same principle of measurement and the same degree of control as the standard method. The temperature bath, however, is small and is made as a solid aluminum block, and the viscometer tubes are straight capillary tubes which permit shorter afflux times. The quantity of asphalt used is also smaller. The temperature bath is built to hold four test tube reservoirs with vacuum connections for two viscosity tests to be run at the same time. The rapid method displays excellent agreement with the standard method in terms of test level. The variability of the rapid method is essentially comparable to the standard method and well within the precision limits for repeatability and reproducibility listed for the standard method. Based on interlaboratory test evaluation, the rapid method is shown to be reliable for use in manufacturing control or in customer laboratories.

RECORD No.: 52.
AUTHOR : R. D. Pavlovich and W. H. Goetz
TITLE : Direct Tension Test Results for Some Asphalt Concretes
JOURNAL : Proceedings Association of Asphalt Paving Technologists
VOLUME No.: 45
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1976
PAGES : 400-428
ABSTRACTOR: PTI
KEYWORDS : Asphalt concrete, asphalt type, temperature, aggregate gradation, strain rate, direct tension, stiffness
ABSTRACT :

Several thickness design and analysis techniques that have recently been made available utilize tensile strain as part of the procedure. The study described in this paper determines the effect of some mixture and environmental variables on strain at failure (limiting strain) for some asphalt concretes. Cylindrical specimens were loaded to failure in direct tension and strain at failure was calculated from axial deformations. Independent variables of the experiment included asphalt type, as described by nominal penetration and viscosity, aggregate gradation, temperature, and strain rate. An incomplete factorial experiment was designed to include asphalt type at six levels (three penetration levels with a high and a low viscosity at each level), aggregate gradation at three levels (coarse, dense, and fine), temperature at six levels (140 to -17.5 F), and four levels of strain rate. The results indicated that temperature is, by far, the most significant factor of the parameters studied affecting limiting strain. Limiting strain at 140 F is approximately 300 to 500 times as great as that at -17.5 F. Strain rate has an effect on limiting strain, however, the effect of strain rate, resulting from large variations in speed of ordinary vehicular loadings, is equivalent to the effect of only a few degrees of temperature change. That is, a small change in temperature affects limiting strain much more than does a large change in vehicle speed. Fine graded mixtures have a somewhat greater limiting strain value for a given temperature and strain rate than do coarser graded mixtures. Within the range of asphalts used for this study, asphalt type has no significant effect on limiting strain as measured by direct tension. Stiffness values that relate stress to strain for a given asphalt, temperature, loading time and aggregate volume, as determined by the Van der Poel nomograph and modified for aggregate content, were reasonably well verified.

RECORD No.: 53.
AUTHOR : P. S. Kandhal
TITLE : Low-Temperature Ductility in Relation to Pavement Performance
JOURNAL : American Society for Testing and Materials
VOLUME No.: STP 628
PUBLISHER : American Society for Testing and Materials
YEAR : 1976
PAGES : 95-106
ABSTRACTOR: PTI
KEYWORDS : Asphalt pavements, ductility, penetration, viscosity performance, field test sections, low temperature

ABSTRACT :

Ductility of asphalts at low temperature has been found to be a good indicator of surface conditions and cracking of pavements in various studies. Ductility of asphalts recovered from 47 pavements in the U.S. has been shown to be of prime importance in determining quality of a bituminous structure; reports on the Zaca-Wigmore Project indicated that the ductility test on recovered asphalts is an important method for judging pavement service performance. Data from cores taken on the Michigan Bituminous Experimental Road indicated that the section containing the lowest ductility had the most pitting and cracking, whereas there did not appear to be any significant differences between the penetrations. Another study of 53 highway pavements in the U.S. showed that severe raveling occurred in cold climates when the ductility at 60 F dropped to 3 CM or below. In this study, data obtained on 10 experimental test pavements constructed during 1961, 1962, and 1964, especially low-temperature ductility data measured at 39.2 and 60 F, have been analyzed and related to the performance of these test pavements. The analysis of the data indicated that aging of the pavement results in progressively lower penetration and higher viscosity. However, the accompanying decrease in low-temperature ductility is an important factor. The pavements containing asphalt with low ductilities are likely to show poorer service than pavements containing asphalts of the same penetration but with high ductilities. The data also indicate the probable ranges of low-temperature ductility values at which the progressive deterioration of the pavement (such as loss of fines, raveling, cracking, etc.) takes place under Pennsylvania climatic conditions. At lower temperatures, the ductility values are lower, reproducible, and better defined than the values at high temperatures determined on long, thin threads of asphalt. Therefore, a specification requirement at a 60 F or lower temperature should provide better criteria. Due to its empirical nature, it is not clearly understood what fundamental property is being measured by the ductility test. However, it is a desirable value indicating pavement performance. More research is needed to develop a rational test method which can be used more effectively to predict pavement performance.

RECORD No.: 54.
AUTHOR : H. E. Schweyer, L. L. Smith and G. W. Fish
TITLE : A Constant Stress Rheometer for Asphalt Cements
JOURNAL : Proceedings, Association of Asphalt Paving Technologists
VOLUME No.: 45
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1976
PAGES : 53-77
ABSTRACTOR: PTI
KEYWORDS : Asphalt cement, viscometer, medium to low temperature, rheological properties.

ABSTRACT :

As asphalt cements become harder with age or as a result of a lower-temperature environment, constant shear rate rheology requires extended lengths of time to attain equilibrium values. The development of a constant stress apparatus and procedure as reported by Schweyer and Kafka has provided a rapid, simple procedure for use in routine operations. The present paper discusses a second-generation model of the Schweyer Rheometer developed to be used routinely for field studies and other research work. The function of the rheometer is to evaluate shear velocity under a constant stress. The basic stress shear rate relations are discussed. Methods of calculating shear rate, shear stress and apparent viscosity are described. Specific considerations for effects of pressure, precision level of the viscometer, and reproducibility are discussed with the aid of representative test results. The benefits of the use of the rheometer are summarized. These include the capability of direct measurement of rheological properties of asphalt at medium and low temperatures, and the fact that it is simple to operate.

RECORD No.: 55.
AUTHOR : Anderson, Douglas I.; Peterson, Dale E.; Wiley, Max
TITLE : Evaluation of Viscosity-Graded Asphalt Cements in Utah
JOURNAL : Transportation Research Record
VOLUME No.: 595
PUBLISHER : Transportation Research Board
YEAR : 1976
PAGES : 9-17
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cements, specifications, penetration, viscosity, ductility, temperature shrinkage
ABSTRACT :

The methods used to grade asphalts (penetration, viscosity, and ductility) were investigated to determine their effectiveness as indicators of performance. A new procedure called force ductility has been correlated to performance. This modification in the standard ductility test measures the force in the asphalt sample versus elongation and is based on the theory that an asphalt must be able to relax as strain from traffic loading and temperature shrinkage is applied to a pavement. 15 refs.

RECORD No.: 56.
AUTHOR : Pavlovich, Raymond D.
TITLE : Limiting Strain as a Failure Criterion for Bituminous Mixtures
JOURNAL : Purdue Univ., Lafayette, Ind. Joint Highway Research Project.(Thesis)
VOLUME No.: JHRP-12-75
PUBLISHER : Purdue University, LaRayette, Ind.
YEAR : 1975
PAGES : 365p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt cements, asphalt concrete mixtures, acoustic emission, limiting strain, temperature gradation
ABSTRACT :

Experiments were conducted to measure strain at failure (limiting strain) for bituminous concretes. A secondary study was included to evaluate the possibilities of using acoustic emission techniques to detect and monitor cracking in portland cement and bituminous concretes. Parameters for the limiting strain experiment included asphalt type, aggregate gradation, temperature, and strain rate analysis of variance was used to evaluate the effect of each of the parameters and regression equations are presented that relate significant independent variables to limiting strain. The most significant parameter affecting limiting strain is temperature; strain rate and gradation do show some effects, but these are minor when compared to temperature. There was no measurable effect, in this experiment, due to asphalt type within a range which included a high and low viscosity material in each of three penetration grades (60-70, 85-100, 120-150). Acoustic emission experiments showed that this technique is effective for detecting micro-cracking long before visual observation indicates the occurrence.

RECORD No.: 57.
AUTHOR : Williams, F. M.; McAdams, M. M.; Reddick, J. S.
TITLE : A Study of the Use of Viscosity-Graded Asphalt Cements in Experimental Sections of Pavement
JOURNAL : Ohio DOT report
VOLUME No.: OHIO-DOT-22-75
PUBLISHER : Ohio Department of Transportation
YEAR : 1975
PAGES : 59p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt cements, viscosity, penetration, test roads, performance, construction
ABSTRACT :

The study investigates the feasibility of using viscosity-graded rather than penetration graded asphalt cements. Four projects were constructed using both viscosity graded and penetration graded asphalt cements. They were observed and evaluated during construction in 1968 and for a five-year period through 1973. This investigation was instrumental in subsequent adoption of viscosity-graded asphalt cement specifications, with corresponding reduction of testing, storage and handling problems.

RECORD No.: 58.
AUTHOR : Zolotarev, V. A.; Isaev, A. I.; Vinogradov, G. V.
TITLE : Viscoelastic Properties of a Bitumen Under Continuous and Cyclic Deformation
JOURNAL : Journal of Engineering Physics (English Translation of Inzhenerno-Fizicheskii Zhurnal)
VOLUME No.: 29, No. 2
PUBLISHER :
YEAR : 1975
PAGES : 1055-1061
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cements, viscoelastic properties, dynamic testing, viscosity, strain amplitude, frequency
ABSTRACT :

A study was made of the viscoelastic properties of a bitumen at various amplitudes and frequencies of the stresses acting on it. The effect of the amplitude of the strain rate on the absolute value of the complex and effective viscosity is established. 24 refs.

RECORD No.: 59.
AUTHOR : Arand, Wolfgant
TITLE : Contribution to the Theory of the Deformation Behavior of Asphalt
JOURNAL : Bitumen-Teere-Asphalte-Peche
VOLUME No.: 26, No. 1-2
PUBLISHER : Bitumen, Terre, Asphalte, Peche, Isevnhagen, Germany
YEAR : 1975
PAGES : 36-42
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cements, rheolgoical properties, molecular structure, idealized model
ABSTRACT :

Rheology aims at formulation of laws governing the behavior of real substances. In this effort it has resorted to the idealized stress-deformation diagram resulting from simple abstract bodies. Complex abstract bodies are subject to such deformation as can be figured as the resultant of deformations sustained by a number of simple abstract bodies. The behavior of abstract bodies lends itself to illustration by models. Such models, applicable to asphalt, were conceived by Krass and Buguslavskij. The author describes them and indicates ways of application. 19 refs. In German.

RECORD No.: 60.
AUTHOR : Gun, R. B.; Budnik, M. A.; Izmailov, A. N.
TITLE : Influence of Feedstock Nature and Asphaltene Structure on Asphalt Properties
JOURNAL : Chemistry and Technology of Fuels and Oils (English translation of Khimiya i Tekhnologiya Topliv i Masel)
VOLUME No.: 10, No. 5-6
PUBLISHER : Plenum, New York
YEAR : 1974
PAGES : 438-440
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cements, plasticity, composition, rheolgoical properties, molecular structure

ABSTRACT :

Results of a study are presented which show that asphalts obtained from West-Siberian reduced crude are characterized by a greater resistance to heat and cold and a wider plasticity range than the asphalts from mixed Tatar reduced crude; this can be explained by differences in the component composition of these materials, but also by differences in structure of the asphaltenes. The asphaltenes recovered from asphalts produced from the West-Siberian crudes are more highly aromatic. Electron microscope studies showed a substantial difference in structural formations of the asphaltenes, which is responsible for a difference in physicomechanical and rheological properties of the oxidized asphalts. The asphaltenes obtained from a highly oxidized asphalt produced from West-Siberian crudes are characterized by a more ordered structure of aggregated globules of botryoidal form, in comparison with a similar film of the asphaltenes from a high oxidized asphalt produced from mixed Tatar reduced crude. 4 refs.

RECORD No.: 61.
AUTHOR : Zakar, Pal
TITLE : Present Trends in Bitumen Research
JOURNAL : Bitumin-Teere-Asphalte-Peche
VOLUME No.: 25, No. 7
PUBLISHER : Bitumen, Terre, Asphalte, Peche, Isevnhagen, Germany
YEAR : 1974
PAGES : 266-267
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cement, rheological properties, adhesion, cohesion
ABSTRACT :

Beside covering the demand for bitumen, the standardization of grades is of utmost importance to all concerned. It is at research level subject to systematic testing and the following description of the characteristics found. The principal questions are answered by rheology and such phenomena as adhesion and cohesion, which in turn are closely allied with the stress-deformation behavior of asphalts. 33 refs. In German.

RECORD No.: 62.
AUTHOR : Fenijn, J.;Guesfeldt, K.H.
TITLE : Stiffness Modulus of Bituminous Materials
JOURNAL : Bitumin-Teere-Asphalte-Peche
VOLUME No.: 25, No. 6
PUBLISHER : Bitumen, Terre, Asphalte, Peche, Isevnhagen, Germany
YEAR : 1974
PAGES : 239-241
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cement, rheolgoical properties, elastic properties, stiffness modulus, temperature, loading time

ABSTRACT :

The behavior of an asphalt cement under stress is an essential characteristic for description of its serviceability. It can be indicated by the stiffness modulus, the magnitude of which is a function of temperature and the period of exposure to stress. The mechanism of deformation under stress can be exemplified by analogy in schemes in which the elastic properties are symbolized by springs and the viscous qualities by absorbing elements. 5 refs. In German.

RECORD No.: 63.
AUTHOR : Fritz, H. W.
TITLE : Determination of Rheological Properties of Asphalts Based on Dynamic Tests
JOURNAL : Bitumin-Teere-Asphalte-Peche
VOLUME No.: 25, No. 1
PUBLISHER : Bitumen, Terre, Asphalte, Peche, Isevnhagen, Germany
YEAR : 1974
PAGES : 6-10
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cements, colloidal nature, viscoelastic properties, road tests
ABSTRACT :

Asphalts are colloidal systems the flow behavior of which is relatively complex. Rheologically seen, they can be classified as visco-elastic substances. Their deformation response to stress can be simulated by theoretical models in which the elastic properties are embodied by springs and the viscous properties by damping elements. The definition of asphalts by purely rheological data can impart a picture quite different from the description by orthodox viscosity data. A road has been completed with one section incorporating a standardized asphalt and another one with an asphalt quality divergent from standards but promising for its rheological features. Any differences in performance are expected to reveal interpretable information. 3 refs. In German.

RECORD No.: 64.
AUTHOR : W. Heukelom
TITLE : An Improved Method of Characterizing Asphaltic Bitumens with the Aid of Their Mechanical Responses
JOURNAL : Proceedings, Association of Asphalt Paving Technologists
VOLUME No.: 42
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1973
PAGES : 67-98
ABSTRACTOR: PTI
KEYWORDS : Asphalts, low-temperature susceptibility, high-temperature susceptibility, penetration, viscosity, stiffness
ABSTRACT :

Existing asphalt performance requirements are expressed in terms of penetration and/or viscosity. In this paper, it is shown that these properties are interrelated and related to the stiffness modulus(s). A direct relation between penetration and stiffness modulus has been formulated by others: log S = 9.4-1.9 log pen (N/M^2). This simple relation is shown to give a reasonable correspondence with experimental results collected using three types of asphalts. The existence of this relation enables performance requirements to be expressed in terms of both penetration and stiffness modulus. Stiffness modulus deals with the total deformation of a bitumen, whereas viscosity is a measure of the viscous flow only. If viscosity data are extrapolated to low temperature, the results may give an entirely wrong impression of the behavior of a bitumen because the delayed elastic deformation then predominates over viscosity flow. Therefore, it is advisable to make use of the stiffness modulus which remains valid in the true viscosity range. As a main conclusion of this work, it may be reported that bitumens can be divided into three classes (S, B, W), each showing a specific type of behavior. Each class must be considered by itself because for each the minimum number of characteristic values (e.g., penetration or viscosity) required for a complete description is different. Class S is characterized by straight lines on the BTDC; therefore, two test values are required. Class B is represented by two interceding straight lines, one representing the high-temperature while the other refers to the low-temperature susceptibility. Two measures in the low-temperature range and two in the high-temperature range are necessary to chacterize these asphalts. Class W (waxy) asphalts are also represented by two straight lines; however, the two lines have nearly equal slopes that are not aligned. For this class, two measurements at very low temperatures and two at high temperatures are also needed. For characterization purposes it is recommended that T800pen be used as the reference temperature and PI(pen/pen) as the temperature susceptibility. These characteristic values belong to the same branch of a curve on the BTDC and thus form a consistent system for all classes of bitumen. The penetration/viscosity system developed by others which will certainly give precise values of the PI of Class S bitumens is likely to

cause difficulties with Class B and W bitumens.

RECORD No.: 65.
AUTHOR : Beecroft, Gordon W.; Jenkins, John C.; Wilson, James E.
TITLE : Service Behavior of Asphalt Concrete. A Ten-Year Study Prepared in Cooperation with Department of Transportation, Washington, D.C.
JOURNAL : (Report) Oregon State Highway Div., Salem. Materials and Research Section.
VOLUME No.:
PUBLISHER : Oregon State Highway Division
YEAR : 1973
PAGES : 44p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt cements, asphalt concrete mixtures, penetration, mixture variables, performance, density
ABSTRACT :

Surface conditions were evaluated and samples of asphalt concrete and stone base were obtained twice yearly for a ten year period at 32 test points on eight Oregon highways. A stepwise linear regression analysis was conducted to determine relationships that exist between different pavement properties and between pavement properties and service characteristics of the pavement. Variables included years service, equivalent wheel loads, a pavement condition code, and wheel track depressions. Properties of the asphalt concrete included in the regression analysis were specific gravity, relative compaction, air voids, stabilometer S values, cohesiometer values, penetration, asphalt content, and aggregate gradation. Also included were properties of the granular base, i.e., density, moisture content, relative compaction and gradation.

RECORD No.: 66.
AUTHOR : Hearld, John L.; Lay, Larkin D.
TITLE : Variation in Temperature and Mechanical Properties of Asphaltic Concrete Due to Storage in Surge Bins
JOURNAL : Louisiana Dept. of Highways, Baton Rouge. Research and Developm
VOLUME No.: RR-67; LA-72-2B(B)
PUBLISHER : Louisiana Department of Highways
YEAR : 1973
PAGES : 19p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt cements, asphalt concrete mixtures, storage, stability, penetration, viscosity
ABSTRACT :

This study was initiated to seek data relative to the effects of storage time and temperature on the physical properties of asphaltic concerete. Thermocouples were installed at various locations within an unheated insulated surge bin to record temperatures. Specimens for Marshall stability and flow were molded at different time intervals during loading and unloading of the surge bin. The asphalt cement, recovered by the Abson Method, was tested for penetration and viscosity. The study was confined to wearing course sand gravel mix.

RECORD No.: 67.
AUTHOR : R. W. Stephenson, and P. G. Manke
TITLE : Ultrasonic Moduli of Asphalt Concrete
JOURNAL : Highway Research Record
VOLUME No.: No. 404
PUBLISHER : Highway Research Board
YEAR : 1972
PAGES : 8-21
ABSTRACTOR: PTI
KEYWORDS : Asphalt concrete, ultrasonic testing, elastic modulus, shear modulus, Poisson's ratio, temperature, void ratio, asphalt content

ABSTRACT :

A need for a nondestructive, dynamic technique for evaluating certain "elastic" constants of asphalt paving materials has previously been observed. In this study, a method is developed by which the dynamic E-modulus, G-modulus, and Poisson's ratio of compacted asphalt-aggregate specimens are determined from measurement of the propagation velocities of pulsed ultrasonic shear and compressional waves through the test material. This test procedure proved to be easily and rapidly performed on standard Hveem-gyratory specimens. The results obtained compared favorably with those reported by other investigators using different procedures. A brief study of a single asphalt-aggregate mixture, using a variety of asphalt and void contents, resulted in the following observations: (a) an increase in the temperature of the test material resulted in a decrease of the values of both the dynamic E- and G-moduli; (b) maximum moduli occurred at an "optimum" asphalt content for wave transmission of 6 percent; (c) the dynamic Poisson's ratio increased directly with increased asphalt content of the specimens; (d) at temperatures greater than approximately 100 F, Poisson's ratios increased rapidly toward the theoretical maximum of 0.50; and (e) the amount of voids contained in a compacted specimen had only a minor influence on the rate of wave transmission through the specimens at low temperatures, but above 80 F this influence was more pronounced.

RECORD No.: 68.
AUTHOR : Allen, David L.
TITLE : Rheological Response of Asphalts
JOURNAL : FHWA REPORT
VOLUME No.: FHWA/RD/M-0346
PUBLISHER : FHWA
YEAR : 1972
PAGES : 32 p.
ABSTRACTOR: NTIS
KEYWORDS : Asphalt cements, rheological properties, apparent viscosity, temperature effects, stress level, pavement design.

ABSTRACT :

The rheological response of asphalt cements to shearing stresses is presented. The behavioral characteristics were measured using a rotating coaxial cylinder viscometer. Little or no development of theory is presented. The viscoelastic portion of deformation is discussed in terms of the creep function. Platic deformation is described using the definitions of apparent and plastic viscosities. Curves showing the effects of temperature, stress level and penetration on these two major components of strain are presented and discussed. Analysis indicated that plastic deformation is the predominante component of strain and, thus, should be considered and incorporated in the design of flexible pavements.

RECORD No.: 69.
AUTHOR : E. K. Ensley
TITLE : The Influence of Intermolecular Interactions in Viscosity at Low Temperature: Forced-Sphere and Forced-Cylinder Viscometer
JOURNAL : American Society for Testing and Materials
VOLUME No.: STP 628
PUBLISHER : American Society for Testing and Materials
YEAR : 1971
PAGES : 43-56
ABSTRACTOR: PTI
KEYWORDS : Asphalt cement, viscosity, thermal history, microcalorimeter, association of asphalt molecules, low temperatures
ABSTRACT :

Viscoelasticity is a manifestation of strong intermolecular interactions inherent in polar materials such as asphalt. A previous kinetic investigation of asphalt association showed that asphalt could be thermally dissociated and, when cooled, would become more associated. The influence of asphalt association on viscosity at low temperatures is studied in this paper. Specially constructed viscometers were used to detect predicted small differences in viscosities between associated and dissociated asphalt. The viscometers employed the principle of measuring the velocity of an object (sphere or cylinder) moving through a viscous medium. Five asphalts were used in the study. The dissociated asphalt sample was prepared by heating about 100 gm of asphalt at 250 C for 1 1/2 hours and then quenching it at room temperature. The more associated asphalt was prepared by heating a similar among of asphalt at 130 C for 15 hours and quenching it at room temperature. A microcalorimeter was used to investigate rates of intermolecular interactions at 130 and 150 C by detecting and reading the difference in temperature or energy flow from reacting and blank cells placed separately in equivalent thermopile assemblies. Viscosities over the temperature range 20 to -6 C were measured using forced sphere and forced cylinder (wire) viscometers. The latter was used for viscosities in the range of 10^10 to 10^12 poises (temperatures below 0 C). Various levels of pulling force were used to study the relation between viscosity and shear rate. Viscosities of different asphalts as measured by forced sphere and sliding plate viscometers were compared at two different temperatures (15.6 C and 25 C), and the results indicated reasonable agreement. Results for the forced cylinder technique showed less agreement with the sliding plate viscometer. Temperature viscosity plots were made using both the Arrhenius exponential and the WLF equations. The exponential plot allowed an apparent viscosity activation energy to be calculated. The activation energy agreed with previously reported data. Whether asphalt is near-Newtonian or Non-Newtonian, the activation energy is a measure of temperature susceptibility and is useful in predicting viscosities at temperatures other than those investigated. The forced sphere and forced cylinder methods were sensitive to differences in thermally associated and

dissociated asphalts. Application of the WLF equation to the associated asphalt and dissociated asphalt viscosity data led to glass transition viscosities. The associated material show a slightly higher glass transition viscosity than that of the dissociated material. In conclusion, these methods offer a means of determining viscosities of asphalt between 25 C and the glass transition temperatures. However, low shear rates (.001 to 0.000001 1/sec, depending on temperature) are necessary in order to have any resemblance of near-Newtonian flow; otherwise, flow is by structural change such as fracturing, not by energy dissipation.

RECORD No.: 70.
AUTHOR : Bynum, D., Jr.; Fleisher, H. O.; Evertson, J. F.; Sartori, M. P.
TITLE : Constitutive Relations for Uniaxial Tests on Bituminous Concrete
JOURNAL : Preceedings, Australian Road Research Lab
VOLUME No.: 4, No.7
PUBLISHER : ARRL
YEAR : 1971
PAGES : 19-32
ABSTRACTOR: compendex Plus
KEYWORDS : Asphalt Concrete, Viscoelasticity, asphalt cement, additives, unaxial tension
ABSTRACT :

The constitutive relations for viscoelastic characterizations and satistical analyses of the results for several asphaltic concretes tested with constant strain rate loading in uniaxial tension and in uniaxial compression are presented. The differences in the fundamental properties due to binder source, binder additive, and percent binder were quantified. Latex additive in the asphalt enhanced the concrete properties using one asphalt, and degraded the concrete properties using a second asphalt. The results might be used in the formulation of performance requirements or for pavement design. 15 refs.

RECORD No.: 71.
AUTHOR : L. W. Corbett
TITLE : Relationship Between Composition and Physical Properties of Asphalt
JOURNAL : Proceedings, Association of Asphalt Paving Technologists
VOLUME No.: 39
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1970
PAGES : 481-491
ABSTRACTOR: PTI
KEYWORDS : Asphalt, generic fractions, viscosity, temperature susceptibility, softening point, ductility, penetration
ABSTRACT :

Asphalts contain an extremely wide variety of hydrocarbon types and sizes, more than is practical to isolate and identify. A reasonably short and practical method that was developed is to separate asphalt into four generic fractions: saturates, Napthene-aromatics, Polar-aromatics, and asphaltenes. To study the function of each fraction, asphalt samples were separated into the four generic fractions and then a series of two-component compositions were prepared such that the data could be interpolated to the 90 penetration level. To determine how each fraction contributes to the rheological characteristic of the asphalt, 35 percent by weight dispersions of asphaltenes in each of the other three fractions were made and their viscosities at 100 F were determined using the sliding plate microviscometer. The results can be summarized as follows: 1) the physical properties of each of the four generic fractions are distinctly different from each other; 2) the fluidity of an asphalt increases (hardness decreases) by the plasticizing effect of the liquid fractions (saturates and naphthene-aromatics) on the solid fractions (polar-aromatics and asphaltenes); 3) the combination of either the saturates or the naphthene-aromatics with asphaltenes improves the temperature susceptibility, and the combination of polar-aromatics with asphaltenes makes the temperature susceptibility poorer; 4) ductility is largely dependent upon the presence of polar-aromatics, while the other three fractions contribute very little if anything to ductility; 5) flow resistance (softening point) is increased by the combination of saturates or naphthene-aromatics with asphaltenes, and is decreased by combination of saturates with polar-aromatics; 6) high viscosity relative to penetration occurs when naphthene-aromatics are combined with asphaltenes, whereas all other combinations tend to lower viscosity; 7) shear susceptibility is primarily due to the combination of saturates or naphthene-aromatics with asphaltenes, whereas polar-aromatics with asphaltenes are Newtonian; and 8) each fraction or combination of fractions performs separate functions with respect to physical properties, and it is logical to assume that the overall physical properties of an asphalt are thus dependent upon the combined effect of these fractions and the proportions in which they are present.

RECORD No.: 72.
AUTHOR : Dickinson, E. J.
TITLE : Visco-elastic Behavior of Confined Liquid Films in the Direction Normal to the Plane of the Film
JOURNAL : Transactions of the Society of Rheology
VOLUME No.: 14, No. 1
PUBLISHER : Society of Rheology
YEAR : 1970
PAGES : 77-81
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cements, viscoelastic properties, dynamic testing, film thickness effects
ABSTRACT :
The viscoelastic behavior of liquids confined as a thin film between parallel rigid plates, and strained in a direction normal to the planes of the plates, is of importance in obtaining an understanding of the deformation and fracture behavior of adhesives and lubricants. Only the condition in which the liquid adheres to the material of the plates is considered. For sinusoidal loading, linear visco elastic theory predicts an approximate relationship between the measured complex, modulus, the complex shear modulus, and the degree of confinementof the liquid as given by the radius/thickness ratio of the film. The ratio of the measured complex modulus to the complex shear modulus, when both are measured at the same temperature and rate of loading (frequency), is predicted to be proportional to the square of the radius/thickness ratio of the film when this ratio is greater than one. Complex modulus measurements under sinusoidal loading on a petroleum bitumen, a silicone oil, and water have confirmed the validity of this relationship. 5 refs.

RECORD No.: 73.
AUTHOR : Marathe, P. D.
TITLE : Study of the Rheological Properties of Bitumen Using a Parallel Plate Viscometer
JOURNAL : Indian Journal of Technology
VOLUME No.: 8, No. 5
PUBLISHER :
YEAR : 1970
PAGES : 165-68
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cement, rheological properties, sliding plate,
ABSTRACT :

The rheological properties of two samples of bitumen (80/1000 and 30/40 Esso) have been determined at 25 plus or minus 0. 5 C using a specially fabricated parallel plate viscometer. Below a certain stress value, the bitumens exhibit viscoelastic behavior, conforming to the Burgers model. Above this value, they exhibit pure viscous flow. The rheological properties of bitumen, which is widely used for road construction, are of considerable importance to field engineers for assessing its service performance.

RECORD No.: 74.
AUTHOR : E. Zube, J. B. Sbog
TITLE : Final Report on the Zaca-Wigmore Asphalt Test Road
JOURNAL : Proceedings, Association of Asphalt Paving Technologists
VOLUME No.: 38
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1969
PAGES : 1-38
ABSTRACTOR: PTI
KEYWORDS : Penetration, viscosity, BPR thin film test, shell modified microfilm durability test, shear susceptibility, hardening, cracking
ABSTRACT :

In 1954, the California Division of Highways introduced improved specification for paving grade asphalts. In order to determine the effect of the specifications under field conditions, 10 different California asphalts of the 200-300 penetration grade, (with 1 exception), were placed in 2500-ft test sections in both new and overlaid pavements. The test sections were constructed under nearly identical procedures, and have been subjected to common climatic and traffic conditions. Complete field studies were carried out during construction, and Abson recovery tests were made on the paving mixtures. Test results and observations confirm the fact that asphalts manufactured by different methods and from different crude sources, although placed under virtually identical conditions, exhibit varying degrees of hardening during the mixing process. This change in asphalt properties during mixing was predicted in a satisfactory manner with the Bureau of Public Roads Thin Film test. Two main types of failure during service life were encountered on the project. The most prevalent was fatigue cracking as displayed by wheel track "alligator" type cracking. The other was a large block-type cracking together with pitting and raveling. This was most prevalent in the passing lane. The amount of fatigue type cracking appears to be related to the penetration and viscosity of the recovered asphalt. The other form of cracking appears to be related to the gain in shear susceptibility during weathering. The rate of hardening of the various asphalts was quite rapid up to approximately 20 months of service, but thereafter was reduced. The durability under equivalent conditions of voids and asphalt content appears to be predicted best by the Shell Modified Microfilm Durability test. On this specific project, there was a very rapid increase in the area of fatigue cracking when the cracked area had reached 10 percent of the total section area.

RECORD No.: 75.
AUTHOR : E. J. Dickinson and H. P. Witt
TITLE : The Viscoelastic Behavior of Confined Thin Films of Bitumen in Tension Compression
JOURNAL : Transactions of the Society of Rheology
VOLUME No.: 13
PUBLISHER : The Society of Rheology
YEAR : 1969
PAGES : 485-511
ABSTRACTOR: PTI
KEYWORDS : Asphalts, shear modulus, longitudinal modulus, confinement viscoelasticity, phase angle
ABSTRACT :

The behavior of confined thin films of a bitumen under sinusoidal loading both in shear and in a direction normal to the plane of the film (tension/compression) has been investigated. For small strains, behavior in tension/compression, like that in shear, is linear and thermorheologically simple and the temperature dependence of the rheological parameters is the same in each case. In tension/compression, the degree of confinement can be defined by the ratio of the radius of the confining plates (r) to the thickness of the film (d). For confinement ratios greater than about one, the longitudinal complex modulus |M*| was found to be more than three times the complex shear modulus 3|G*| (the value expected for shear behavior). The complex modulus ratio |M*|/3|G*|, where |M*| and |G*| are measured at the same frequency and temperature, was found to be approximately proportional to the square of the confinement ratio over the confinement ratio range 4.5 to 45. This relationship should be predicted by the theory of the purely elastic situation. The energy loss factor under sinusoidal loading, 2 tan (phi) (where phi is the angular phase difference between stress and strain), was found to be different in tension/compression from that in shear. As the confinement ratio increases, the energy loss factor decreases more rapidly with frequency than for shear conditions. To indicate the temperature/frequency region for this decrease, the behavior where tan = 1 was evaluated and found to correspond to an |M*| value of about 8 x 10^8 dynes/cm. (The same value is obtained in shear for tan (phi) = 1.) The particular relationship (for the bitumen tested) between the temperature, the frequency, and the confinement ratio when tan (phi) = 1 was determined for the range of frequencies and temperatures covered experimentally. The theoretical implications of the results and their relation to the deformation, fracture, and fatigue behavior of bitumen bonded road surfacing materials are briefly discussed.

RECORD No.: 76.
AUTHOR : Schweyer, H. E.; Busot, J. C.
TITLE : Research on Asphaltic Materials
JOURNAL : Final Report
VOLUME No.: CR-5949; B-1-63
PUBLISHER : Florida University, Gainsville. Engineering and Industrial Experiment Station
YEAR : 1969
PAGES : 67p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt cements, rheological properties, oxidative aging, specifications
ABSTRACT :

The terminal report includes summaries of reports submitted during the course of a 6-year laboratory study of selected asphalt cements. Also included is an updating of basic rheological and compositional information on several asphalts and a rheological evaluation developed using an Instron extrusion technique. Rheological responses were studied by a computerized cluster analysis technique. This analysis was extended to durability responses using the Thin Film Oven Test and a special Weatherometer test. The cluster technique enables classification of asphalts in groups with similar responses. Identification of these groups with levels of performance could possibly be of value for specification purposes.

RECORD No.: 77.
AUTHOR : Herrin, Moreland; Marek, Charles R.
TITLE : Relationship of Ductility Test to the Fundamental Mechanical Properties of Asphalts
JOURNAL : Highway Engineering Series
VOLUME No.: Ser-33
PUBLISHER : Illinois University, Urbana Department of Civil Engineering
YEAR : 1969
PAGES : 121p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt cements, ductility, temperature, rate of strain, stiffness tensile strength, shear susceptibility, fracture toughness, composition

ABSTRACT :
Ductilities were obtained at four temperatures, 25C (77F), 18C (64.4F), 11C (51.8F), 4C (39.2F), and at two rates of pull, 5 and 1 cm/min, on seven viscosity-graded asphalt cements and on eight asphalt cements. The ductility measurements were correlated with each of the following mechanical properties: (a) maximum load required to stretch the ductility specimens, (b) deformation to maximum load, (c) pseudo-stiffness (maximum load divided by deformation to maximum load, (d) tensile strength in thin films, (e) shear strength, (f) shear susceptibility (negative ratio of an increment of log viscosity to the corresponding increment of log rate of shear, and (g) brittle fracture. The conclusions arrived at by the researchers include the following: (1) There did not appear to be any relationship between ductility and any of the mechanical properties at all test temperatures for all the asphalt cements. (2) At cold temperatures (4C), the ductility of an asphalt is related to its brittle fracture (fracture toughness). (3) At warmer temperatures there appears to be an inverse relationship between log ductility and log shear strength. (4) At a specific temperature there is probably an inverse relationship between shear susceptibility and log ductility. It was further concluded that the ductility test is not strictly a mechanical test but one that probably measures both strength and chemical properties of the asphalt. A linear relationship between log viscosity of an asphalt and its tensile strength in thin films was found.

RECORD No.: 78.
AUTHOR : Priniski, George S.; Lambiotte, David J.
TITLE : Comparison of Sliding Plate Microviscometer and Conventional Asphalt Tests
JOURNAL : Naval Civil Engineering Lab.(report)
VOLUME No.: NCEL-TN-995
PUBLISHER : Naval Civil Engineering Lab., Port Hueneme, Calif.
YEAR : 1969
PAGES : 26p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt cements, penetration, ductility, viscosity, oxidative hardening
ABSTRACT :

Asphalt deterioration in past years has been studied using the empirical penetration and ductility tests. However, in recent years a sliding plate microviscometer has been developed which is capable of determining the viscosity of asphalts, thus reflecting a fundamental property. In the report an attempt is made to correlate the viscosity of aged asphalts with the empirical conventional asphalt tests. Viscosity test data were compared with penetration and ductility test data for selected aged asphalts from four Navy airfields. Also, one new asphalt was tested. The correlation obtained between penetration and viscosity for aged asphalts did not allow prediction of penetration from viscosity, and vice versa, to a sufficiently accurate degree for adoption of the viscosity test at this time. However, the data for the new, unaged asphalt showed excellent correlation and compared favorably with research done by others. In addition, it was found that the inflexible limit of the ductility test precluded any reasonable correlation between viscosity and ductility.

RECORD No.: 79.
AUTHOR : Bartenev, G. M., Ermilova, N. V.
TITLE : Theory of Rheological Properties of Quasi-Solid Disperse Structures
JOURNAL : Colloid J of USSR (English translation of Kolloidnyi Zhurnal)
VOLUME No.: 31, No. 2
PUBLISHER :
YEAR : 1969
PAGES : 1359
ABSTRACTOR: Compendex Plus
KEYWORDS :
ABSTRACT :

Disperse systems may be represented by two types of rheological flow curves - type one, characterized by single- valued dependence of the shear velocity gradient on the stress, type two, by decrease of shear stress in a certain range of deformation rates, and increase outside this range. In absence of complete experimental data, it is possible in some cases to predict the character pf the flow curves from available data. Examples relate to flow of bitumen and bentonite suspensions.

RECORD No.: 80.
AUTHOR : Traxler, R. N.
TITLE : Stiffness of Asphalt Cements Evaluated by Compression
JOURNAL : Texas Transportation Inst., College Station., Progress Report
VOLUME No.: No. 16 (Final)
PUBLISHER : TTI
YEAR : 1968
PAGES : 76p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt cements, stiffness, compression, rheological properties

ABSTRACT :

The report describes preliminary development of a procedure for evaluating the rheological and mechanical properties of asphalt cements at low atmospheric temperatures.

RECORD No.: 81.
AUTHOR : Codling, P. J.
TITLE : An Automatic E. V. T. Viscometer
JOURNAL : Road Research Lab., Crowthorne (England).
VOLUME No.: RRL-LR211
PUBLISHER : RRL
YEAR : 1968
PAGES : 14p
ABSTRACTOR: NTIS
KEYWORDS : Tars, viscometer, equi-viscous temperature
ABSTRACT :

The equi-viscous temperature (e.v.t.) viscometer, used to determine the viscosity of road tar has beet automated. This has been achieved by using a reversible motor in combination with a constant sequence timer to twist the torsion head. When the tar reaches the equi-viscous temperature a stud fixed to the fly-wheel makes electrical contact with a fixed pointer, thereby activating a buzzer and breaking all other electrical circuits. No loss in accuracy is caused by automation. Disposable plastic tar cups can be used as an alternative to the standard metal cup without affecting the precision of the instrument. Instead of using a standard tar, silicone fluid which has a much superior storage stability can be used to calibrate the viscometer.

RECORD No.: 82.
AUTHOR : Boyd, H. J.
TITLE : Oxidation Cracking of Asphalt Pavement
JOURNAL : Report
VOLUME No.: (Rept. no. 2 on Phase 1)
PUBLISHER : Mississippi State University, State College. Engineering and Industrial
YEAR : 1968
PAGES : 56p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt concrete mixes, oxidative hardening, sonic modulus, permeability, moisture effects, healing, pressure
ABSTRACT :

The weathering effects of fluids on an asphalt-aggregate mixture are being investigated in an effort to determine the mechanisms of deterioration of such a system. The physical properties being observed during the weathering process are the changes in sonic modulus, which correlate with Young's modulus, and the changes in permeability, which is an indicator of pore channel sizes. The results presented in this report indicate that: the sonic test method can be used to investigate weathering effects; weathering with ambient air or water alone at 70F has no effect on the sonic modulus; permeability increases upon weathering with air and decreases upon weathering with water; weathering with hot air causes a slight decrease in the sonic modulus; and after subjecting the asphalt-aggregate system to a destructive test, the system will 'heal' under the application of a confining pressure.

RECORD No.: 83.
AUTHOR : E. J. Dickinson
TITLE : The Assessment and Improvement of Paving Bitumen Performance
JOURNAL : Proceedings of Association of Asphalt Paving Technologists
VOLUME No.: 36
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1967
PAGES : 562-581
ABSTRACTOR: PTI
KEYWORDS : Asphalts, aging, specifications, flow-temperature relation, flow-rate of loading relation, viscosity, viscoelasticity

ABSTRACT :

This paper reviews present knowledge on the factors known to cause change in the bitumen during service--chemical attack by oxygen in the presence and absence of solar radiation, microbiological oxidation, and loss of oils by evaporation. It also reviews the stressing conditions that the bitumen may go through--moving or stationary traffic, thermal contraction or expansion, and stresses imposed by the structure under the surface. This paper gives a brief presentation of the rheological behavior to be considered in relation to performance--behavior for small strains, and behavior for large strains (failure). For small strains, consideration should include: (1) the response at low rates of loading (creep), for which viscosity measured at high and low temperature may be a good measure to include in specification to control plastic deformation at high temperatures and thermal cracking at low temperatures; (2) response at high rates of loading (vibration), for which a measurement of the elastic component of the dynamic (complex) modulus G' and the phase angle tan (phi) is suggested as measurements to control specifications. A minimum value at 60 C and 50 cps of G' and a maximum value of tan (phi) are suggested to control rutting and shoving at high temperatures. For low temperature fatigue cracking and fretting, a maximum value of G', and a minimum value of tan (phi) at 10 C and 50 cps should be specified. These limits are considered for Australian climate conditions. To control the hardening properties and their effect on performance, it is suggested that specifications should include: (1) tests on delivered material--max viscosity (Va) at 60 C, temperature at which viscosity=2 poises, flash point, specific gravity, solubility in carbon tetrachloride, and minimum G' and maximum tan (phi) at 50 cps and 60 C; (2) tests on materials subjected to treatment simulating hot mixing conditions--minimum a at 60 C, minimum G, and maximum tan (phi) at 50 cps and 60 C; (3) tests on material subjected to treatments simulating hot mixing and weathering on the road--maximum Va at 25 C and 0.001 1/sec, maximum G; and minimum tan (phi) at 50 cps and 10 C. The paper emphasizes the need for development of aging procedures for simulating weathering on the road. It proposes the use of a thin film sliding plate viscometer to measure a and the vibratory concentric cylinder developed by Thrower (axil vibration of the inner cylinder of a coaxial set up with thin films of asphalt in between) for

measuring G' and tan (phi). Possible ways to improve resistance to oxidation by modified processing or additives are discussed.

RECORD No.: 84.
AUTHOR : P. J. Serafin, L. L. Kole, and A. P. Chritz
TITLE : Michigan Bituminous Experimental Road: Final Report
JOURNAL : Proceedings, Association of Asphalt Paving Technologists
VOLUME No.: 36
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1967
PAGES : 582-614
ABSTRACTOR: PTI
KEYWORDS : Asphalt, test sections, viscosity, penetration, ductility, composition, aging, mixtures, performance.

ABSTRACT :

In 1950 it appeared that several new sources of asphalt cement would become available to contractors. Therefore, the Michigan Department of State Highways began an investigation to compare qualities of these new sources with others that had previously met specifications and given satisfactory service. A laboratory study of 35 different asphalts within penetration grades 60-70, 85-100, and 150-175, was completed in 1952 and a supplement study of material from Wyoming and Canadian crude oil sources was completed in 1954. Reports on these studies indicated that viscosity, temperature susceptibility (measured by viscosities at 275, 300, and 325 F), and heat stability (measured by heating samples in closed containers for 2 hours at 500 F) are the main physical characteristics of new asphalts found to be different from those with which satisfactory experience had been obtained. The test road consisted of a 6-mile resurfacing of a 40-ft-wide four-lane reinforced concrete pavement constructed in 1931. The test road was constructed in six identical sections of 2400 ft each. The same source of aggregate, and the same construction procedures were used to eliminate any effects of such variations. The asphalt content and mixing and placing temperature were the only variables varied for each 2400-ft section. Six types of asphalt were used, one for each section. The temperature levels for the asphalts were chosen to give equal saybolt Furol viscosity of 75 sec at the high temperature level, 200 sec at the low temperature, and the average of these two for the medium level. Temperatures of each truck load were measured at the plant and paver. Truck loads were sampled to supply mixture for Marshall specimens which were used to determine mix properties, mix analyses and recovery tests. Samples of pavement produced from the same truck loads were taken for similar purposes. In 1954, the test road coring program began. Through 1957, at least four core samples at two to four locations in each subsection were obtained annually for laboratory analysis. In December, 1957, the number of core samples was increased so that both the center and one wheel track of each lane could be analyzed. Skid resistance tests were conducted on the road in 1958 and 1963. The lack of any significant differences of friction coefficient indicated the absence of any effect of asphalt source on this property. Visual observations have been made at periodic intervals. No serious deterioration has been observed in any of

the test sections other than fairly extensive reflective cracking. Some differences in coloration do appear between sections, but not to any degree that can be correlated with the core data obtained. Rut depth measurements were made in 1966. No correlations were found with core information or with the horizontal or vertical alignment. No correlation could be established regarding the relation of increase in rut depth to decrease in asphalt viscosity. Imprecision of rut depth measurements is thought to have contributed to the poor correlations. An extensive laboratory study was conducted to measure original properties of asphalts used as well as to monitor changes in these properties as measured by tests on recovered asphalts throughout the period of the project. The measurements included, among others, penetration, ductility, and Olienis spot test at 0, 3, 17, 29, 40, and 52 months after construction. Percent voids in cores of pavement surface coarse was also measured. Aging tests on original asphalts were performed using the Bureau of Public Roads thin film test, the Shattuck test and the Michigan Highway Department Recovery test. Extensive laboratory study was also undertaken to measure the Marshall stability and flow, voids content, percent voids filled with asphalt, and percent compaction of samples taken from each of the test sections. Cores were taken after different periods of service and the change in voids content and Marshall stability and flow were followed. For comparison purposes, a solvent separation was made on the six test road asphalts set aside during construction and asphalts recovered after 3 1/2 years in service. Quantitative analyses of asphaltenes, oily constituents, light resins, and heavy resins were carried out. In addition, the iodine number was determined for each asphalt. The voluminous data gathered from this project were an excellent source of valuable information that is available for further evaluation by others. Since there may have been variations in condition of the concrete pavement at the time of resurfacing as well as in the underlying base materials, it would be difficult to make any firm, significant conclusions regarding any differences in condition among the six test sections.

RECORD No.: 85.
AUTHOR : Puzinauskas, V. P.
TITLE : Evaluation of Properties of Asphalt Cements with Emphasis on Consistencies at Low Temperatures
JOURNAL : Asphalt Inst., College Park, Md. (report)
VOLUME No.: RR-67-3
PUBLISHER : Asphalt Institute
YEAR : 1967
PAGES : 57p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt cements, viscosity, low temperature, temperature susceptibility
ABSTRACT :

The testing program described in this report had several purposes. One was to develop suitable and significant tests to measure consistency of asphalt cements at temperatures encountered during pavement service. The second was to establish low-temperature limits in the proposed study specifications for asphalt cements, based on the developed test method. Finally, the verification of established viscosity limits at 140 and 275 F temperatures were considered as an additional aim of this testing program.

RECORD No.: 86.
AUTHOR : Mossbarger, Jr, W. A.; Deacon, J. A.
TITLE : Flow Behavior of Asphalt Cements
JOURNAL : Kentucky Dept. of Highways, Lexington. Div. of Research.
VOLUME No.: (Research rept.)
PUBLISHER : Kentucky Department of Highways
YEAR : 1967
PAGES : 152p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt cements, creep testing, viscometer, asphalt concrete mixtures, pavement design
ABSTRACT :

The Kentucky Department of Highways in cooperation with the Bureau of Public Roads is conducting a continuing investigation of the fundamental mechanical properties of flexible pavement materials. The ultimate objective of this investigation is to gain sufficient knowledge of the fundamental mechanical behavior of these materials to support the establishment of a responsive flexible pavement design procedure. The current report summarizes results of a second phase of the continuing investigation in which the preparatory efforts have been expended to encompass the creep testing of 13 asphalt cements in a second rotating coaxial cylinder viscometer. The 13 asphalt cements were selected to represent a variety of crude sources, penetration grades, and manufacturing processes.

RECORD No.: 87.
AUTHOR : Schweyer, H. E.; Busot, J. C.
TITLE : Research on Asphaltic Materials
JOURNAL : Florida Univ., Gainesville. Engineering and Industrial Experiment (Report)
VOLUME No.: (Annual rept.)
PUBLISHER : Florida University
YEAR : 1967
PAGES : 148p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt cements, rheological properties, complete flow, composition, viscometers, viscosity, geometry, oxidative hardening

ABSTRACT :

The report is a summary of work during FY 1967 of the subject study. As in previous annual summaries, organization is in three parts covering the three general study areas. Part A - Rheological Studies. Correlations are indicated between Newtonian flow response (viscosity) and molecular weight and between glass transition temperature and 'complex flow' and aromaticity and molecular weight distribution. The significance and degree of these correlations will be determined by regressional analysis. An evaluation was made of the Cone Plate Viscometer, Sliding Plate Viscometer and Instron Rheometer to determine the cause of instrument-related differences observed in viscosity results. Instrument geometry, temperature-gradients and type of flow path during shear appear to be among the factors contributing to viscosity differences found. Part B - Composition of Asphalts. Work in this area consisted mainly of efforts to improve fractionation procedures to permit processing of samples larger (10 grams) than previously used (6 grams), to improve solvent removal and to replace dimethyl formamide as an eluent, and characterization of fractions by Nuclear Magnetic Resonance techniques. Part C- Durability. A considerable amount of data are presented with respect to Thin Film Oven and Weather-o-meter tests. The data given essentially complete the durability tests planned.

RECORD No.: 88.
AUTHOR : Skok Jr, Eugene L.; Diethelm, Paul J.
TITLE : Application of AASHO Road Test Results to Design of Flexible Pavements in Minnesota
JOURNAL : Proceedings, Association of Asphalt Paving Technologists
VOLUME No.: 35
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1966
PAGES : 45p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt cements, asphalt concrete mixtures, pavement design, test road performance, penetration, ductility, softening point

ABSTRACT :

The paper is based on selected aspects of a continuing HPR study having the same title. The purpose of the study is to obtain data on existing pavements that will lead to the adaptation of AASHO Road Test concepts and equations for use in Minnesota. In 1963 and 1964 50 representative projects located throughout the state were selected for preliminary investigation. A 1200-foot long by one-lane wide test section was selected in each project for intensive study. The construction history of each project was studied and field inspections were made to obtain general information on the pavement design and condition, roadbed materials, drainage and topography. In the 1200-foot test sections, borings were made to check the uniformity of pavement structure thicknesses and roadbed materials. Initial PSI values were established either by estimation or by roughometer measurements obtained at the time of construction. Periodic roughometer measurements are being made to obtain PSI values for determining performance trends. Periodic plate bearing and Benkelman beam tests are being made to determine the strengths of the various pavement system components. Classification tests of all materials were made. Stabilometer and CBR tests were run on all roadbed materials and on some base and subbase materials. Asphalt was extracted and recovered from the asphalt concrete, and penetration, softening point and ductility tests were made on the recovered asphalt. Flexural beam, modified tension and repeated load tests are being made on the asphalt concrete. Traffic volume, classification and weight data were compiled and a procedure for determining trafficloadings in terms of equivalent daily 18-kip single-axle loads for each test section was developed.

RECORD No.: 89.
AUTHOR : Kamran Majidzadeh, and Herbert E. Schweyer
TITLE : Non-Newtonian Behavior of Asphalt Cements
JOURNAL : Proceedings, Association of Asphalt Paving Technologists
VOLUME No.: 34
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1965
PAGES : 20
ABSTRACTOR: HRB
KEYWORDS : Asphalt cement, non-Newtonian behavior, complex flow, thixotropy, viscosity, steric hardening, stress, shear rate

ABSTRACT :

The non-Newtonian behavior of asphalt cements is studied by application of microrheological and reaction kinetic principles. This investigation includes both theoretical and experimental evaluation of anomalous flow characteristics of asphalts through measurements of viscosity, complex flow, and thixotropy. The theories related to the effect of internal structure on the non-Newtonian behavior of asphalts is reviewed and the shear dependence of viscosity is discussed. The effect of the flow of macromolecular units as distinguished from the flow of a single molecule on the observed non-Newtonian behavior is emphasized. It is indicated that the degradation of these flow units is the controlling factor in the anomalous flow characteristics. The theoretical analysis of the structural changes occurring in the material as a result of application of shear stress is presented. The Newtonian and non-Newtonian behaviors which are related to these structural changes are studied by application of a reaction kinetic principle. The utilization of this principle yields an equilibrium constant for the reaction between the broken and unbroken portions of the internal structure. To confirm the above theories, experiments were conducted on various types of asphalt cements by utilization of a sliding plate microviscometer. The rheological data were collected at various temperatures ranging from 60 F to 122 F.

RECORD No.: 90.
AUTHOR : Williams, Frank M.; Grimmer, L. E.; McAdams, M. M.
TITLE : A Study of Ductility Characteristics of Bituminous Material
JOURNAL : Ohio State Highway Testing Lab., Columbus.(Report)
VOLUME No.: No. 0448
PUBLISHER : Ohio State Highway Department
YEAR : 1965
PAGES : 82p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt cements, ductility, tensile strength, penetration, viscosity, oxidative hardening, tension test
ABSTRACT :

The study is concerned with the ductility characteristics of paving asphalts, particularly as evaluated by a tensile strength test. Included was the development of a new test procedure, using a Thwing-Albert Tensile Tester, for determining tensile strength at different temperatures and rates of deformation. A total of 27 asphalt cements were examined both before and after the thin-film oven test. Test data were obtained for tensile strength, ductility, penetration, absolute viscosity and softening point. These data were examined by means of correlation coefficients, ratios, regression curves, and slopes of curves. The authors conclude that additional investigation is needed to determine the value of the tensile strength testing for asphalt cements. Recommendations for further improvement of the test are included. The authors also conclude that viscosity and tensile tests show more clearly the effects of thin-film hardening than does the penetration test. (BPR abstract)

RECORD No.: 91.
AUTHOR : Chambliss Jr, C. T.
TITLE : Effect of the Viscosity of Asphalts on the Properties of Bituminous Mixtures
JOURNAL : Florida State Road Dept. Div. of Materials, Research and Training.(Research Bulletin)
VOLUME No.: No. 94
PUBLISHER : Florida State Road Department
YEAR : 1965
PAGES : 56p.
ABSTRACTOR: NTIS
KEYWORDS : Asphalt cements, temperature susceptibility, viscosity, asphalt concrete mixtures, stability, oxidative hardening
ABSTRACT :

The first part of this report presents in graphical form the temperature-viscosity relationships of 85-100 penetration grade asphalts available to the State of Florida from 12 sources. These sources were sampled at two subsequent intervals and it was found that some variation existed in the viscosity of samples obtained from the same supplier over a period of time. The second part of the report deals with the effects of asphalt viscosity on the physical properties of laboratory specimens of bituminous concrete. The asphalt viscosity was varied by controlling the mixing and compaction temperatures over a range of 125-350F. Three 85-100 penetration grade asphalts, representing high, medium, and low viscosity, were incorporated in bituminous mixtures which were molded in accordance with Hubbard-Field and Marshall procedures and tested for stability, density, and percentage of air voids. The results showed that as the viscosity during mixing was decreased, there was a general increase in stability of the mixture, but there was no effect on density or voids. As the viscosity during compaction was decreased, there was a general increase in stability and density, and a corresponding decrease in voids. The hardening of one of the asphalts during mix preparation was studied by recovering the asphalt from Marshall specimens which were mixed from 270-350F, and compacted at 225F. There were significant increases in viscosities for all mixing temperatures but the higher temperatures caused no greater increase in viscosity than did the lower temperatures. (Author)

RECORD No.: 92.
AUTHOR : Hagstrom, Jon
TITLE : Further Studies of Mass Viscosity by a Modified Stress Relaxation Method
JOURNAL : Massachusetts Inst. of Tech., Cambridge. Dept. of Civil Engineering.
VOLUME No.: R65-51; 0316
PUBLISHER : MIT
YEAR : 1965
PAGES : 23p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt cements, viscosity, compaction, asphalt concrete mixtures, stress relaxation, creep, constant rate of strain, model, viscoelasticity
ABSTRACT :

The relationship between compaction behavior and asphalt viscosity in bituminous concrete is of interest. One way to explore this is to study asphalt viscosityinfluences on the mass viscosity-temperature characteristics of the mix. An experimental method for the latter was investigated. It uses a series of constant-rate-deformation-at-constant-load flow periods separated by intervals of stress relaxation. Results of such tests can be analyzed in terms of component contributions from the mix system, represented by a model containing an elastic spring, a dashpot and a plastic yield mechanism. Linear viscoelastic techniques do not appear suitable. The direction of future work is outlined. (Author)

RECORD No.: 93.
AUTHOR : E. M. Krokosky, and J. P. Chen
TITLE : Viscoelastic Analysis of the Marshall Test
JOURNAL : Proceedings, Association of Asphalt Paving Technologists
VOLUME No.: 33
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1964
PAGES : 406-436
ABSTRACTOR: HRB
KEYWORDS : Asphalt concrete mixtures, Marshall test, viscoelastic properties, stress relaxation, dynamic testing
ABSTRACT :

Materials which exhibit flow properties dependent on time and temperature have been described by different types of tests and parameters. These tests and parameters (e.g., stress-relaxation and shift factors) form a basis for a classical approach which is known as a viscoelastic or rheological analysis. Since most of the popular and better correlated tests presently employed in the design of mixes for pavement are not based on viscoelastic theory, or the rheological implications of these tests are hidden, a study was conducted into the rheological meaning of one such procedure, the Marshall test. Stress-relaxation tests were conducted with modified Marshall equipment and using the standard Marshall test. Correlations were made among (a) the stability/flow values of the Marshall test, (b) the stress-relaxation data on Marshall specimens, and (c) tests with triaxial size specimens (4" x 8"). Various shift factors were employed on the stress-relaxation data for different asphalt contents determining the rate of relaxation as a function of temperature. An attempt was made to predict the engineering modulus of the material from the stability/flow values of the Marshall test by means of a shape factor. The universal applicability of this specimen shape (or dimension) factor has yet to be determined for different aggregate gradations although it seems to be independent of asphalt content. Dynamic tests were also conducted to verify further the short time stress-relaxation modulus of the material and the relation of the dynamic modulus to low-temperature Marshall relaxation moduli.

RECORD No.: 94.
AUTHOR : Charles A. Pagen, and Bee Ku
TITLE : Effect of Asphalt Viscosity on Rheological Properties of Bituminous Concrete
JOURNAL : Highway Research Record
VOLUME No.: 34
PUBLISHER : Highway Research Board
YEAR : 1964
PAGES : 124-140
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, asphalt concrete mixture, rheological properties, viscosity, creep testing, viscoelastic models
ABSTRACT :

The mechanical properties of the asphaltic concrete layers and the rheological response of the asphalt component of these layers are factors which greatly influence the design and construction of multilayer flexible pavements. The goal of this research is to relate changes of asphalt viscosity to changes of the mechanical properties of asphaltic concrete mixtures. The data obtained can be used to evaluate: (a) limits of asphalt viscosity which will produce specified changes of rheological strength properties and material deformation, and (b) procedures to predict strength moduli and mixture strain based on asphalt viscosity over a range of loading times and temperatures. Constant-load compressive tests were performed on unconfined test cylinders prepared by a kneading compactor from five asphaltic concrete mixtures. Experimental loads and temperatures were varied over a wide range. Using a standard creep testing program, the instantaneous elastic, time-dependent elastic, and plastic deformation were recorded and analyzed. Cyclic repetition of loading and unloading was also studied. Viscosity of the asphalts was measured using a sliding plate microviscometer. Correlations between asphalt viscosity and rheological strength moduli of the bituminous mixes were developed. The application of the linear viscoelastic theory and the time-temperature superposition concept to define the mechanical properties of asphaltic concrete mixtures has been rigorously investigated. An equation of state to describe the load, deformation, time, and temperature-dependent behavior of asphalt concrete is presented. Two methods were employed to determine the equations of state: (a) curve-fitting procedures utilizing equations of the form of a generalized Voigt model, and (b) a Scatran computer program where the equations developed were in the form of sixth-degree polynomials. Strain-time curves were evaluated by the time-temperature superposition concept and by the equation of state. The agreement of the data verifies the ability of the linear viscoelastic theory to describe the response of asphaltic concrete and the application of the derived equations of state and the time-temperature superposition concept of these materials.

RECORD No.: 95.
AUTHOR : W. J. Halstead
TITLE : The Relation of Asphalt Ductility to Pavement Performance
JOURNAL : Proceedings, Association of Asphalt Paving Technologists
VOLUME No.: 32
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1963
PAGES : 247-270
ABSTRACTOR: PTI
KEYWORDS : Asphalts, ductility, penetration, performance composition
ABSTRACT :

This report emphasizes the advantages of considering the log ductility-penetration relationship of an asphalt in evaluating the effect of the asphalt characteristics on pavement performance. Available data analyzed on this basis indicate that asphalts from the same source have the same ductility for equal penetration, unless oxidation or other changes have occurred in the asphalt composition. Thus, the difference between ductility values compared at the same consistency for original and aged asphalts is a measure of the ductility destroyed or lost. This ductility decrease can also be considered a measure of the degree of change caused by oxidation or other alterations in composition. There is a critical log ductility-penetration curve below which low ductility would be a potential cause of poor service and above which ductility would not be a significant factor affecting pavement durability. Published and unpublished data from a number of important pavement projects were examined to determine the importance of the penetration-ductility relationship. Log ductility versus penetration of asphalts used in these projects was plotted and studied. Good general correlations between reported performance and the critical ductility-penetration curves were obtained. Requirements for minimum ductility at 77 F based on the critical curve of TFOT residue illustrated in this report may serve to eliminate potentially unsuitable materials. More research is needed to clearly define the significance of the ductility test with respect to pavement performance.

RECORD No.: 96.
AUTHOR : J. York Welborn, W. J. Halstead, and R. E. Olsen
TITLE : Relation of Absolute Viscosity of Asphalt Binders to Stability of Asphalt Mixtures
JOURNAL : Public Roads
VOLUME No.: 32, No. 6
PUBLISHER : Bureau of Public Works
YEAR : 1963
PAGES : 145-152
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, viscosity, temperature susceptibility, asphalt concrete mixtures, aggregate gradation
ABSTRACT :

This article presents the results of laboratory compressive strength test made to show the relationship of asphalt viscosity to the stability of pavement mixtures. A summary of the more important conclusions drawn by other authors in previously reported research is included in an Appendix. The results reported here illustrate the significant effect of the type and gradation of aggregate on compressive strengths of asphalt mixtures and the variation of strength that can occur at different temperatures for mixtures made with asphalts of the same penetration grade but with different viscosity-temperature susceptibilities. When comparisons were at the same temperature, mixtures of a particular asphalt and the crushed stone aggregate used in these studies had significantly higher strengths than mixtures of the same asphalt and the gravel aggregate, which in turn had higher strengths than the mixtures made with sand. Such differences in strengths of the crushed stone, gravel, and sand mixtures were indicated to be more significant at temperatures around 140 F than at lower temperatures. When comparisons of compressive strengths were made on the basis of equal absolute viscosities, the differences caused by the three types of aggregates were still significant, but the strength of mixtures made with the same type and grading of aggregate and the same percentage of asphalt were equal for equal viscosities regardless of the source and grade of the asphalt.

RECORD No.: 97.
AUTHOR : D. G. Williams, C. L. Garey, and G. A. Hemstock
TITLE : A New Instrument for High Shear Viscometry
JOURNAL : Transportation Society of Rheology
VOLUME No.: 9
PUBLISHER : Society of Rheology
YEAR : 1962
PAGES : 93
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, viscometer, coaxial cylinder, shear rate
ABSTRACT :

A high-shear viscometer capable of producing rheograms under conditions approaching those estimated to exist in coating equipment is described. The instrument is of a coaxial cylinder type with translational movement supplied by air pressure. The shear rate, measured by means of a magnet transducer, and the shear stress, measured by means of an electrostrictive transducer, are recorded with the aid of an oscilloscope. This instrument is capable of operation to shear rates of 1.2 x 10^5 1/sec at rates of change of rate of shear of 1.9 x 10^9 1/sec. Because of the short time of operation in obtaining a rheogram, there is no unnecessary working of the test fluid and only a minimum temperature rise. Rheograms of mineral oil, glycerin, and a paper coating color for shear rates up to 6.3 x 10^4 1/sec at rates of change of shear rate to 4.7 x 10^6 1/sec are discussed.

RECORD No.: 98.
AUTHOR : J. J. Heithaus
TITLE : Measurement of Asphalt Viscosity with a Vacuum Capillary Viscometer
JOURNAL : American Society of Testing and Materials, Special Technical Publication
VOLUME No.: 309
PUBLISHER : American Society of Testing and Materials
YEAR : 1961
PAGES : 63
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, capillary viscometer, viscosity, shear rate, non-Newtonian behavior

ABSTRACT :
This paper describes the use of a vacuum-operated capillary viscometer in measuring the viscosity of bituminous materials. The instrument discussed is adapted from one described in the literature. The range of the viscometer is from approximately 10 to 100,000 poises. Thus, it is well suited to measurements of the viscosities of asphalt cements at 140 F, cutback asphalts at 77 F, and fractions separated from asphalt over a considerable range of temperature. Since the shear rate can be varied, the instrument can be used satisfactorily for measurements on non-Newtonian materials. The within-laboratory coefficient of variation of measurements by the method described is about 1.91 percent of the mean value.

RECORD No.: 99.
AUTHOR : E. N. Thrower
TITLE : Technique for Measuring the Elastic Properties of Bitumens, Tars and Soils Under Dynamic Loading
JOURNAL : Journal of Scientific Instruments
VOLUME No.: 38
PUBLISHER :
YEAR : 1961
PAGES : 69
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, rheological properties, dynamic testing, complex shear modulus, complex uniaxial modulus
ABSTRACT :

A technique is described for the measurement of the components of the complex (dynamic) Young's modulus (E*) and the complex rigidity modulus (G*) of bitumens, tars and soils under sinusoidal loading. The equipment is capable of measuring the complex Young's modulus up to about /E*/=5 x 10^10 dyn/cm (10^6 lb/in) and the complex rigidity modulus up to /G*/=2 x 10^10 dyn/cm (3 x 10^5 lb/in) over the frequency range 5 to 500 c/s and at temperatures between -20 and +30 C. To measure the complex Young's modulus, an axial sinusoidally varying force is applied to a cylindrical specimen by a moving-coil vibrator. Piezoelectric gauges are used to convert the force applied to the specimen, and the displacement of its driven end, into voltages, which are measured on a phase-sensitive voltmeter. The complex modulus is derived from a comparison of these voltages with those obtained using a steel calibration spring. For the measurement of the complex rigidity modulus, the material is sheared in the annulus between two cylinders, the inner being driven by the vibrator. The same two gauges now serve to measure the force applied to the inner cylinder, its displacement and their relative phase.

RECORD No.: 100.
AUTHOR : P. R. Wood, H. C. Miller
TITLE : Rheology of Bitumens and the Parallel Plate Microviscometer
JOURNAL : Highway Research Board Bulletin
VOLUME No.: 270
PUBLISHER : National Academy of Science-National Research Council
YEAR : 1960
PAGES : 38-46
ABSTRACTOR: PTI
KEYWORDS : Asphalts, viscosity, film thickness, microviscometer, viscoelasticity, tensile strength, steady slate flow

ABSTRACT :

The viscoelastic behavior of bitumens varies with film thickness. Therefore, for correlation of laboratory testing with field performance in bituminous pavements, it is important to match the geometry of testing to the geometry of end use. The parallel plate microviscometer is well suited for this work, but the total displacement suggested by previous authors for most paving asphalts is too low. Rotating parallel plates have been used to extend the useful range of the microviscometer. It was introduced to the bituminous field in 1954 by Labout and Van Oort. Griffin et al. simplified the thin film preparation. The Naugatuck Chemical Division's work began before a commercial instrument was available, so the Division designed and built its own. The instrument is described as an example of an inexpensive unit which is both versatile and precise. The parallel plate microviscometer is an important contribution to the bituminous field and especially to the paving field, not only because it is a fundamental instrument, but because it is perhaps the only instrument in which thin films, duplicating the binder thickness in a pavement, can be studied. In bituminous concrete pavements, the film thickness of the asphalt binder is on the order of 5-10 microns. This is vastly different from the film thickness encountered in most instruments used for viscosity measurement. The previous authors have reported that the physical behavior of bitumens does not change with film thickness which would make the latter advantage of the microviscometer unimportant. However, the authors have found that viscoelastic behavior does change with film thickness, and therein lies the real advantage of the microviscometer. In addition, the authors have found that for most paving asphalts, the suggested displacement of 200 microns of the upper plate for each shearing stress is insufficient.

RECORD No.: 101.
AUTHOR : J. G. Brodnyan, F. H. Gaskins, W. Phillippoff, and E. Thelen
TITLE : The Rheology of Asphalt III. Dynamic Mechanical Properties of Asphalt
JOURNAL : Trans. Society of Rheology IV
VOLUME No.: 4
PUBLISHER : Society of Rheology
YEAR : 1960
PAGES : 279
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, rheological properties, testing techniques, dynamic testing superposition principles, softening point, molecular flow

ABSTRACT :

The dynamic mechanical properties of 10 asphalts, representing 3 major categories, have been determined using a variety of instruments. The validity of the time-temperature superposition principle was established by the agreement between data obtained at high frequencies and values predicted by superposition of low-frequency, low-temperature measurements. This made it possible to describe the properties of asphalts by three general curves: the dependence of G' and ' on the reduced frequency and the temperature dependence of a . These curves have been determined experimentally. The curves of the moduli versus reduced frequency cover approximately 23 decades of reduced frequency at 25 C. The temperature dependence was seen to be that given by the Williams-Landel-Ferry equation over a wide range of temperatures. The characteristic temperature, T , was found to be nearly equal to the ring and ball softening points of the asphalts. Other bitumens, such as coal, tar, and a filled asphalt, have the same general characteristics. A rearrangement of Rouse's theoretical equations as modified by Ferry made it possible to estimate the molecular weights of the flow units and these were seen to be quite large.

RECORD No.: 102.
AUTHOR : F. H. Gaskins, J. G. Brodnyan, W. Phillippoff, and E. Thelen
TITLE : The Rheology of Asphalt II. Flow Characteristics of Asphalt
JOURNAL : Transactions, Society of Rheology
VOLUME No.: 4
PUBLISHER : Society of Rheology
YEAR : 1960
PAGES : 265
ABSTRACTOR: Society of Rheology
KEYWORDS : Asphalt cements, rheological properties, steady-state, Newtonian, non-Newtonian, time, temperature, stress

ABSTRACT :

The rheological properties of 10 representative asphalts were investigated under conditions of steady-state shear and laminar flow. Two instruments were utilized: a coni-cylindrical (rotational) viscometer and a high-pressure capillary tube viscometer. The results of the investigation show that asphalts are viscoelastic bodies which exhibit both Newtonian and non-Newtonian flow behavior with no evidence of yield value, structural breakdown, or work-hardening. Thus, asphalts deliberately selected to represent extremes in structures and properties are similar to concentrated polymer solutions and molten polymers in their response to stress. The extreme variations noted in the rheological behaviors of asphalts can generally be accounted for by the parameters of time, temperature, and stress.

RECORD No.: 103.
AUTHOR : T. Holt
TITLE : The Stress Dependence of the Softening Temperatures of Bituminous Compounds
JOURNAL : J. Institute Petroleum
VOLUME No.: 46
PUBLISHER : Institute of Petroleum
YEAR : 1960
PAGES : 237
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, softening point, load level
ABSTRACT :

Data are presented showing that extremely misleading information regarding the softening temperature of a bituminous cpd can be obtained by using the ring and ball method of measurement. The Kramer-Sarnow method gives more reliable information, but it is recommended that the softening temperature over a range of loads be used in place of a single 5-g determination, for this too falls in the critical range. Should this be inconvenient, single load values determined at higher stresses will be more reliable than the ring and ball measurement.

RECORD No.: 104.
AUTHOR : K. Krenkler
TITLE : Studies on the Practical Value of the Ductility Test
JOURNAL : Bitumen, Teere, Asphalte, Peche
VOLUME No.: 11, No. 1
PUBLISHER : Bitumen, Terre, Asphalte, Peche, Isevnhagen, Germany
YEAR : 1960
PAGES : 3
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, ductility test, viscosity, composition
ABSTRACT :

Ductility differences among 61 bitumens were shown to depend mainly on the type of crude oil from which they were derived. Among the softer bitumens, the highest ductility was shown by those from highly asphaltic crudes. With increasing hardness, bitumens from moderately asphaltic crude exhibited higher ductility than those from highly asphaltic oils. Special high-resin bitumens and extraction residues showed the greatest ductility of all the soft grades. Samples from mixed-base and paraffinic crudes showed moderate and very low ductility, respectively. Ductility at 2 C showed virtually no correlation with plasticity or viscosity and only partial correlation with resin-asphaltene ratio.

RECORD No.: 105.
AUTHOR : Anon
TITLE : Error Sources in Determining the Softening Point of Bitumen by the Ring and Ball Method
JOURNAL : Bitumen, Terre, Asphalte, Peche
VOLUME No.: 10
PUBLISHER : Bitumen, Terre, Asphalte, Peche, Isevnhagen, Germany
YEAR : 1959
PAGES : 168
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, softening point, heating rate
ABSTRACT :

Effects of overheating in melting are discussed. The chief errors in the determination lie in sample preparation and irregular heating rate. Thermometer arrangement and bath preheating can give unimportant variations.

RECORD No.: 106.
AUTHOR : S. H. Kuhn, and P. J. Rigden
TITLE : Measurement of Viscosity of Very Small Samples of Bituminous Binders for Study of Weathering on Road
JOURNAL : Proceedings, Association of Asphalt Paving Technologists
VOLUME No.: 28
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1959
PAGES : 372-384
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, viscosity, ball viscometer, age hardening
ABSTRACT :

A method for measuring the viscosity of small samples (40-80 mg) of bituminous binders is described. It consists essentially of compressing a small sphere of the binder under a known load and measuring the deflection as a function of time. The instrument used in the work measures viscosities in range 10^7 - 10^12 poises. The ball viscometer has been used to follow increases in viscosity produced by weathering of binders on the road, and a method for the sampling of weathered binders from a surface treatment and for the preparation of the sample for viscosity measurement is described. The accuracy of this method has been shown to be sufficient for measuring the large changes in viscosity produced by weathering on the road. The results of tests on a full-scale surface treatment experiment are given as an illustration of the use of this method.

RECORD No.: 107.
AUTHOR : F. Hempel
TITLE : Structural Mechanics of Bitumen, Their Meaning in the Rheological Sense and From the Viewpoint of Conventional Testing Methods
JOURNAL : Bitumen, Teere, Asphalte, Peche
VOLUME No.: 10
PUBLISHER : Bitumen, Terre, Asphalte, Peche, Isevnhagen, Germany
YEAR : 1959
PAGES : 12
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, viscoelastic properties, dynamic testing, viscosity, complex flow, Fraass brittle point, temperature susceptibility, softening point
ABSTRACT :

Flow behavior of most variable bitumen types is investigated at widely different temperatures by investigating the velocity gradient in dependence on deformation forces. Evaluation of measured value is possible by a graphical presentation of linear temperature dependence of dynamic viscosity over a large range in the coordinate system log log n against log T by two measuring principles, namely, at constant shearing stress and at constant velocity gradient. Through the concept of "relative thermoplasticity," a definable limitation of the complex flow behavior (structural viscosity) of the bitumen qualities--very variable according to raw material origin and processing technique--is possible. The great importance due to structural viscosity in the practice of bitumen application emphasizes the observation of this rheological phenomenon, also from the perspective of conventional evaluation according to DIN 1995. A method is described for predicting--with the help of conventional testing methods, soft point K-S, drop point after Ubbelohde, and point of refraction after Fraass--the whole rheological behavior, including the degree of structural viscosity of a bitumen, with close approximation to the measured results by rheological abs methods. The outline of a double diagram makes possible graphical representation of relations between temperature-dependent viscosity according to two measuring principles, and temperature-dependent penetration of a bitumen, including test value for point of refraction after Fraass, soft point K-S, soft point R and B method, also for drop point after Ubbelohde.

RECORD No.: 108.
AUTHOR : E. N. Thrower
TITLE : The Rheological Properties of Bitumens and Tars
JOURNAL : Journal of Institute of Petroleum
VOLUME No.: 45
PUBLISHER : Institute of Petroleum
YEAR : 1959
PAGES : 80
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, tars, rheological properties, temperature susceptibility, brittle properties, shear strain
ABSTRACT :

A general discussion is given to tars and bitumens, stress applied to road surfaces, and the composition of bitumens and tars. Rheological properties are discussed separately for high and low temperatures. For bitumens of known penetration, the relation between log viscosity and log temperature (deg F) is nearly a straight line over a wide range. The viscosity of tars and bitumens in thin films such as are used on roads is apparently the same as in bulk. The elastic properties of tars and bitumens are discussed for low temperatures, and mathematical expressions are derived for shear strain, etc., and the effect of superposed stresses is discussed. Brittle properties of tars and bitumens are also discussed and discrepancies are pointed out.

RECORD No.: 109.
AUTHOR : S. Vajta, and L. Fajta
TITLE : Impact Bending Test for Bitumen with a Swinging Hammer Mechanism
JOURNAL : Bitumen, Teere, Asphalte, Peche
VOLUME No.: 10
PUBLISHER : Bitumen, Terre, Asphalte, Peche
YEAR : 1959
PAGES : 396
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, impact properties, testing technique
ABSTRACT :

A pendulum-hammer striking apparatus has been designed for impact bend testing of bitumen on samples 2.5 x 1.5 cm. This method is suitable for estimating the characterizing sp impact work (cm.kg/cm) for mechanical properties of the tested bitumen, or, in the case of similar normal test bodies, the impact work (cm/kg). The necessary apparatus for preparing test samples is illustrated, and testing technology is presented. The method is equally suitable for testing highly-elastic (e.g., rubber bitumen) and brittle (e.g., briquette bitumen). Testing data are tabulated.

RECORD No.: 110.
AUTHOR : Paul R. Wood
TITLE : Rheology of Asphalts and Its Relation to Behavior of Paving Mixtures
JOURNAL : Highway Research Board Bulletin
VOLUME No.: Bulletin 192
PUBLISHER : Highway Research Board
YEAR : 1958
PAGES : 20-25
ABSTRACTOR: PTI
KEYWORDS : Asphalt binders, film thickness, viscosity, rate of shear, asphalt concrete mixes, impact resistance, aging

ABSTRACT :

Pavement performance associated with binder properties can be best correlated with laboratory tests which are not only of a fundamental nature, but which also duplicate film thicknesses encountered in the pavement. This necessity of matching geometry of testing to geometry of end use results from changes in viscoelastic behavior with film thickness. The shell parallel plate microviscometer offers a simple laboratory means for studying these films. Tests carried out with this type of viscometer indicated that shear properties of bitumens are dependent upon film thickness.

The paper discusses the data collected and the merits of the geometry-matching approach. Two samples of Venezuelan asphalt obtained from the same supplier with identical penetration values (114 and 116), softening point (118 for both), and all other specification test data, were tested. These two asphalts are known to show marked differences when used in pavement sections. Testing the two asphalts in thick films using the usual type fundamental viscometers, such as capillary, rotational, and falling cylinder, indicated no differences in the relation between viscosity at 77 F and rate of shear in the range of .001 - 1 (1/sec). However, testing thin (10-micron-thick) films with the shell microviscometer indicated significant differences between the bitumens. The differences are attributed to differences in molecular composition. It is suggested that molecules at the surface of a wettable solid have a free surface and are exposed to a stronger field of forces than molecules in the interior. These forces are responsible for adhesion and the distance over which these forces acts varies for polar and nonpolar liquids. Therefore, film thickness will have a significant effect on flow properties measured. Results indicated that bitumens have what might be called an infinite thickness region, above which the viscosity becomes constant for a given rate of shear--in this particular case, above 0.04 cm thickness. An infinite thickness region is also encountered for bitumens under tensile stress. The magnitude of infinite thickness varies with the bitumen and is determined by molecular composition. An air-blown asphalt and a 5-percent rubberized asphalt were added to the testing program. Impact resistance of

typical aggregate-binder hot-mix samples made with the four asphalts was measured. Samples were rectangular blocks 1 1/2-in thick, 2-in wide, and 6-in long. The impact resistance was measured by number of drops of a 150-gm steel ball required to fracture the specimen at temperatures varying between 0 and 15 C. Also, the same blocks were used to measure the time required to sag 1/8 in when loaded on one end with a 2500-g load at 140 F. Results show significant differences in number of ball drops and time required to sag. Empirical and thick film fundamental tests on bitumens did not indicate differences in asphalts. To study change in impact strength after aging, aggregate-binder mixes were made and aged in an oven at 225 F. The mixes were aged in 1/2-in thick layers in trays and then molded into rectangular blocks for impact testing. The ability of the rubberized asphalt to maintain flexibility longer was clearly observed.

RECORD No.: 111.
AUTHOR : John G. Brodnyan
TITLE : Use of Rheological and Other Data in Asphalt Engineering Problems
JOURNAL : Highway Research Board Bulletin
VOLUME No.: 192
PUBLISHER : Highway Research Board
YEAR : 1958
PAGES : 1-19
ABSTRACTOR: PTI
KEYWORDS : Asphalts, rheological behavior, penetration, softening point, impact resistance
ABSTRACT :

A wide variety of asphalts have been investigated with respect to (a) rheological behavior under both static and dynamic load, (b) breaking properties, and (c) other properties such as water permeability, photochemical decomposition, etc. The rheological data are condensed to generalized curves of both the dynamic storage (G') and loss moduli (G") versus frequency, the temperature dependence of these curves, and the dependence of the initial viscosity on temperature. The asphalts investigated were divided into three families--Gel, Medium, and Sol--depending on the slope of the relation between log penetration at 77 F and softening point (100/400 + softening point). Generalized curves of G' and G" were obtained for each family using data collected by the Franklin Institute's vibration tester and Ferry's method of reduced variables. By the use of softening point and penetration, it is shown how, with the aid of the slated curves and empirical relationships, the whole rheological behavior of an asphalt may be determined. Several prototype examples of engineering problems are solved, demonstrating that asphalts, no less than metals, can be dealt with as engineering materials. A flow problem is solved with the aid of the curves of initial viscosity versus temperature. Use of the two rheological moduli in solving engineering problems is shown for the case of the attenuation of vibrations. Also the method of extending classical elastic theory to these viscoelastic materials is outlined, with the particular case of a bending beam given in detail. Finally, the problem of whether thermal changes will cause cracking of an asphalt is investigated. Impact resistance of the various asphalts was investigated with a Tinius Olsen Impact machine, and the results showed that the asphalts have very similar impact resistances. However, comparing two asphalts indicates that the one with the lower storage modulus and higher tang at the frequency of impact (100 to 1000 cycles per sec) is better.

RECORD No.: 112.
AUTHOR : G. M. Dorman, and A. W. Jarman
TITLE : Some Factors Influencing Behavior of Bitumen Road Surfacings
JOURNAL : Journal of Applied Chemistry
VOLUME No.: 8
PUBLISHER : Society of Chemical Industry, London
YEAR : 1958
PAGES : 823-838
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, stiffness modulus, pavement performance, cracking, durability, adhesion
ABSTRACT :

The concept of stiffness of bitumen (ratio of tensile stress to tensile strain) and methods for its determination are examined in this paper, with special reference to behavior of road surfacings under different conditions. The mechanism of cracking, deformation under load, fretting, and factors which may interfere with durability and adhesion are also studied.

RECORD No.: 113.
AUTHOR : John G. Brodnyan
TITLE : Use of Rheological and Other Data in Asphalt Engineering Problems
JOURNAL : Highway Research Board Bulletin
VOLUME No.: 192
PUBLISHER : Highway Research Board
YEAR : 1958
PAGES : 1-19
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, rheological properties, static testing, dynamic testing, breaking properties, permeability, age hardening, cracking, pavement performance

ABSTRACT :

The inservice performance of asphalts in various systems depends both on the influence to which the material is subjected and the intrinsic properties of the asphalt itself. A wide variety of asphalts has been investigated with respect to (a) their rheological behavior under both static and dynamic load, (b) their breaking properties, and (c) other properties such as water permeability, photochemical decomposition, etc. The rheological data are condensed to generalized curves of both the dynamic storage and loss moduli versus frequency, the temperature dependence of these curves, and the dependence of the initial viscosity on temperature. By the use of the softening point and penetration, it is shown how, with the aid of the stated curves and empirical relationships, to find the whole rheological behavior of an asphalt. Several prototype examples of engineering problems are solved, and are evidence that asphalts, no less than metals, can be dealt with as engineering materials. A flow problem is solved with the aid of the curves of initial viscosity versus temperature. Use of the two rheological moduli in solving engineering problems is shown for the case of the attenuation of vibrations. Also the method of extending classical elastic theory to these viscoelastic materials is outlined, with the particular case of a bending beam given in detail. Finally, the problem of whether thermal changes will cause cracking of an asphalt is investigated.

RECORD No.: 114.
AUTHOR : A. B. Brown, and J. W. Sparks
TITLE : Viscoelastic Properties of a Penetration Grade Paving Asphalt at Winter Temperature
JOURNAL : Proceedings, Association of Asphalt Paving Technologists
VOLUME No.: 27
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1958
PAGES : 35
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, viscoelastic properties, creep, creep recovery, stress relaxation, viscosity, elasticity
ABSTRACT :

A typical paving asphalt has been shown to conform at winter temperature conditions to the behavior of a linear viscoelastic material by creep, creep recovery, and stress relaxation tests. In this respect, it is similar rheologically to many of the synthetic elastomers and plastics. The range and magnitude of the discrete viscous and elastic moduli have been determined in creep and creep recovery; the same moduli can be used to predict the behavior of the asphalt in stress relaxation. Resolution of the stress-strain-time behavior pattern into separate components of elasticity and of viscosity has advantages in the study of asphalt behavior in practical structures.

RECORD No.: 115.
AUTHOR : J. Huet
TITLE : Introduction to the Study of Rheological Properties of Hydrocarbon Mixtures
JOURNAL : Centre de Recherches Routieres (Brussels), Rapport de Recherche
VOLUME No.: No. 57
PUBLISHER : Centre de Recherches Routieres (Brussels)
YEAR : 1958
PAGES : 97pp
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, asphalt concrete mixtures, viscoelastic properties, dilatancy, thixotropy, Weissenberg effect, rheological model, shear, tension, compression

ABSTRACT :

Rheology as the science of deformation and flow is today comparatively young, particularly in the field of materials with viscoelastic behavior. Both theoretically and experimentally, the phenomena under study are not only varied but also complex. This report is an introduction to the study of the rheological behavior of bituminous mixtures used in road construction. It deals with the establishment of some particular rheological properties of bitumens: dilatancy, thixotropy, and the Weissenberg effect. Some of the examined properties are not fundamentally specific to the bituminous materials and it is possible to consider them in the study of the mechanical behavior of clay and concrete. Chapter I shows the importance of the type of applied stresses and that a complete description of the rheological properties of a material requires the knowledge of the three types of deformation obtained in simple shear, tension, and compression. The fact that a liquid appears to be Newtonian in simple shear does not necessarily mean that it is also Newtonian in tension or compression. Chapter II deals with the volume variation, positive under tension and negative under compression, of materials such as bituminous mixtures and concrete which, after compaction, contain various amounts of voids. However, a volume increase under tension is not necessarily accompanied by a volume decrease under compression. This is because of the possible existence of dilatancy. Dilatancy is the volume increase accompanying simple shear, and a phenomenon that is associated to a cross-viscosity coefficient. Chapter III shows the advantage of the coni-cylindrical viscometer for measuring the viscoelastic characteristics of highly viscous liquids such as the fundamental flow properties of bituminous road binders. This form of rotating cylindrical viscometer gives consistency curves which are analytically similar to the mathematical functions of the rheological equations of state for the Newtonian liquid, the Bingham-body and the generalized Newtonian liquid. The influence of the thixotropic, dilatant, and elastic characteristics of the materials on the form of the consistency curves is also examined. The bituminous road binders may have such properties and in particular, the Weissenberg effect

is associated to finite elasticity phenomena. Chapter IV contains an examination of some experimental methods used for the study of the rheological properties of bitumens and gives a summary of the conclusions of the most important works published at the present time, in the field of bituminous materials.

RECORD No.: 116.
AUTHOR : J. Huet
TITLE : Contribution to an Experimental Study of the Rheological Properties of Bitumens
JOURNAL : Centre de Recherches Routieres (Brussels) Raport de Recherche
VOLUME No.: No. 55
PUBLISHER : Raport de Recherche Routieres (Brussels)
YEAR : 1958
PAGES : 112 pp
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, penetration, ductility, viscosity, simple shear, Weissenberg effect, time of loading
ABSTRACT :

The report deals with the establishment of the rheological properties of bitumens from the same or from different origins. The study is based on the following experimental determinations: penetration, softening point, coefficient of viscosity in simple shear, and Weissenberg effect. The experiment shows that for all bitumens, the relation of Saal and Labout (Saal and Labout: Physics, 7:408 (1936)) between the logarithm of the penetration and the logarithm of the time remains linear. It is shown that the penetrometer method greatly minimizes the elastic effects and a new relationship is found to exist between the logarithm of the penetration and the logarithm of the load of the needle. The fundamental flow properties of the bituminous road binders are examined with a viscosimeter of the rotating cylindrical type (the Hoppler microplastometer) over a range of temperatures from 20 to 60 deg C. It appears that bitumen flows under the smallest stress-difference and, rheologically, may therefore be considered as a viscous liquid, Newtonian or non-Newtonian. In most cases, the examined material is non-Newtonian: the consistency curve representing the rheological equation is a line with a continuous curvature. The curve can clearly be extrapolated towards the origin from which it evidently starts at a definite slope Vl; with increasing shearing stress, the viscosity is reduced and finally, the bitumen behaves as a simple Newtonian liquid with the constant viscosity f. The ratio Vl/Vf is a suitable means of characterizing the rheological behavior of the bitumen in simple shear. It has been shown that the value of a fundamental rheological property as the viscosity coefficient, is more characteristic of the mechanical behavior than the correlation with data from routine test methods as

RECORD No.: 117.
AUTHOR : G. M. Sreekantath, and C. A. Vergheese
TITLE : A Compensated Moving Cylinder Viscometer
JOURNAL : Journal of Scientific Instruments (England)
VOLUME No.: 35
PUBLISHER :
YEAR : 1958
PAGES : 160
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, viscometer, viscosity
ABSTRACT :

Based on the principle of Lawaczeck's falling cylinder viscometer, a new viscometer has been designed, in which the only measurement to be made is the time taken by the cylinder to move a definite distance, without the necessity of either observing the movement of the cylinder or measuring the densities of the cylinder and of the liquid. The instrument consists of two exactly similar light solid cylinders or cylindrical bulbs moving in similar vertical tubes of slightly larger diameters containing the liquid at the same temperature. The ends of each cylinder are made conical to ensure its coaxial movement in the tube, and the cylinders are attached to the ends of a nylon fiber which passes over a light frictionless pulley. Attached to the same fiber at suitable heights above the cylinders are two similar lightweight carriers on either of which riders of equal mass may be placed. When a certain number of riders are placed on one side, the cylinder on that side moves down while the other cylinder moves up with uniform speed, the pulley turning round once in a time T which is directly proportional to the viscosity of the liquid. This result may be used to compare the viscosities V1 and V2 of two liquids using the same number of riders and noting the times T1 and T2, respectively, for a complete rotation of the pulley, V1/V2 - T1/T1. The instrument is capable of high accuracy and has the special feature that a knowledge of the density of the liquid is not needed in the calculation of the result.

RECORD No.: 118.
AUTHOR : L. E. Wood, and W. H. Goetz
TITLE : The Relationship Between the Unconfined Compressive Strength of a Bituminous Mixture and the Viscosity of the Binder
JOURNAL : Proceedings, Association of Asphalt Paving Technologists
VOLUME No.: 27
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1958
PAGES : 563
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, asphalt concrete mixtures, viscosity, unconfined compressive strength, strain rate
ABSTRACT :

The sliding plate microviscometer was used to obtain the absolute viscosities of four different asphalts at 40, 100, and 140 F. Specimens of paving mixtures containing these asphalts were tested for unconfined compressive strength. Specimens were 2-in high and 4-in in diameter and were cured for two days at 75 +/- 5 F. Cured specimens were tested for failure at deformations of 0.2, 0.02 and 0.002-in per minute. All tests were repeated at 40, 100, and 140 F. No direct relationship was found between the unconfined compressive strength of sheet asphalt mixtures and the viscosity of the asphaltic binder used.

RECORD No.: 119.
AUTHOR : L. Hubrecht
TITLE : Sonic Tests of Hydrocarbon Mixtures for Road Surface
JOURNAL : Centre de Recherches Routieres (Brussels) Raport de Recherche
VOLUME No.: No. 59
PUBLISHER : Centre de Recherches Routieres
YEAR : 1958
PAGES : 99
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, asphalt concrete mixtures, dynamic testing, rheological properties

ABSTRACT :

A comprehensive report is given on the relation between dynamic modulus of elasticity E and other properties of various hydrocarbon mixtures used for road surfaces. E is measured by the characteristic frequency of resistance of a sample set in vibration. For a given aggregate and binder, the maximum value of E corresponds to a mixture of greatest d. As voids increase, E decreases. For cements and mortars with a low percentage of voids, the nature and grain size of sands and fillers do not have an important influence on E. With concrete, properties of the aggregate affect E, slag having a pronounced influence. Rheological properties of the binder impart changes to E, chiefly through relations between temperature and E.

RECORD No.: 120.
AUTHOR : N. V. Tyabin, and G. V. Vinogradov
TITLE : Application of the Approximation Method to Flow Calculations for Dispersion Systems
JOURNAL : Colloid
VOLUME No.: 19
PUBLISHER :
YEAR : 1957
PAGES : 505
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, viscosity, shear stress, shear strain, coaxial cylinder viscometer

ABSTRACT :

For a lubricating grease at 20 deg, the relation between shear stress and velocity gradient in D can be approximated by T = 79,000 + 5.2D (all in CGS units) with an error less than 5 percent. For an asphalt, the relation T = 1.25 x (10^11) D holds as long as is less than 11,000 and the relation T = 11,000 + 3.9 x (10^6) D if T is between 11,000 and 50,000. Equations are given for (a) the shearing (between two coaxial cylinders) of a material for which the function T = f (D) can be approximated by V equations of the type T = a + VD; and (b) the sliding down and incline of a material whose behavior is approximated by two equations each, of the type T = VD and T = a + VD.

RECORD No.: 121.
AUTHOR : A. B. Brown, J. W. Sparks, and F. M. Smith
TITLE : Viscoelastic Properties of a High-Consistency Asphalt
JOURNAL : Journal of Colloid Science
VOLUME No.: 12
PUBLISHER :
YEAR : 1957
PAGES : 283
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, rheological properties, linear viscoelasticity, creep, creep recovery, stress relaxation

ABSTRACT :

High-consistency asphalts behave, rheologically, in the complex viscoelastic pattern common to many macromolecular species such as synthetic plastics and elastomers. A correlation with accepted linear viscoelastic theory has been developed for the behavior pattern, under tensile test conditions, of a typical hard asphalt in creep, creep recovery, and stress relaxation. The same simple viscous and elastic moduli are found to determine these several action modes. The range and magnitude of discrete moduli have been determined from the empirical creep time and creep recovery time relations. Calculated values of stress relaxation, based on these moduli derived from creep and creep recovery, compared favorably with results from direct experimentation.

RECORD No.: 122.
AUTHOR : H. Eisenberg
TITLE : Rotation Viscometer Directly Measuring the Ratio of the Shearing Stress to the Rate of Shear
JOURNAL : Review of Scientific Instruments
VOLUME No.: 28
PUBLISHER :
YEAR : 1957
PAGES : 927
ABSTRACTOR: HRB
KEYWORDS : Testing techniques, viscometer, non-Newtonian behavior, rate of shear
ABSTRACT :

A rotation viscometer directly measuring the ratio of the shearing stress to the rate of shear, is described in detail. The reading for Newtonian liquids is independent of the speed of rotation, and for non-Newtonian liquids, it gives a direct indication of the dependence of the apparent viscosity on the rate of shear. The principle of the measurement is as follows. With a slit proportional in width to the shearing stress, rotates together with the rotating cylinder of the viscometer; a narrow beam of light passes through the slit and falls on a photo-electric cell. The time of illumination of the photo-electric cell is proportional to the viscosity. The instrument may be used over a wide range of viscosities and rates of shear.

RECORD No.: 123.
AUTHOR : E. J. Barth
TITLE : Asphalt
JOURNAL : Petroleum Engineering
VOLUME No.: 29
PUBLISHER :
YEAR : 1957
PAGES : C13-18
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, pavement performance, rheological properties, age hardening, specifications
ABSTRACT :

This paper discusses the various causes of pavement failure, determination of the rheological properties of asphalt, the use of rheological diagrams, behavior of asphalts in cold, age hardening, elasticity, temperature susceptibility, and deformability of asphalt. New specifications for paving asphalts are recommended.

RECORD No.: 124.
AUTHOR : R. L. Griffin, T. K. Miles, C. J. Penther, and W. C. Simpson
TITLE : Sliding Plate Microviscometer for Rapid Measurement of Asphalt Viscosity in Absolute Units
JOURNAL : American Society for Testing and Materials, Special Technical Publication
VOLUME No.: 212
PUBLISHER : American Society for Testing and Materials
YEAR : 1956
PAGES : 36
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, sliding plate microviscometer, viscosity, temperature susceptibility

ABSTRACT :

A sliding plate microviscometer for determining the viscosity of asphalt in absolute units is described. The instrument utilizes the same constant temperature water baths normally found in control and materials testing laboratories. It is sufficiently accurate and simple to permit bringing the measurement of viscosity in fundamental units into the control laboratory and eventually into asphalt specifications. The sliding plate microviscometer is suitable for routine measurement of viscosity-temperature relationships and viscosity-shear rate dependence. It is compact, rugged, and simple to operate and has a working range of 100 to 100 billion poises. This range permits overlapping with a capillary viscometer in the low viscosity region and allows measurement of the viscosity of the hardest paving grade asphalt at 32 F. Methods for expressing the viscosity-temperature relationship of asphalt are reviewed. Two equations which give straight-line relationships between asphalt viscosity and temperature are discussed. Data obtained with the microviscometer are presented to illustrate these relationships.

RECORD No.: 125.
AUTHOR : J. W. A. Labout, and W. P. Van Oort
TITLE : Micromethod for Determining Viscosity of High Molecular Materials
JOURNAL : Analytical Chemistry
VOLUME No.: 28
PUBLISHER : American Chemical Society, Washington, DC
YEAR : 1956
PAGES : 1147
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, sliding plate microviscometer, viscosity
ABSTRACT :

In studying the durability of bitumens by exposing thin bitumen films to the atmosphere, viscosity determinations on minute quantities of material are necessary. For that purpose a microviscometer has been developed which requires only 12 to 30 mg of bitumen. The method is based on simple shear of the substance between two parallel plates and can be used for the determination of the viscosity of thermoplastic materials in the range of 10^4 to 10^9 poises, with an accuracy within 5 percent. The microviscometer is suitable for investigations in which it is essential to work with small quantities of material, and it is a valuable aid in the analysis of bitumens recovered from bituminous construction, such as road carpets. The method may also offer advantages in the study of fractionating processes, as viscosity measurements may be made on small fractions.

RECORD No.: 126.
AUTHOR : Saal, R. N. J.
TITLE : Mechanical Testing of Asphaltic Bitumen
JOURNAL : Fourth World Petroleum Congress, Proceedings
VOLUME No.: Section VI
PUBLISHER : World Petroleum Congresses, London
YEAR : 1955
PAGES : 29
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, rheological properties, fracture properties, stiffness, penetration.

ABSTRACT :

This paper discusses the relation between a number of conventional mechanical tests for asphaltic bitumen and its mechanical properties. To develop a quantitative mechanical formulation for any particular application of bitumen, it is necessary to consider two basic properties of this material: its rheological behavior and its tendency to fracture. Rheology is described in terms of a generalized modulus of elasticity (stiffness); fracture is described in terms of breaking strength. Both are presented in their relationship to the hardness and type of the bitumen, and to temperature and time. Next, current routine tests, including penetration, softening point, ring and ball, flow tests, Fraass breaking temperature, shatter tests, and ductility are analyzed in terms of these properties. It is shown how data obtained with these routine tests may be translated into terms of stiffness and breaking strength. The conclusion is that the first four tests are valuable in their relationship to these fundamental properties, but that the value of the ductility tests is very limited and that shatter tests still need further clarification.

RECORD No.: 127.
AUTHOR : P. D. Garn, and W. E. Campbell
TITLE : A Ball and Cup Absolute Microviscometer
JOURNAL : Analytical Chemistry
VOLUME No.: 26
PUBLISHER : American Chemical Society, Washington, DC
YEAR : 1954
PAGES : 1609
ABSTRACTOR: HRB
KEYWORDS : Oils, viscometer, ball and cup viscometer, viscosity
ABSTRACT :

The need for a convenient method of determining the viscosity of oils from bearing greases, or from other sources where only a small sample is obtainable, led to the study of the ball and cup viscometer. This viscometer was originally designed to test lubricants in the shop. The results show that the ball and cup viscometer is capable of reasonable accuracy and precision when used with either an inversion or a balance technique. The drop or pull-up time is proportional to the absolute viscosity. The sample may be as little as 0.035 ml. This viscometer permits quick and convenient determination of viscosity using a very small sample and permitting complete recovery of the sample. The standard deviation of a set of data is generally less than 2%.

RECORD No.: 128.
AUTHOR : C. Van der Poel
TITLE : A General System Describing the Visco-Elastic Properties of Bitumens and Its Relation to Routine Test Data
JOURNAL : Journal of Applied Chemistry
VOLUME No.: 4
PUBLISHER : Society of Chemical Industry, London
YEAR : 1954
PAGES : 221
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, stiffness modulus, stress, time, temperature, penetration, softening point, penetration index, Fraass breaking point

ABSTRACT :

After dynamic and static experiments on the mechanical behavior of bitumens, an attempt was made to incorporate all the essential factors into a simple system. This was found to be possible in the form of a nomograph, by means of which the deformation of bitumens can be calculated as a function of stress, time, and temperature. Origin or method of manufacture proved to be of less importance than hardness and rheological type. For correlation with standard test methods, the ring-and-ball temperature and the penetration index were found to be suitable parameters. The nomograph enables the average behavior of a given grade to be calculated with an accuracy sufficient for engineering purposes. Another feature of the nomograph is that it makes possible the interpretation of other routine tests. By way of example, both penetration and the Fraass breaking point test are discussed.

RECORD No.: 129.
AUTHOR : S. L. Neppe
TITLE : Classification of Bitumens in Asphalt Technology by Certain Rheological Properties. Part I--The Use of Viscosity and Consistency Tests in the Classification of Asphaltic Bitumens: A Critical Survey of Existing Knowledge
JOURNAL : Journal of Institute of Petroleum
VOLUME No.: 38
PUBLISHER : Institute of Petroleum
YEAR : 1952
PAGES : 109
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, viscosity, temperature susceptibility, penetration, penetration index, ductility, softening point

ABSTRACT :

The paper presents a discussion of bitumen consistency tests, measurement of bitumen viscosity, and graphical representation of the relation between viscosity and temperature. It examines the ring-and-ball softening point and its relation to viscosity, the penetration test and the relation between penetration and temperature, ductility test and certain aspects of ductility, the relation of ductility to penetration and softening point and the penetrometer method for the measurement of flow properties. A new conception of true comparative utility values of various temperature-susceptibility factors and penetration indices.

RECORD No.: 130.
AUTHOR : S. L. Neppe
TITLE : Classification of Bitumens in Asphalt Technology by Certain Rheological Properties. Part II--The Conception and Derivation of Viscosity Number and Other Related New Indices
JOURNAL : Journal of Institute of Petroleum
VOLUME No.: 38
PUBLISHER : Institute of Petroleum
YEAR : 1952
PAGES : 257
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, viscosity, penetration, temperature susceptibility, softening point
ABSTRACT :
This paper strongly advocates the general adoption in bitumen investigations of a modified form of trough viscometer to give identical readings to the BRTA orifice instrument in a more rapid and convenient manner. As a sequel to exhaustive experimentation with a very wide range of bitumens specially produced in the laboratory by diverse processes from a large variety of petroleum crude oils, the author has made a graphical study of the interrelationships between various rheological characteristics of asphaltic bitumens. Conclusive evidence is provided that the dimensions and shape of the penetrometer needle are responsible for certain breaks in the curves relating penetration with other properties. These breaks occur at 54 pen in accordance with the writer's conception of "true penetration" outlined in Part I of this work. Consequent upon a number of striking observations made from a critical examination of the graphs, the author has developed three new classification methods in which identical index values have been assigned to each class of perfectly normal bitumens irrespective of the system used. These are: (1) viscosity number--relating viscosity at any one of three temperatures with bitumen penetration at 77 F; (2) softening point number-- relating softening point and penetration; and (3) softening point viscosity number--relating viscosity with softening point. The higher the viscosity number (or related index) for a given penetration of bitumen, the lower is the susceptibility to temperature change. The rationality of the viscosity number chart is clearly demonstrated by the fact that a true linear relationship exists for all values of log log viscosity plotted against log absolute temperature. Moreover, in a single chart coordinating viscosity number and softening point number data, the author shows that for a given series of perfectly normal bitumens of fixed viscosity number, all the softening points lie in one and the same straight line. The theoretical viscosities at softening point temperatures noted from this diagram and ranging from 6,000 to 40,000 poises agree very well with previously recorded figures. Equations are presented for different classes of bitumen relating viscosities in poises with softening points.

RECORD No.: 131.
AUTHOR : S. L. Neppe
TITLE : Classification of Bitumens in Asphalt Technology by Certain Rheological Properties. Part III--The Practical Value of Viscosity Number and Related Indices as Compared with Other Established Methods of Bitumen Characterization
JOURNAL : Journal of Institute of Petroleum
VOLUME No.: 38
PUBLISHER : Institute of Petroleum
YEAR : 1952
PAGES : 344
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, penetration index, viscosity number, softening point
ABSTRACT :

The criteria of a satisfactory bitumen penetration index are defined, and graphical methods based on the author's own experimental work are used to demonstrate conclusively that the indices of Pfeiffer and van Doormaal and of Holmes, Collins, and Child are basically unsound. The trends of such curves are most confusing, and contradictory conclusions may be derived from the same analytical data. According to these methods one class of bitumen may appear to be superior to another when compared for certain penetration values, while the reverse may apply for other degrees of hardness. On the other hand, viscosity number, softening point number, and softening point--viscosity number--as developed by the author in a previous publication--are shown to be fundamentally more rational in character, so that reliable conclusions may be drawn. The practical utility of these new methods of bitumen classification and their value in indicating abnormal rheological behavior are pointed out.

RECORD No.: 132.
AUTHOR : E. C. Hughes and R. B. Faris, Jr.
TITLE : Low Temperature Maximum Deformability of Asphalts
JOURNAL : Proceedings, Association of Asphalt Paving Technologists
VOLUME No.: 19
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1950
PAGES : 329
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, asphalt concrete mixtures, penetration, temperature susceptibility, mixture properties
ABSTRACT :

Asphalts and asphaltic mixtures were subjected to a high rate of deformation in a specially constructed apparatus. Some differences were found in the asphalts, but none in the paving mixtures. No distinction was found for mixtures made from 20 to 210 penetration asphalt. The effect of temperature was much less than would have been predicted by its effect on related physical properties. Studies also were made at rates 100,000 times slower than were used originally. Under these conditions failures vary with penetration of the asphalt. Data distinguished between asphalts from different sources. There is a general relationship to the temperature susceptibility of the asphalts.

RECORD No.: 133.
AUTHOR : M. Reiner, P. J. Rigden, and E. N. Thrower
TITLE : The Volume Flow of Asphalt
JOURNAL : Journal of Society of Chemical Industry
VOLUME No.: 69
PUBLISHER : Society of Chemical Industry, London
YEAR : 1950
PAGES : 257
ABSTRACTOR: HRB
KEYWORDS : Asphalt cement, volume change, elastic response, viscous response, Poisson ratio

ABSTRACT :

The paper presents a mathematical approach to the dimensional changes and progressive volume increase recorded on an artificially prepared "asphalt" subjected to a traction (i.e., tension) of 100 psi. In extension (the case here under review), dilatancy caused by the tractional shear forces plus Reiner's volume (or isotropic) flow act in the same direction to yield a volume increase. In compression these effects act in opposite directions, so that volume changes may be in either direction according to the predominating effect. Details of the apparatus are given together with a set of results. These are analyzed on the theory that both the shear and volume flow have elastic (recoverable) and viscous (permanent) components in parallel. These components are calculated, and the corresponding deformation and viscous Poisson ratios (i.e., lateral change: longitudinal change) are calculated.

RECORD No.: 134.
AUTHOR : H. Eilers
TITLE : Colloidal Structure of Asphalt
JOURNAL : Journal of Physics and Colloid Chemistry
VOLUME No.: 53
PUBLISHER :
YEAR : 1949
PAGES : 1195
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, composition, colloidal structure, rheological properties, sol, gel, peptization, steric hardening

ABSTRACT :

A survey is made of the interrelation between the composition and the colloidal structure of asphalts. Asphalts are classified into three rheological-colloidal types. 1. Asphalts with purely viscous flow. That is, in which the rate of shear at constant stress is independent of time, the deformation per unit of time is proportional to the shearing stress, and there is no elastic recovery. These are either homogeneous, asphaltene-free substances, or they contain well-peptized asphaltenes of low voluminosity and consequently poor deformability. 2. Sol-type asphalts in which viscous flow is accompanied by an elastic effect. This manifests itself under constant shearing stress in an initially decreasing rate of deformation and, after the stress has been removed, in a partial elastic recovery. These asphalts contain free miscelles which at room temperature consist of asphaltenes and the most polar components of the maltenes. 3. Gel-type asphalts. The elastic recovery after slight deformations under a small stress is almost complete. When the shearing stress exceeds a certain value (the yield value), the recovery becomes incomplete. The rate of deformation under constant stress may increase with time, but after removal of the stress the original value of the resistance to shear is gradually recovered. These gel-type asphalts contain an insufficient amount of the absorbable maltene components to peptize completely the high percentage of asphaltenes, so that the miscelles coagulate and build up a continuous gel structure in the material. On heating, this skeleton and even the miscelles disintegrate, and its reconstruction on cooling is only slow, causing a definite age hardening.

RECORD No.: 135.
AUTHOR : J. W. Romberg and R. N. Traxler
TITLE : Rheology of Asphalt
JOURNAL : Journal of Colloid Science
VOLUME No.: 2
PUBLISHER :
YEAR : 1947
PAGES : 33
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, apparent viscosity, constant power input, complex flow, stress relaxation
ABSTRACT :

The viscosities of asphalts, measured in a rotary viscometer, can be compared at a rate of shear of 0.1 sec, but in certain cases convergence of stress/shear(F/S^c) curves may lower or affect a reversal of the true viscosities; the same objections apply to viscosity measurements at constant shearing stress, as in the falling coaxial cylinder viscometer. By comparing viscosities at constant power input per unit volume of sample, FS^c, these ambiguities can be avoided, and in the experiments described FS = 1,000 has been chosen. The superiority of this method over others is illustrated. Complex flow may be evaluated by the expression M = F/S^c, where c is the slope of the log F/log S plot and M is the value of F when S = 1. When c = 1 the equation reduces to the simple viscosity relationship. The elasticity of asphalt, which deforms continuously under stress, can be measured by: (1) Subjecting the sample to alternating stresses the frequency of which is high compared with the relaxation time; (2) Comparing heat losses during viscous flow, measured by the damping effect on a torsional vibration, with the total energy input: (3) Application of Maxwell's equation for deformation of materials F = GDexp (-t/T), where G is the modulus of elasticity in shear, D is the strain in shear in time t, and T is the relaxation time; (4) Measurement of relaxation by following the decrease in shearing stress after shearing is stopped. It is found that (3) is useless for asphalts, for T is a function of temperature, F, and the sample size. If the time for F to decrease to half its original value (relaxation one-half time) is evaluated at values of FS = 1,000, the elastic effects of different asphalts can be compared. Nutting's law of deformation is examined for asphalt, and the physical significance of the constants is indicated. It is shown that Nutting's equation cannot hold for all deformations, and if it is simplified, holding F constant, the errors involved are still of the same order as in the original equation indicating that inaccuracies lie mainly in the shear-time relation.

RECORD No.: 136.
AUTHOR : R. N. Traxler
TITLE : Review of the Rheology of Bituminous Materials
JOURNAL : Journal of Colloid Science
VOLUME No.: 2
PUBLISHER :
YEAR : 1947
PAGES : 49
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, viscosity, degree of complex flow, steric hardening, temperature susceptibility, thixotropy, fillers, penetration, ductility, softening point
ABSTRACT :

The flow of bitumen is discussed in relation to the following factors: measurements of viscosity, simple and complex flow, age hardening, temperature susceptibility, thixotropy, elasticity, filled asphalts, and rheological aspects of (a) penetration test, (b) ductility test, and (c) ring-and-ball softening point. Viscosities should be measured in a rotating coaxial cylinder viscometer and the results expressed as a rheology diagram (see Abstract No. 1092, J. Coll. Sci., 1947, 33). The penetration test is criticized in that the magnitude of necessary corrections exceeds the true value of the consistency, and the adhesiveness of asphalt to steel, for which no correction is possible, is also measured. The ring-and-ball softening point measures consistency, density, thermal conductivity, and heat capacity, all of which vary with temperature. The ductility test likewise depends on factors other than consistency and hence is of little value. The paper ends with a discussion on the colloidal aspects of asphalts in relation to their rheological properties. A comprehensive list of references is given.

RECORD No.: 137.
AUTHOR : Traxler, R. N., Schweyer, H. E., and Romberg, H. W.
TITLE : Rheological Properties of Asphalt
JOURNAL : Industrial and Engineering Chemistry
VOLUME No.: 36, No. 9
PUBLISHER : American Chemical Society, Easton, PA
YEAR : 1944
PAGES : 823
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, viscometers, viscosity, shear rate, complex flow, steric hardening, empirical tests.

ABSTRACT :

The flow characteristics of 27 asphalts obtained from different sources and processed by various methods are evaluated in rotary viscometers of a type suitable for the measurement of high consistencies at a constant rate of shear. Consistencies of each asphalt at fixed temperatures were determined at two or more mean rates of shear. If an asphalt is a complex liquid, the measured consistency decreases as the rate of shear is increased. The magnitude or degree of complex flow may be evaluated by c in the equation $M = F/S^c$; c is unity for asphalts that are simple (Newtonian) liquids but varies from unity for those that are complex liquids. This equation is valid over a considerable range in rate of shear and is not limited to one type or size of viscometer. Data are given which show that certain asphalts are simple liquids at service (atmospheric) temperatures, while others have the characteristic of complex liquids. Evidence is given that the type of flow (and, if complete, the degree) depends on the source of the asphalt, the method and degree of processing, the age of the sample, and the temperature at which the evaluation is made. It is shown that some asphalts retain their complex flow characteristic at temperatures as high as their ring-and-ball softening point. The relations between the fundamental rheological characteristics of asphalts and the empirical tests commonly used by bituminous technologists are also illustrated.

RECORD No.: 138.
AUTHOR : Mack, Charles
TITLE : Rheology of Bituminous Mixtures Relative to the Properties of Asphalts
JOURNAL : Proceedings, Association of Asphalt Paving Technologists
VOLUME No.: 13
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1942
PAGES : 194
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, viscosity, penetration, softening point, colloidal structure, age hardening.
ABSTRACT :

Specifications for paving asphalts usually include tests which measure viscosity by some relative means such as penetration, softening point, or ductility. It was found by experience that these tests are not useful for the correlation of the properties of asphalt with their behavior on the road, the main reason being that the flow properties of asphalts as caused by their colloidal structure are not taken into consideration. The influence of the flow properties of asphalts and their change during aging as factors influencing the mechanical properties of bituminous pavements is unknown, and forms the basis of the work presented in this paper. The guiding principle in devising the test methods for this investigation was simplicity, so that they can be carried out with the equipment available in most laboratories.

RECORD No.: 139.
AUTHOR : Traxler, R. N., Romberg, J. W., and Schweyer, H. E.
TITLE : Rotary Viscometer for Determination of High Consistencies
JOURNAL : Industrial and Engineering Chemistry, Analytical Edition
VOLUME No.: 14, No. 4
PUBLISHER : American Chemical Society, Easton, PA
YEAR : 1942
PAGES : 340
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, rotating cylinder viscometer, viscosity, shear rate, complex flow, elastic properties.
ABSTRACT :

The design, construction, and operation of a new rotating cylinder viscometer are discussed. Its application to rheological studies is illustrated by results for asphalts over a range of 0.0001 to 1,000 megapoises. Novel features of the instrument comprise corrections for both top and bottom end effects and a special design whereby the viscosity is measured at a constant mean rate of shear. The apparatus is particularly adaptable for measurements of equilibrium consistency, studies of complex flow, and determination of the elastic properties of materials with relatively high viscosities.

RECORD No.: 140.
AUTHOR : A. P. Anderson and K. A. Wright
TITLE : Permeability and Absorption Properties of Bituminous Coatings
JOURNAL : Industrial and Engineering Chemistry
VOLUME No.: 33
PUBLISHER : American Chemical Society, Easton, PA
YEAR : 1941
PAGES : 991-995
ABSTRACTOR: PTI
KEYWORDS : Asphalt, permeability, oxygen, water, filler diffusion, ions
ABSTRACT :

The permeability properties of bituminous coatings for the usual corrosive agents have been studied. Water and oxygen slowly permeate the coatings by molecular diffusion, but their concentrations remain so low as not to cause corrosion. Electrolytes are effectively excluded by macroscopically intact coatings. Practical tests show that pipelines may be adequately protected from the action of corrosive soils by bituminous coatings that have been formulated correctly for the desired physical properties and have been properly applied.

RECORD No.: 141.
AUTHOR : G. W. Scott Blair
TITLE : Measurement of the Rheological Properties of Some Industrial Materials
JOURNAL : Journal of Scientific Instruments
VOLUME No.: 17
PUBLISHER :
YEAR : 1940
PAGES : 169-177
ABSTRACTOR: HRB
KEYWORDS : Rheological properties, testing techniques, asphalt cements, tars
ABSTRACT :

The eight factors listed as important in a preliminary survey of the rheological properties of a new material are: viscosity, elastic modulus, elastic after-effect, rate of shear or stress, the change of slope of the viscosity-stress curve, the amount of breakdown under shear which is only recovered slowly or not recovered at all, work or strain hardening, and tensile strength. Numerous techniques are listed for testing a given material by rheological methods, and a table is constructed in which the rheological properties of a number of materials are evaluated (table includes asphalts, tars and bitumens, road surfacing materials).

RECORD No.: 142.
AUTHOR : T. F. Ford, and K. G. Arabian
TITLE : The Measurement of the Deformation Properties of Asphalts
JOURNAL : Proceedings, American Society for Testing and Materials
VOLUME No.: 40
PUBLISHER : American Society for Testing and Materials
YEAR : 1940
PAGES : 1174
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, penetration, viscosity, viscometer, elasticity
ABSTRACT :

The characterization of the deformation behavior of asphalts by the penetration test or by other empirical tests is recognized as being inadequate, particularly for asphalts which are elastic as well as viscous. The rotating cylinder type of viscometer permits the separation of elastic and viscous effects, since it permits the observation of changes in deformation rate with deformation itself. Rotating cylinder viscometer, however, are usually considered too time consuming for the results obtained. Here a simple instrument of this type is reported, which is designed for routine use. Results obtained using this instrument compare favorably with results obtained using a more elaborate coni-cylindrical viscometer. Since a single deformation constant such as viscosity does not completely describe the flow of plastic asphalts, three deformation constants are evaluated: a coefficient of viscosity, a coefficient of elasticity in shear, and a coefficient of internal slip.

RECORD No.: 143.
AUTHOR : A. R. Lee, J. B. Warren, and D. B. Waters
TITLE : The Flow Properties of Bituminous Materials
JOURNAL : Journal of Institute of Petroleum
VOLUME No.: 26
PUBLISHER : Institute of Petroleum
YEAR : 1940
PAGES : 101
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, asphalt concrete mixtures, viscosity, tensile properties, aggregate gradation
ABSTRACT :

Some results are given from investigations now in progress on the fundamental flow properties of bitumens and bitumen-aggregate mixtures. A coni-cylindrical viscometer has been used for measuring the effect of stress and temperature on the viscosity and elastic recovery of various types of bitumens. The relation between rate of shear (D) and shearing stress (S) for all but the most plastic bitumens may be represented by an equation of the form $D = (1/V)S^p$, where V and p are constants. The use of the index p as a "plastic-flow index" provides a method of expressing the degree of plasticity of a bitumen, where this is considered as the divergence from ideal viscous flow. Different bitumens with the same penetration (65) may have very different viscosities. The bitumens so far investigated have been found to differ chiefly in their plastic and elastic properties. The effect of stress and temperature on the flow properties of roller-compacted specimens of bitumen-aggregate mixtures has been investigated by beam and tensile tests. The relation between stress (S) and minimum rate of strain (R) may be expressed by the equation $R = KS^p$, where K and P are constants. The flow properties at the minimum rate of deformation under conditions of constant tensile stress may be expressed completely by a number of constants--namely P, Ko (the minimum rate of strain at unit stress at 0 C), N (the rate of change of log K with change of temperature), and the extensibility at failure. The values of these constants are determined by the nature and grading of the aggregate. Gradings containing more plastic bitumens have greater values for P than those containing non-plastic bitumen; the value of P is affected more by the grading and proportion of the aggregate than by the nature of the bitumen.

RECORD No.: 144.
AUTHOR : A. R. Lee and J. B. Warren
TITLE : Flow Properties of Asphaltic Bitumens with Reference to Road Behavior
JOURNAL : Proceedings, Association of Asphalt Paving Technologists
VOLUME No.: 12
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1940
PAGES : 340
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, viscosity, stress effects, temperature effects, linear/nonlinear behavior, asphalt concrete mixtures, creep recovery

ABSTRACT :

The effect of stress and temperature on the viscosity of different types of bitumen has been examined as part of an investigation of the significant physical properties of bitumen in relation to road behavior. A similar examination of the flow properties of asphaltic road mixtures is in progress, and a study is being made of the behavior of asphaltic materials under normal traffic conditions. The instruments used to cover the range of viscosities between atmospheric and mixing temperatures were: a rotating coni-cylindrical viscometer, an Ostwald viscometer for opaque viscous liquids, and a falling cylinder viscometer. These instruments are discussed. Measurements on a 65 pen. Mexican bitumen showed that viscosity diminished with increasing shearing stress at temperatures below 70 C, while at higher temperatures the bitumen behaved as a Newtonian liquid. The relation between shearing stress and rate of shear did not obey the Bingham law D - 1/V (S-So), and could not be represented by other equations but could be expressed to a first approximation by D - kS^p, k and p being constants, except for bitumens deviating markedly from Newtonian flow. It is thought that an equation introducing one term representing Newtonian flow and a second term representing additional flow due to breakdown of the structure would be more logical, but without a value for viscosity at zero stress this cannot be satisfactorily checked. The value of p in D - kS^p gives a measure of the deviation from Newtonian flow and provides a method of expressing the degree of plasticity. Examination of a number of 65 pen. bitumens indicated a tendency for asphaltene and plastic flow index to increase together. Differences in viscosity of bitumens of the same penetration are said to affect directly the mechanical properties of surfacing materials containing the bitumens. In discussing the effect of temperature on viscosity, it is pointed out that bituminous materials present particular difficulty in attempts to obtain a value for the temperature susceptibility of viscosity, owing to their relatively large temperature susceptibilities. It has been found that the equation k - A/T^n, where T is temperature F, and A and n are constants, holds for the range from about 20 C to 90 C. The coefficient n, the slope of the straight line obtained on plotting log k against log T, is termed the logarithmic temperature coefficient, and provides a criterion for distinguishing between the relative susceptibilities of bitumens. No relation was found between asphaltene content and the temperature coefficient. Specimens of road-surfacing materials have been found to exhibit similar log temperature coefficients, when tested under conditions of steady stress, to those of the bitumens, and it is concluded that the susceptibility of the road mix is determined by that of the binder. It is stated that it is not clear what significance the elastic properties of a bituminous binder have with respect to road behavior. The elastic properties are most prominent when the stress is rapidly applied, but even under conditions of continuously-applied constant stress, elastic recovery occurs on the sudden removal of the stress. The amount of recovery depends on the stress applied and the degree to which the material has been previously sheared. The evaluation of the elastic constants is said to offer some difficulty, but the total recovery gives an adequate means of distinguishing this property. Results obtained indicate that the elastic properties are directly related to the asphaltene content.

RECORD No.: 145.
AUTHOR : C. C. Mill, and V. G. W. Harrison
TITLE : Measurement of Flow Properties of Asphalts by the Penetrometer
JOURNAL : Journal of Society of Chemical Industry
VOLUME No.: 59
PUBLISHER : Society of Chemical Industry, London
YEAR : 1940
PAGES : 66-67
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, viscosity, penetration
ABSTRACT :

Using the fundamental equations describing viscous flow and plastic flow, an equation is calculated describing the behavior of viscous and plastic asphalts of the same viscosity.

RECORD No.: 146.
AUTHOR : R. N. Traxler, H. E. Schweyer, and J. W. Romberg
TITLE : Rheological Interpretation of Asphalt Tests
JOURNAL : Proceedings, American Society for Testing and Materials
VOLUME No.: 40
PUBLISHER : American Society for Testing and Materials
YEAR : 1940
PAGES : 1182
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, rheological properties, colloidal nature, penetration, ductility, softening point, viscosity
ABSTRACT :

The uses for asphalts are generally governed by their flow properties under application or service conditions. An evaluation of these properties in absolute units would be more satisfactory than the use of numerous empirical tests now employed. The types of flow encountered in asphalts are illustrated by rheological diagrams and terms employed in the rheology of asphalts are defined. A brief review is given concerning the colloidal nature of asphalt as related to its flow properties. Data are given to show the relation between ASTM penetration test values at 77 deg F and consistency in absolute units (poises) and it is concluded that this test is not satisfactory for the evaluation of rheological properties. The rheological aspects of the ring-and-ball test are discussed and an equation relating consistency and ring-and-ball softening points for certain asphalts is given. The physics of the ductility test are discussed and it is concluded that the test is too empirical to be helpful in the evaluation of the flow properties of asphalts. Other empirical tests such as float, fluidity factor, and penetrations at high and low temperatures are also discussed as being inadequate for the quantitative evaluation of flow properties. The rotating cylinder viscometer is advocated for determining the consistencies of the asphalts in absolute units.

RECORD No.: 147.
AUTHOR : Saal, R. N. J., and Labout, J. W. A.
TITLE : Rheological Properties of Asphaltic Bitumens
JOURNAL : Journal of Physical Chemistry
VOLUME No.: 44
PUBLISHER :
YEAR : 1940
PAGES : 149-165
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, rheological properties, sol, gel, composition, creep testing, recovery.
ABSTRACT :

After an extensive study of the rheological properties of two quite different bitumens made by measuring the deformation under constant shearing stress, the elastic recovery, and different combinations of these by means of a coni-cylindrical viscometer, Saal and Labout conclude that asphaltic bitumens must be considered mixed gel-sol systems and that the degrees of structure exhibited can vary widely with composition. These conclusions were reached previously by Pfeiffer and van Doormaal.

RECORD No.: 148.
AUTHOR : R. N. Traxler
TITLE : Flow Properties of Asphalts, Measured in Absolute Units
JOURNAL : Industrial and Engineering Chemistry
VOLUME No.: 30
PUBLISHER : American Chemical Society, Easton, PA
YEAR : 1938
PAGES : 322
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, viscosity, testing techniques, steric hardening, thixotropy, temperature susceptibility
ABSTRACT :

The asphalt technologist is confronted with the problem of measuring a wide range of consistencies. Methods are described for measuring low and high viscosities in absolute units and for evaluating the flow of nonviscous fluids. The capillary tube or rotating cylinder type of viscometer is recommended for low viscosities (less than 50,000 poises). The latter instrument, or a viscometer utilizing the principle of the falling coaxial cylinder, is suggested for measuring the viscosity of highly viscous asphalts. The flow properties of nonviscous bitumens (e.g., most air-blown asphalts) can best be evaluated with a rotating cylinder type of viscometer. Properties of asphalt that have been recognized by means of sensitive rheological methods are the existence of viscous and nonviscous asphalts, the phenomena of age hardening, thixotropy, and elasticity, and the precise evaluation of change of consistency with temperature (susceptibility).

RECORD No.: 149.
AUTHOR : R. N. Traxler, and L. R. Moffatt
TITLE : Flow in Asphalts Shown by the Method of Successive Penetrations
JOURNAL : Industrial and Engineering Chemistry
VOLUME No.: 10
PUBLISHER : American Chemical Society, Easton, PA
YEAR : 1938
PAGES : 188-191
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, penetration, rheological properties
ABSTRACT :

Rheological diagrams obtained by the method of successive penetrations show negative yield values, indicating that the method is not rheologically sound. The technique followed and the theory which postulates laminar flow are the probable sources of error. With a transparent bakelite resin, photographs show that the penetrometer needle is not completely wetted; a resin containing air bubbles being penetrated by the needle does not show a laminar but rather a very complex flow. Advantages and disadvantages of the method are enumerated.

RECORD No.: 150.
AUTHOR : H. G. Nevitt, and L. C. Krchma
TITLE : Effect of Temperature on the Consistency of Asphalts
JOURNAL : Ind. and Eng. Chem., Analytical Edition
VOLUME No.: 9
PUBLISHER : American Chemical Society, Easton, PA
YEAR : 1937
PAGES : 119
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, viscosity, temperature susceptibility
ABSTRACT :

Since the absolute measure of consistency is viscosity, the authors point out that the change of consistency of an asphalt with temperature would be more logically measured as the change of viscosity with temperature. The objections to the usual empirical susceptibility indexes are discussed and the requirements of a satisfactory index outlined. The viscosity temperature susceptibility coefficient is presented as a more fundamental viscosity-temperature formula and is mathematically represented as,

$$S = 0.221 [\log [\log (u1 + 0.8/\log (u2 + 0.8)]/\log (T2/T1)]$$

Where S is the viscosity-temperature coefficient and u1 and u2 are the kinematic viscosities at absolute temperatures T1 and T2. Data presented indicate that the viscosity-temperature susceptibility coefficient is applicable to a wide range of temperatures and viscosities.

RECORD No.: 151.
AUTHOR : J. P. Pfeiffer, and R. N. J. Saal
TITLE : Some Remarks on Ductility Determination of Asphaltic Bitumen
JOURNAL : Proceedings, Second World Petroleum Congress
VOLUME No.: Section II
PUBLISHER : World Petroleum Congresses, London
YEAR : 1937
PAGES : 665
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, temperature susceptibility, penetration index, ductility,

ABSTRACT :

The determination of the ductility of asphaltic bitumens is reviewed. It is demonstrated that as a rule in bitumens at temperatures at which their penetration is equal, low temperature susceptibility (high penetration index) is accompanied by low ductility (rate of strain 5 cm/min). Besides this, ductility determinations at other rates of strain (1/5 to 25 cm/min) are reported: a number of cases prove to exhibit a complicated character. A qualitative interpretation of the general relationship between the ductility and penetration index of a bitumen can be based on its plastic and elastic properties. It may at the same time also be seen from some further experiments in what direction deviations from this general relation may be sought. Quantitative interpretation of the ductility test appears, however, to be attended by serious difficulties owing to its very complicated character. From the facts brought forward it may be concluded that the statement to the effect that the ductility may be regarded as a measure for the binding capacity ("cohesion") of asphaltic bitumen is too general and must therefore certainly be looked upon as incorrect.

RECORD No.: 152.
AUTHOR : Edmund Thelen
TITLE : Method for Measuring the Rheological Properties of Materials of Great Consistency Such as Asphalts
JOURNAL : Journal of Applied Physics
VOLUME No.: 8
PUBLISHER :
YEAR : 1937
PAGES : 135-137
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, penetration, temperature, softening point, mobility
ABSTRACT :

An ASTM penetrometer needle was allowed to sink into various asphalts for a series of successive time intervals. The rate of flow varied linearly after the first penetrations. Results are nearly independent of shearing stress. The shape of the surface at point of punch affected the mobility but not the yield value. The negative log of mobility varied linearly with temperature. Yield values for particular crude-stock asphalts varied directly as the asphaltene content. On aging, asphalts increased in yield value but decreased in mobility. In two particular stocks, it was found that the melting point could be predicted from the mobility at 77 deg F.

RECORD No.: 153.
AUTHOR : F. R. Grant, and H. B. Pullar
TITLE : A Study of the Relationship Between Ductility and Tensile Strength When Measured Simultaneously
JOURNAL : Proceedings, Association of Asphalt Paving Technologists
VOLUME No.: 8
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1936
PAGES : 124
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, ductility, force, penetration
ABSTRACT :

An apparatus to determine the ductility of a bitumen and at same time graphically measure the force required to obtain it is described. Data on the results obtained on asphalt cements from several sources and of several penetration grades are given.

RECORD No.: 154.
AUTHOR : R. N. J. Saal and J. W. A. Labout
TITLE : Relation Between Absolute Viscosity and Penetration of Asphaltic Bitumens
JOURNAL : Physics
VOLUME No.: 7
PUBLISHER :
YEAR : 1936
PAGES : 408-412
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, viscosity, penetration
ABSTRACT :

The relation between absolute viscosity, V, and penetration, viz., V = 5.13x10^9/(penetration)^1.93, published by Saal and Koens (Chemical Abstracts, Vol. 27, 2795 (1933)), has been questioned by Traxler, Pittman and B urns (Chemical Abstracts, Vol. 29, 3505 (1939)). The authors now give the results of extensive investigations to determine the possible influence on final results of variations in test conditions, such as interruption of the penetration test to allow for dissipation of elastic tension, imperfect adhesion of the bitumen to the needle, etc. The objections raised by T., P. and B. seem to have been due to failure to consider the elastic behavior of the bitumens under test, and the authors conclude that the equation given is valid within the limits claimed for it, viz., 10 to 15 percent.

RECORD No.: 155.
AUTHOR : R. N. Traxler and H. E. Schweyer
TITLE : Measurement of High Viscosity-A Rapid Method
JOURNAL : Proceedings, American Society for Testing and Materials
VOLUME No.: 36
PUBLISHER : American Society for Testing and Materials
YEAR : 1936
PAGES : 518
ABSTRACTOR: HRB
KEYWORDS : Asphalt cement, viscosity, dynamic testing, steady-state, viscometers

ABSTRACT :

Diagrammatic illustrations, directions for operating and formulas used for calculating the viscosities in absolute units are given for the following types of instruments: 1. The capillary tube viscosimeter modified to measure viscosities from 10 to 1,000,000 poises. 2. The alternating stress method for viscosities from 1,000,000 to 100,000,000 poises. 3. The rotating concentric cylinder viscosimeter which may be used to measure a wide range of viscosities. 4. The falling, coaxial cylinder type which can also be used over a wide range. When considering the development of a rapid, accurate method for control purposes, the last-mentioned type of instrument offered several possible advantages over the other types.

RECORD No.: 156.
AUTHOR : R. N. Traxler, C. U. Pittman, and F. B. Burns
TITLE : Rheological Properties of Asphalt. II. Discussion of Penetration-Viscosity Relationships
JOURNAL : Physics
VOLUME No.: 6
PUBLISHER :
YEAR : 1935
PAGES : 58-60
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, viscosity, penetration
ABSTRACT :

The viscosity-penetration equation of Saal and Koens (Chemical Abstracts, Vol. 28, 7511 (1934)), was tested in the temperature range of 15-130 deg C with 5 different asphalts. It was also tested with asphalts of varying consistency. About one-third of the calculated viscosities deviated from the experimental values by at least 15 percent.

RECORD No.: 157.
AUTHOR : R. N. J. Saal
TITLE : Determinations Regarding the Plastic Properties of Asphaltic Bitumen
JOURNAL : Proceedings, First World Petroleum Congress
VOLUME No.: 2
PUBLISHER : World Petroleum Congresses, London
YEAR : 1933
PAGES : 515
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, viscosity, softening point, penetration, ductility, pressure effects, thixotropy, viscometers
ABSTRACT :
For the usual asphalt analyses a series of methods are applied to characterize the phenomena of flow. These are, from high to low temperatures: (a) viscosity, for instance, Redwood II, Engler, etc; (b) float test; (c) softening point, either Ring and Ball or Kraemer-Sarnow; (d) penetration; (e) breaking point; (f) and further, as a special method, ductility. There is an objection to this series of determinations, in as much as their results cannot be combined as such to one viscosity-temperature curve. For this reason this report mentions a number of measurements in which the viscosity at all possible temperatures is no longer indicated in the form of the conventional methods referred to above, but is expressed in absolute units. The unit chosen by which to express all viscosities is the dynamic, the poise. (An oil with a viscosity of 1 poise shifts 1 cm in a 1 ml cube at a shearing stress of 1 dyne/cm.) For this method of determination the following series of instruments were used, adjusted, if necessary, to the particular product and viscosity range. (1) Redwood II, cap. visc., measuring range about 1-50 poises; Vogel-Ossag, cap. visc., measuring range about 0.01-100 poises; (2) sinker viscometer--A cylindrical object sinks in a tube with a slightly larger diameter filled with the asphaltic bitumen; measuring range about 1-10^5 poises; (3) capillary-pressure viscometer. The asphaltic bitumen flows out under a pressure of up to 10 atm. Measuring range to about 10^6 poises; (4) concentric viscometers. Two concentric cylinders rotate with respect to each other round their common axis. The intervening space is filled with asphaltic bitumen. Measuring range 10^4 - 10^8 poises; (5) pochettino viscometer. Two concentric cylinders, the space between which is filled with asphaltic bitumen, are moved in opposite directions along the axis. Measuring range 10^7 - 10^10 poises; (6) rod viscometer. A rod of asphaltic bitumen of 10 x 2 x 2 cms. is clamped in on either side and loaded in the middle, the whole being so constructed that chiefly shearing takes place. Measuring range 10^7 - 10^13 poises. By means of this series of instruments the behavior under flow of asphaltic bitumen has been examined under various conditions. The data furnished are a supplement to and extension of an article in Journ. Inst. Petr. Techn., 1933, 19, 176. The following properties of the asphaltic bitumen were subjected to a closer

examination: 1. For non- or hardly plastic asphaltic bitumens, viscosity-temperature curves were plotted over a large temperature interval (0-175C). These were found to come up to Walther's formula, so that they can be characterized by two constants. 2. The determination of the penetration as a sort of viscosity measurement was examined both experimentally and theoretically. 3. For a number of plastic asphaltic bitumens plasticity curves were plotted and formulated. 4. The influence of the pressure on the viscosity of asphaltic bitumen was subjected to an examination. It transpired that especially the size of the "free volume" determines the viscosity. 5. A high degree of thixotropy was found to be especially possible with hard-blown asphaltic bitumens. 6. The elasticity of asphaltic bitumen was examined more closely. This property is chiefly determined by the degree of plasticity.

III. Thermal Cracking Studies

RECORD No.: 1.
AUTHOR : Ralph Haas, F. Meyer, G. Assaf, H. Lee
TITLE : A Comprehensive Study of Cold Climate Airport Pavement Cracking
JOURNAL : Proceedings, Association of Asphalt Paving Technologists
VOLUME No.: 56
PUBLISHER : 1987
YEAR : 198-245
PAGES : Association of Asphalt Paving Technologists
ABSTRACTOR: PTI
KEYWORDS : Asphalt cements, asphalt concrete mixtures, cracking, stiffness, coefficient of contraction, penetration, viscosity, temperature susceptibility
ABSTRACT :

The purpose of the study was to develop cracking prediction models for design and to access the feasibility of using proposed new asphalt specifications for controlling the cracking problem. Lab tests on core samples from 26 airports (bulk density, coefficient of thermal contraction, low temperature stiffness at -35 C, -18 C, and 0 C, binder control, penetration, and viscosity on the recovered asphalt) were carried out. Crack survey plus other available design and construction data from the sites were acquired. The 26 airports are all located along the southern boarders of Canada where the freezing index ranges between 2000-5000 F days. The Statistical Analysis System (SAS) package, a simple correlation matrix of 64 variables, including various asphalt and mix properties as well as climatic, geometric, and crack pattern properties, was constructed. Spacing of transverse and longitudinal cracking were found to be in good correlation with 5 variables: (a) McLeod's Pen Viscosity Number (PVN), (b) temperature susceptibility of the mix in terms of stiffness drop between 0C and -17 C, (c) minimum attained temperature in the area, (d) the asphalt layer thickness, and (e) the coefficient of thermal contraction of the asphalt concrete. Regression analysis showed that average spacing of transverse cracks can be expressed in terms of different combinations of these variables. Three different models were proposed for estimating transverse crack spacing with R2 value ranging between 0.70 to 0.56. N. W. McLeod, in a prepared discussion, presents numerous field and lab data to support that the temperature susceptibility of a paving asphalt, in terms of its PVN value, remains essentially unchanged throughout its service life even if this is from 30 to 40 yr. B. A. Vallerga introduces two important points. (a) First, cracking patterns similar to those observed in cold climate regions are being observed in hot, desert areas. In these areas the thermal changes (160 F to subzero) create thermal stresses and cracking. Therefore cracking should be looked at not as one of low temperature cracking but as one of high viscosity cracking. Aging, particularly in desert areas, may work in combination with thermal changes to increase the viscosity and stiffness of asphalt. R. Haas, in his reply, confirms crack observations in hot areas and states that there may be other factors related to the larger number of thermal cycles in hot areas. Second, longitudinal cracks at construction joints are being observed in almost every job. They are not thermal-induced because they occur in jobs under all types of environments. Therefore, they are caused by shrinkage,

or volume changes, of the asphalt concrete mixes. Also many observations indicate that thermal cracks, after initiation, continue to widen and the material shrinks. R. Haas, in his reply, confirms the phenomena and states that there is not enough information in this area to decide whether aging, thermal cycles, or other factors are the essential cause of this phenomenon.

RECORD No.: 2.
AUTHOR : N. W. McLeod
TITLE : Using Paving Asphalt Rheology to Impair or Improve Asphalt Pavement Design and Performance
JOURNAL : Asphalt Rheology: Relationship to Mixture, ASTM
VOLUME No.: STP941
PUBLISHER : 1987
YEAR : 51-75
PAGES : ASTM
ABSTRACTOR: PTI
KEYWORDS : Temperature susceptibility, PVN, traffic, pavement temperature, pavement cracking, polymer modified asphalts
ABSTRACT :

The particular rheological property of a paving asphalt considered in this paper is its temperature susceptibility. The paper defines this property and a method of its measure is indicated. The influence of paving asphalt temperature susceptibility on pavement design and performance in hot climates without frost, and in cold climates with frost is described. A design chart for selecting paving asphalts with various combinations of temperature susceptibilities and penetrations at 25 C (77 F) to avoid low-temperature transverse pavement cracking at selected minimum winter temperatures and to provide adequate pavement stability at summer temperatures is introduced. The chart is based on data from three Ontario test roads, and on field performance of thousands of miles of paved roads. Using the freezing index, F (C) days, as the criterion for the minimum temperature at any paving site, a very simple method is illustrated for selecting the optimum paving asphalt or asphalts for surface, binder, and base course layers. A set of requirements for paving asphalt temperature susceptibility, which can be added to a paving asphalt specification is proposed and discussed. It is shown that by the addition of suitable polymers, the temperature susceptibility of asphalts can be improved.

RECORD No.: 3.
AUTHOR : Leung, Sui C.; Anderson, Kenneth O.
TITLE : Evaluation of Asphalt Cements for Low-Temperature Performance
JOURNAL : Transportation Research Record
VOLUME No.: 1115
PUBLISHER : 1987
YEAR : 23-32
PAGES : Transportation Research Board
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cements, temperature susceptibility, fracture characteristics, asphalt concrete mixtures, tensile strength
ABSTRACT :

This research project evaluates the temperature susceptibility and low-temperature fracture characteristics of asphalt cements from heavy crude sources in western Canada. Six samples of asphalt of grades 85/100 and 200/300 formulated from crude oils from Cold Lake, Lloydminster, and Redwater sources were tested to determine their physical properties. From the results of the laboratory tests, it is concluded that the Redwater asphalt is the most temperature susceptible of the the three asphalts studied. It was also confirmed that temperature as well as grade and crude source of asphalts have quite marked effects on the tensile properties of asphalt concrete mixtures. The asphalt cements produced from heavy crude sources of the Cold Lake and Lloydminster areas have been found to perform better at low temperature than those produced from the lighter crude source of the Redwater area. The 200/300 asphalt is also expected to perform better than the 85/100 asphalt. (Edited author abstract) 15 refs.

RECORD No.: 4.
AUTHOR : P. S. Kandall, W. C. Koehler
TITLE : Effect of Rheological Properties of Asphalts on Pavement Cracking
JOURNAL : ASTM Symposium on Rheological Properties of Asphalts and Their Effects on Mixture Preparing and Pavement Performance, Nashville, TN, December 11, 1985
VOLUME No.: Special Technical Publication, STP 941
PUBLISHER : 1985
YEAR :
PAGES : American Society for Testing and Materials
ABSTRACTOR: PTI
KEYWORDS : Cracking, penetration, viscosity, stiffness, age hardening, asphalt cements, asphalt concrete mixtures, diametral creep, ductility
ABSTRACT :

To identify the rheological properties of the asphalt binder responsible for both load and nonload-associated cracking of asphalt pavements, six test pavements were constructed in Pennsylvania in 1976 using AC-20 asphalt cements from different sources. For 7 yr (1976-1984), periodical pavement performance evaluations were carried out, and climatological data were gathered. The rheological properties of original and aging asphalt binders were evaluated from periodic core samples. The stiffness modules of original and aged asphalt binders and asphaltic concrete were determined by two indirect methods (Heukelom and McLeod) at -23 C (-10 F) to evaluate low-temperature nonload-associated transverse cracking. Diametral creep measurements on pavement cores after 7 yr in service. Creep moduli were determined over a convenient range of loading time up to 1000s and in the 4 to -20 C (39.2 to -20 F) temperature range. The creep data for each asphalt were reduced to a master curve using the super position method so that the stiffness modules of the viscoelastic asphaltic concrete can be obtained at a desired temperature and time of loading. The results of the study indicated that asphalts with high temperature susceptibility, as measured by PI and PVN, developed extensive low-temperature transverse cracking after the first winter. While PVN values remain essentially unchanged on aging, PI (Heukelom) values change drastically and do not maintain a consistent ranking order of the temperature susceptibility of the asphalts. The stiffness moduli values obtained using the McLeod direct determination method were consistent with the extent of transverse cracking. The incidence of transverse cracking increased with the increase in the asphalt binder stiffness. McLeod's suggestion that low-temperature transverse cracking is likely to become serious when stiffness is 70300 kg/cm (1x10 psi) at the lowest pavement temperature for a loading time of 20000s seems to have been confirmed on this project. Asphalt ductility values determined at 15.6 C (60 F) just after construction and after 6 yr in service seem to be consistent with pavement performance, especially the resistance to load-associated longitudinal cracking. This was also verified in an earlier study. Minimum acceptable ductibility should be 30cm (12in) to minimize the load-

associated longitudinal cracking.

RECORD No.: 5.
AUTHOR : Marks, Vernon J.; Huisman, Charles L.
TITLE : Reducing the Adverse Effects of Transverse Cracking
JOURNAL : Transportation Research Record
VOLUME No.: 1034
PUBLISHER : 1985
YEAR : 80-86
PAGES : Transporation Research Board
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cements, pavement cracking, temperature susceptibility, asphalt content
ABSTRACT :

This research was initiated to identify methods of reducing the occurrence of transverse cracking. Eight (four repetitive) research sections were established to study three variations in the asphalt concrete pavement. The first variation was the comparison of low- and high-temperature-susceptible asphalt cement (AC) from two different sources. The second variable was to saw and seal transverse joints at spacings varying from 40 to 100 ft. The third variable was to increase the AC content in the asphalt treated base by 1 percent. The research sections were constructed with relatively few problems. Crack and joint surveys have been conducted on all research sections at intervals of less than 1 year since construction. No cracking was identified after the first winter season. The sawed joints also remained sealed through the first sinter. At an age of approximately 1 1/2 years there was substantial cracking of the high-temperature-susceptible AC sections and substantial failure of the sealant material in the sawed joints. (Edited author abstract) 2 refs.

RECORD No.: 6.
AUTHOR : J. H. Keyser and B. E. Ruth
TITLE : Analysis of Asphalt Concrete Test Road Sections in the Province of Quebec, Canada
JOURNAL : Transportation Research Board
VOLUME No.: 968
PUBLISHER : 1984
YEAR : 54-65
PAGES : Transportation Research Board
ABSTRACTOR: PTI
KEYWORDS : Penetration, viscosity, ring and ball softening point, cracking, recovered asphalts, riding quality, rutting

ABSTRACT . :

The results of analyses performed on data collected from 23 test road sections in the Province of Quebec, Canada, provided information on the effect that certain parameters have on the properties and performance of asphalt concrete. The most significant finding was that consistency of recovered asphalts (penetration at 25 C) and traffic level (light, heavy) defined to a high degree of significance (R = 0.855-0.933) the amount of transverse cracking (number of cracks/3km) on 6- to 9-year-old pavements. Pavement cracking was found to be substantially reduced if penetration is never less than 40. Relationships developed between penetration, viscosity, and ring and ball softening point of recovered asphalts demonstrate that these consistency measurements are related to such a high degree of significance that only one of these consistency parameters is needed to characterize the asphalt. However, viscosity penetration relationships for original asphalts are not uniquely related, and form the basis for selection of asphalts to minimize low temperature cracking. Parameters based on penetration and softening point, such as penetration index (PI), is found to be of questionable value. The effects of air void content on asphalt hardening and indirect tensile strength at 0 C (32 F) were identified. Relationships were developed by using the results of a previous investigation that compared voids and penetration by using the 60C (140F) oven aging test. A tentative procedure for prediction of in-service hardening of bitumens is suggested for use in determining effects of air void content and age on the indirect tensile strength and consistency (penetration or viscosity) of the asphalt border. Several existing models were used to predict transverse cracking and cracking temperature. Analysis of these values and the actual number of observed transverse cracks provided absolutely no correlation between predicted and actual cracking. The depth of rutting was insignificant, except for five sections that had ruts in excess of 0.5 in. No relationships were found to define the amount of rutting. Analysis of ride quality using the Mays meter indicated that amount of transverse cracking had little effect on ride quality. A relationship was developed between subgrade moduli and Dynaffact fifth-sensor deflections.

RECORD No.: 7.
AUTHOR : C. A. Bell
TITLE : Use of the Shell Bitumen Test Data Chart in Evaluation of Asphalt Data
JOURNAL : Proceedings of the Association of Asphalt Paving Technologists
VOLUME No.: 52
PUBLISHER : 1983
YEAR : 1-31
PAGES : Association of Asphalt Paving Technologists
ABSTRACTOR: PTI
KEYWORDS : Asphalt cements, temperature susceptibility, penetration, softening point, viscosity, stiffness, fatigue, oxidative hardening, BTDC

ABSTRACT :

This paper reports an investigation of the use of the Bitumen Test Data Chart (BTDC) to predict penetration at 25 C (Pen 25) and the ring and ball softening point (SP) from measured viscosity at the standard temperatures of 60 C (140 F) and 135 C (275 F). These values can be used in conjunction with Van de Poel's nomograph to predict the stiffness of an asphaltic mix (having calculated the penetration index, PRI) or they can be used in the Nottingham fatigue nomograph requiring SP only, or other such nomographs, for demonstrating the effects of mix variables on stiffness and fatigue. Further, a procedure is presented, which classifies asphalts into three classes: Class S (comprising straight run residual and cracked asphalts), Class B (blown asphalts), and Class W (waxy asphalts). The classification is done by comparison of predicted and measured penetrations at 25 C. It is based on the shape of the consistency versus temperature plot. Also, the procedure develops two other parameters, Class Number (CN) and Hardening Number (HN) which reflects the change in CN after aging:

CN - [log Pen25 (Predicted - log Pen 25 (measured)]/ (log Pen25 (measured)]*100

HN - CN of original - CN or aged asphalt.

A basic computer program, CLASS, was developed, which, in addition to the above information, outputs temperature susceptibility values for the viscosity and penetration temperature ranges. Hence, from measuring viscosity at 60 C and 135 C and penetration at 25 C, a substantial amount of data can be generated and utilized to make decisions on the temperatures to use in mixing, and to identify possible problem asphalts before and after construction. A high positive or negative CN value indicates an asphalt with different temperature susceptibilities at high and low temperatures. HN value will indicate whether an asphalt will retain its class characteristics in service, and the extent to which it is sensitive to a change in class on aging. Three sets of data were analyzed: 93 asphalt samples from Oregon DOT, 68 samples from a 1979 Asphalt Institute study, and 16 samples from a 1981 Texas Transportation Institute study. The analysis indicated that 2/3 of the asphalts could be classified

as class W, 1/5 as class S, and 1/7 as class B. Class W is expected to include asphalts that will be more viscous at low temperature than suggested by the viscosity measurements. The comparison of class, CN, and HN for the Texas asphalts with observed performance indicates that problems may be caused by asphalts with high CN and a negative HN. A modified version of the BTDC is presented that permits the plotting of low temperature viscosity data and the display of all consistency data, so that all classification and temperature susceptibility values can be easily determined. The analysis of the data indicates that there is a strong case for using penetration tests for at least one temperature other than 25 C in standard specifications, or viscosity tests to completely characterize an asphalt. Also, temperature susceptibility would be better described by the slope of a portion of the line in the BTDC, since it was established that PI and VTS are not compatible parameters. The analysis procedure developed in this study may be used in identifying those asphalts with differing high and low temperature susceptibility, and in deciding appropriate temperatures to be used in the mixing and laying down of asphalt concrete.

RECORD No.: 8.
AUTHOR : K. O. Anderson and J. A. Epps
TITLE : Asphalt Concrete Factors Related to Pavement Cracking in West Texas
JOURNAL : Proceedings of Association of Asphalt Paving Technologists
VOLUME No.: 52
PUBLISHER : 1983
YEAR : 151-197
PAGES : Association of Asphalt Paving Technologists
ABSTRACTOR: PTI
KEYWORDS : Asphalts, asphalt concrete mixtures, thermal cracking, stiffness, tension tests, conventional lab tests, field performance

ABSTRACT :

The paper is concerned primarily with the role of asphalt concrete and the contributions to cracking made by the components, namely, the asphalt cement binder, and the aggregate. Results of extensive laboratory tests are reported that identify physical properties of the asphalt concrete and components of samples taken from six pavement sections located in one area of west Texas. The results and environmental factors were analyzed for correlations between the results and field performance in order to more adequately define the pavement cracking problem for this area of the United States. Conclusions of the study may be summarized as follows: (a) conventional mix design tests (Marshall stability and Hveem stability) conducted on cores taken from the six test pavements are of limited usefulness. Resilient modulus tests at low temperatures (<72 F) and 0.1 sec loading could not be related to performance; (b) direct tension tests conducted over the range of testing temperatures from 75 to -9 F have shown failure stress and E-modulus (a term similar to "stiffness molulus;" essentially, independent of strain rate at the lower temperature tested); (c) indirect tension tests conducted indicate significantly lower failure stress values at the lower temperatures when compared to those obtained by direct tension. E-modulus values were also different than those measured by the direct method; (e) the aggregate soundness determined by the resistance of aggregate to disintegration by a saturated solution of magnesium sulfate after four cycles of wetting and drying, is not a reliable indicator of pavement condition, at least within the ages of the pavements examined; (f) pavement sections with the lowest direct tension failure stress at -12 C (10 F) showed significant deterioration early in their pavement life, while the highest strength pavement still has not cracked; (g) predicting pavement cracking by assuming a critical stiffness of $1x10^9$ N/M^2 gives cracking temperatures that are all below the minimum expected temperature of the pavement. The most badly cracked section comes fairly close, while the two sections still not cracked have the lowest predicted cracking temperatures; (h) use of the COLD program to predict cracking by thermal shrinkage indicates that the program does produce predictions of low temperature cracking that are verified by two sections of pavement included in the study.

RECORD No.: 9.
AUTHOR : Lytton, R. L.; Shanmugham, U.; Garrett, B. D.
TITLE : Design of Asphalt Pavements for Thermal Fatique Cracking
JOURNAL : FHWA report
VOLUME No.: TTI-2-8-80-284-4; FHWA/TX-83/06-284-4
PUBLISHER : 1983
YEAR : 279p
PAGES : Texas Transportation Institute
ABSTRACTOR: NTIS
KEYWORDS : Asphalt concrete mixtures, thermal fatigue cracking, thermal stress, fracture mechanics, model, field performance, asphalt cements, computer model

ABSTRACT :

This report describes the development of a design procedure for asphalt pavements to resist thermal fatigue cracking. The first step is the development of a computer model based on fracture mechanics for predicting transverse cracking due to thermal fatigue cracking in asphalt concrete pavements. The effectiveness of the model developed is demonstrated by comparing its results with field data from Michigan. The design equation is developed by regression analysis of the results of 576 separate runs of the computer model for a variety of climatic conditions. The design procedure is automated, using a computerized pattern search routine to select the best combination of asphalt concrete thickness, bitumen and mix properties to withstand thermal fatigue for a specified period of time in a specified climate.

RECORD No.: 10.
AUTHOR : Anderson, K. O.; Epps, J. A.
TITLE : Asphalt Concrete Factors Related to Pavement Cracking in West Texas
JOURNAL : FHWA report
VOLUME No.: TTI-2-9-80-287-3; FHWA/RD/TX-83/287/2
PUBLISHER : 1983
YEAR : 80p
PAGES : Texas Transportation Institute
ABSTRACTOR: NTIS
KEYWORDS : Asphalt concrete mixtures, thermal cracking, computer program, field performance
ABSTRACT :

This report presents results of research to define the influence of various properties of the asphalt concrete on pavement cracking due to low temperatures experienced on several projects in West Texas. Cracking due to thermal shrinkage can be predicted by methods that have been used in the colder climates of Canada and elsewhere. The computer based prediction model for low temperature cracking referred to as COLD (Computation of Low-Temperature Damage) was used to analyze data from this project. Two sections were compared, one which exhibited cracking, with the other having no cracking. Thermally induced stresses that exceeded the tensile strength were obtained for the one section, but were far less than the expected strength for the other section exhibiting no cracking. Use of the COLD program to predict cracking by thermal shrinkage yielded results which were compatible with observed field performance of these two pavements in West Texas.

RECORD No.: 11.
AUTHOR : Epps, J. A.; Button, J. W.; Gallaway, B. M.
TITLE : Paving with Asphalt Cements Produced in the 1980'S.
JOURNAL : Natl Coop Highw Res Program Rep
VOLUME No.: 269
PUBLISHER : 1983
YEAR : 34
PAGES : Transportation Research Board
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cement, temperature susceptibility, pavement performance, steric hardening, setting rate
ABSTRACT :

The overall objectives of the NCHRP Project 1-20 research study were: (1) to determine the range or extent of variability in temperature susceptibility of asphalt cements currently being used in road construction, (2) to evaluate the effects of asphalt cement properties on pavement construction operations and short-term performance of pavements over the full range of service temperatures, (3) to identify the limits of variability in asphalt cement properties that can be accommodated through application of known mixture design techniques, and (4) to determine procedures for accommodating or controlling that variability in temperature susceptibility of asphalt cements that cannot be accommodated by known asphalt technology. The findings of this research are presented in this report, NCHRP Report 269, 'Paving With Asphalt Cements Produced in the 1980's,' and in a companion report, NCHRP Report 268, 'Influence of Asphalt Temperature Susceptibility on Pavement Construction and Performance'. 41 refs.

RECORD No.: 12.
AUTHOR : Stein, Johann
TITLE : Rheological Properties of Coal Tar Binders
JOURNAL : Chemische Technik (Leipzig)
VOLUME No.: 35, No. 1
PUBLISHER : 1983
YEAR : 24-26
PAGES :
ABSTRACTOR: Compendex Plus
KEYWORDS : Coal tars, temperature susceptibility, softening point
ABSTRACT :

This paper presents results of an examination of ten coal-tar pitches of different origin and prepration which showed that the viscosity-temperature behavior of the pitches is different. Plots of lg-lg viscosity versus lg absolute temperature are linear in a wide range. The slopes, however, are distinctly different. A translation parallel to the temperatures axis therefore does not result in a congruity of plots for all pitches. Consequently the determination of the softening point is not sufficient to describe the viscosity-temperature behavior of coal-tar pitches of different origin and preparation. 17 refs. In German.

RECORD No.: 13.
AUTHOR : Ruth, Byron E.; Schweyer, Herbert E.
TITLE : Asphalt and Mixture Rheology as Related to Cracking of Asphalt Concrete Pavements.
JOURNAL : Proc Paving Conf 18th, Univ of NM, Albuquerque, NM,
VOLUME No.:
PUBLISHER : 1981
YEAR : 45-82
PAGES : University of New Mexico
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cements, constant stress testing, cracking, thermal effects, fatigue, load, rheolgoical properties
ABSTRACT :

The cracking of asphalt concrete pavements is usually associated with fatigue or thermal stress conditions. Research efforts and analysis methods that have been developed are generally directed toward one problem without consideration of the interaction between load and thermal behavior. This paper presents the basic concepts and methods for analysis of pavements using well defined behavioral aspects of bitumens and asphalt concrete materials. It discusses asphalt rheology, constant stress testing, asphalt mixture rheology, relationships between asphalts and mixtures, development of a thermal stress equation, and other aspects of the subject.

RECORD No.: 14.
AUTHOR : Noureldin, Magdy S.; Manke, Phillip G.
TITLE : Study of Transverse Cracking in Flexible Highway Pavements in Oklahoma
JOURNAL : Transportation Research Record
VOLUME No.: 695
PUBLISHER : 1978
YEAR : 28-33
PAGES : Transporation Research Board
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cements, cracking, asphalt concrete mixtures, low temperature properties

ABSTRACT :

The results of a research study to determine the nature and extent of transverse cracking on Oklahoma flexible pavements and to investigate the possible causes of this form of distress are reported and discussed. Nine test sites with various degress of cracking were selected for comprehensive study. An indirect tensile-splitting test apparatus was developed to evaluate the low-temperature tensile properties of asphalt concrete cores obtained from the test sites. Use was made of the concept of the stiffness modulus to characterize the low-temperature behavior of recovered asphalt cements and mixtures. 13 refs.

RECORD No.: 15.
AUTHOR : Gaw, W. J.
TITLE : Measurement and Prediction of Ashalt Stiffnesses at Low and Intermediate Pavement Service Temperatures
JOURNAL : Proceedings, Association of Asphalt Paving Technology
VOLUME No.: 47
PUBLISHER : 1978
YEAR : 457-494
PAGES : Association of Asphalt Paving Technologists
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cements, stiffness, sliding plate, thermal cracking
ABSTRACT :

Ideally,low temperature asphalt stiffnesses should be measured directly for greatest accuracy. However, instruments capable of making these measurements are not generally available, and this makes the prediction of accurate low temperature asphalt stiffnesses still a matter of some concern. In North America the most commonly used asphalt stiffness prediction procedures are based on C. van der Poel's monograph, one using asphalt penetration index based on J. Ph. Pfeiffer and P. M. van Doormaal's original index, and another, a modified procedure introduced by N. W. McLeod, which uses penetration-viscosity numbers. Asphalt stiffnesses predicted from Van der Poel's nomograph using both these procedures are compared in this paper with experimental stiffness data for four asphalts, to establish the magnitude of the prediction errors in each case. 27 refs.

RECORD No.: 16.
AUTHOR : Noureldin, Magdy S.; Manke, Phillip G.
TITLE : Application of the Stiffness Concept to Transverse Pavement Cracking in Oklahoma.
JOURNAL : Proceedings, Association of Asphalt Paving Technologists
VOLUME No.: 47
PUBLISHER : 1978
YEAR : 270-280
PAGES : Association of Asphalt Paving Technologists
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cements, stiffness modulus, cracking, asphalt concrete mixtures
ABSTRACT :

The paper reports on a study to investigate the behavior and response of Oklahoma asphalt binders and mixtures at low temperatures and to try to relate this behavior with field cracking data. The stiffness moduli of recovered field asphalt cements and mixtures were determined and results were related with the observed degree of pavement cracking. Different 85-100 penetration grade asphalt cement samples were secured from various sources in Oklahoma and their stiffness moduli were determined using N. W. McLeod's indirect method and compared to his recommended limiting values. The study also included determining the stiffness moduli of different penetration grades of asphalt binders and laboratory mixtures made from these asphalt cements. 12 refs.

RECORD No.: 17.
AUTHOR : Kandhal, Prithvi S.
TITLE : Low Temperature Shrinkage Cracking of Pavements in Pennsylvania
JOURNAL : Proceedings, Association of Asphalt Paving Technologists
VOLUME No.: 47
PUBLISHER : 1978
YEAR : 73-114
PAGES : Association of Asphalt Paving Technologists
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cements, field performance, rheological properties, cracking, low temperature
ABSTRACT :

Six test pavements were constructed on Traffic Route 219 in Pennsylvania in September 1976 using AC-20 asphalt cements from different sources. The research was undertaken as a long term durability project with the following objectives: to study the changing asphalt properties in the aging pavements in service; to determine the effect of rheological properties of AC-20 asphalt cements at 77 F (25 C) or lower temperatures on the pavement performance and durability; and to develop suitable specifications for AC-20 asphalt cement to insure durable pavements. The 1976-1977 winter following the construction of these test pavements was very severe in Pennsylvania. Visual observation of the six test pavements after the winter revealed that two test pavements have developed extensive low temperature associated cracking. Similar cracking was also observed on several pavements in Northern Pennsylvania where the AC-20 asphalt cement came from the same source. The paper discusses testing and analyses done to study the cause of this cracking problem. 14 refs.

RECORD No.: 18.
AUTHOR :
TITLE : ASTM D832-64: Standard Recommended Practice for Rubber Conditioning for Low-Temperature Testing
JOURNAL : 1977 Annual Book of ASTM Standards
VOLUME No.: Part 37
PUBLISHER : 1977
YEAR : 205-213
PAGES : American Society for Testing and Materials
ABSTRACTOR: PTI
KEYWORDS : Rubbers, low temperature testing, crystallization, transition temperatures
ABSTRACT :

This standard of recommended practice covers general theory of low-temperature testing of rubbers and rubber-like materials. The occurrence and effects of first and second order transitions (e.g., glass transitions, crystallization) are discussed. Conditioning procedures are given for materials that exhibit simple viscoelastic behavior, and for materials that exhibit significant crystallization. A table is given which lists recommended conditioning times for samples of various sizes and shapes. Recommended test temperatures are -70, -55, -40, -25, -10, 0, and 23 C (-94, -67, -40, -13, +14, 32, and 73 F). For samples which do not crystallize, testing may begin as soon as equilibrium is reached. For instance, if the sample is prepared at 25 C and tested at -25 C, and is in the form of a sheet or bar 0.5-in thick, after 980 seconds the center of the sample will be at about -24.5 C (from table 2). This represents a conditioning time of about 16 minutes. The testing would then commence. For samples which may crystalize, the sample is tested immediately after equilibrium is reached, and again after 72 hours of conditioning at the lowest temperature. If crystallization is occurring, the second test will show a higher modulus or hardness. Typically, an optimum crystallization temperature exists at which crystallization is most rapid. This can be found by conditioning and testing at various temperatures. In any case, the results of tests are usually plotted against temperature in order to locate first or second order transitions. This standard also contains plans for various low-cost, low temperature cabinets. The simplest such system consists of an insulated wood cabinet and a wire basket, with dry ice in a separate chamber. A fan connected to a thermoregulator blows air over or through the dry ice into the test chamber for cooling. A heater may also be used for more precise temperature control.

RECORD No.: 19.
AUTHOR : Pechenyi, B. G.
TITLE : Asphalt Quality and Strength of Asphalt Pavements
JOURNAL : Chemistry and Technology of Fuels and Oils (English translation of Khimiya i Tekhnologiya Topliv i Masel)
VOLUME No.: 13, No. 9-10
PUBLISHER : 1977
YEAR : 719-722
PAGES : Plenum, New York
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cements, asphalt pavements, cracking, shoving failure envelopes, structural transition, loading rate, asphalt cement
ABSTRACT :

The selection of an asphalt for paving mixtures is governed by the need to provide adequate resistance to shifting and cracking of the pavement. The cracking resistance of an asphalt pavement can be judged by the magnitude of its maximum deformation (before breaking) in comparison with the design-allowable flexure of the pavement at 0 degree C; the cracking resistance can also be judged by the levels of the structural transition temperatures. In the reported experiments, the nature of the failure envelopes of asphalt pavements was studied in order to determine the feasibility of using these envelopes to characterize failure. Experimental data are presented which show that as the asphalt structure changes over from a sol to a gel, the resistance of the pavement to breakdown decreases. At higher rates of load application to the pavement, the failure stress SIGMA and the deformation at failure EPSILON have higher values than for failure at lower loading rates. Higher asphalt contents give pavements with better breakdown resistance. 11 refs.

RECORD No.: 20.
AUTHOR : W. J. Gaw
TITLE : Measurement and Prediction of Asphalt Stiffnesses and Their Use in Developing Specifications to Control Low-Temperature Pavement Transverse Cracking
JOURNAL : American Society for Testing and Materials
VOLUME No.: STP 628
PUBLISHER : 1976
YEAR : 57-67
PAGES : American Society for Testing and Materials
ABSTRACTOR: PTI
KEYWORDS : Low-temperature cracking, asphalt stiffness, penetration, specifications, waxy asphalts, air blowing
ABSTRACT :

Recent field and laboratory investigations have confirmed that cracking occurs when the thermal stresses induced in the pavement by cooling exceed the breaking strength of the pavement material. The evaluation of the St. Anne Test Road showed that the most significant mix property that influenced cracking was the low-temperature mix stiffness, and consequently asphalt stiffness at the low temperatures. One relatively simple instrument, the sliding-plate rheometer, conveniently measures low-temperature asphalt stiffness, but its upper limit of S = 1x10^8 N/M^2 is too low for direct evaluation of asphalt stiffness of pavement cracking temperatures. The alternative is to predict the stiffness from Van der Poel's stiffness nomograph. However, this nomograph can be used only with asphalts containing less than 2 percent wax. Heukelom proposed modified procedures for using the nomograph to improve stiffness prediction accuracy for both waxy and nonwaxy asphalts. Recent work, however, concluded that even with these modified procedures, stiffness prediction errors can be substantial for waxy asphalts at temperatures above -20 C. An empirical procedure was developed recently that allows stiffness predicted from Van der Poel's nomograph to be corrected by means of a single experimental stiffness measurement at one temperature (in this case, -10 C). The new procedure gives stiffnesses that differ from measured values in the temperature range of 10 to -20 C, generally by less then a factor of two. However, comparison of experimental, predicted, and corrected stiffness of three asphalts used in St. Anne Test Road sections, which include waxy and nonwaxy asphalts, indicates that the predicted stiffnesses from Van der Poel's nomograph, in the range of the pavement cracking temperatures, are within a factor of two of the experimentally corrected predicted stiffness for both waxy and nonwaxy asphalts. Thus the correction procedure for waxy asphalts for stiffness values above 1x108 N/M2 appears unnecessary; values predicted from Van der Poel's nomograph are acceptable indicators of pavement cracking trends. Instead of using stiffness values, a more direct indication of pavement cracking can be obtained by predicting cracking temperatures from a developed penetration nomograph. The temperatures can be determined using the asphalt penetration at 25 and 5 C, which can be easily measured. The nomograph is based and derived from asphalt stiffnesses predicted from Van der Poel's nomograph in the

temperature range where pavement cracking occurs. The St. Anne Test Road asphalts were examined using the cracking temperatures nomograph, and the results show good agreement with the actual road surface cracking temperatures. Nomographic cracking temperatures based on penetrations at 25 C and 5 C are proposed to be used to formulate asphalt specifications by selecting nomographic cracking temperatures appropriate to region low-temperature extremes. The soundness of this approach is demonstrated in a specific case where the low-temperature properties of a waxy asphalt are improved by air blowing an otherwise highly crack-susceptible vacuum-flashed residue.

RECORD No.: 21.
AUTHOR : Novak, E. C., Jr.
TITLE : Evaluation of a Model for Predicting Transverse Cracking of Flexible Pavement
JOURNAL : FHWA report
VOLUME No.: FHWA/RD/M-0338
PUBLISHER : 1976
YEAR : 39p
PAGES : Michigan Department of State Highways and Transportation
ABSTRACTOR: NTIS
KEYWORDS : Asphalt concrete mixtures, thermal cracking, stiffness, tensile strength, asphalt cements, prediction method
ABSTRACT :

This report describes a study comparing actual transverse cracking performance with that predicted by the Hajek-Haas method. No functional relationship was found to exist, and a limited laboratory study was conducted in an attempt to determine why. The study also considered the fact that transverse cracking in Michigan could have been essentially eliminated using McLeod's mix stiffness criteria; however, these criteria would exclude from use many stiff bituminous mixes which have given essentially crack-free service. Results indicated that the tensile strength, as well as stiffness modulus, both influence a bituminous mix's ability to resist cracking. Since stiffness modulus and tensile strength are not necessarily related, both should be included in models for predicting transverse cracking. Aggregate tensile strength also has a significant effect on the tensile strength of the mixes, thus mix tensile strength should not be estimated from asphalt cement properties alone. The data also indicate that bituminous stiffness can be lowered to such extent that tensile strength of the mix will no longer influence transverse cracking potential.

RECORD No.: 22.
AUTHOR : Nour Eldin, Magdy S.; Manke, Phillip G.
TITLE : Evaluation of Bituminous Mixes in Pavement Structures. Interim Report III. A Preliminary Study of the Use of the Stiffness Concept in Minimizing Low-Temperature Transverse Cracking
JOURNAL : FHWA report
VOLUME No.: PUB-R(S)-11; FHWA/OK-77/72-03-3
PUBLISHER : 1976
YEAR : 46p
PAGES : Oklahoma State University
ABSTRACTOR: NTIS
KEYWORDS : Asphalt cements, rheological properties, asphalt concrete mxitures, thermal stresses, cracking, stiffness, low temperature
ABSTRACT :

A review is presented of pertinent literature on characterizing the rheological properties of bitumen at low-temperatures, and relating these properties to the development of transverse cracks in flexible pavements. Various methods for direct and indirect determination of the 'stiffness modulus' of asphalt binders and mixtures are discussed. The stiffness moduli of thirty-one Oklahoma asphalt cement samples and a series of asphalt concrete mixtures were determined. Results were compared with limiting values suggested in the literature. A majority of the tested asphalt cements and mixtures exceeded the recommended critical stiffness values. The results indicated that the stiffness modulus approach can be applied to Oklahoma materials to identify suitable low-temperature characteristics that will mitigate transverse pavement cracking.

RECORD No.: 23.
AUTHOR : Chang, Hang-Sun; Lytton, Robert L.; Carpenter, Samuel H.
TITLE : Prediction of Thermal Reflection Cracking in West Texas
JOURNAL : FHWA report
VOLUME No.: TTI-2-8-73-18-3; FHWA/RD-76-S0464
PUBLISHER : 1976
YEAR : 106p
PAGES : Texas Transportation Institute, College Station.
ABSTRACTOR: NTIS
KEYWORDS : Asphalt concrete mixtures, stress analysis, viscoelastic properties, thermal stress, fracture mechanics, fatigue
ABSTRACT :

An economical means of rehabilitating deteriorated pavement is through the use of an overlay. This study presents a rational approach of the prediction of overlay life and gives recommendations which are expected to extend the life of overlays. The predictions are made using linear elastic and mechanics. Initially, a prediction scheme for viscoelastic thermal stresses in the overlay and old asphalt surface is used to predict thermal stresses more acurately than any previous attempt. These stresses are then applied to the crack surface to study the effects of material properties on crack development. The stress intensity factors necessary for this analysis are calculated using the finite element technique with the crack tip elements developed by Pian. Predicitons of service life are made using the empirical relationship developed by Paris.

RECORD No.: 24.
AUTHOR : R. J. Schmidt
TITLE : Use of ASTM Tests to Predict Low-Temperature Stiffness of Asphalt Mixes
JOURNAL : Transportation Research Record
VOLUME No.: 544
PUBLISHER : 1975
YEAR : 35-45
PAGES : Transportation Research Board
ABSTRACTOR: PTI
KEYWORDS : Asphalt, low-temperature cracking, stiffness, penetration, viscosity, aging
ABSTRACT :

There are several methods for estimating the temperature at which thermally induced pavement cracking can be expected. Some methods assume, in the analysis, a linear viscoelastic plate or beam, and require, as input, the stiffness and tensile strength of the mix over the temperature range considered, a rate of temperature drop, and the coefficient of expansion of the mix. An alternate approach is the limiting stiffness method, which assumes that a mix will not crack if its stiffness (for some appropriate loading time) does not exceed a certain value at the lowest expected field temperature. Limiting stiffness can be expressed in terms of either mix stiffness (SLM) or binder stiffness (SLA). An SLA of 20,000 psi at a 10,000-sec loading time has been chosen in this study to represent the limiting stiffness. The purpose of this investigation is to clarify the extent to which ASTM tests can be used to predict thermally induced pavement cracking. Mix stiffnesses obtained from diametral configuration creep tests were compared with ASTM stiffnesses. The relationship reported between thermally induced pavement cracking and TL, or the temperature at which the 10,000-sec asphalt stiffness is 20,000 psi, is qualitatively supported by field tests. TL, estimated from ASTM penetration at 39.2 F, along with the ASTM penetration at 77 F or the viscosity at 140 F on rolling thin film (RTF-C) oven residue, correlates well with the measured TL from mix creep tests. The use of penetration at 39.2 F is supported as a specification requirement. Good correlation was also found on asphalts recovered from the mixes. TL correlated poorly with penetration at 77 F along with softening point or viscosity at 140 F on both RTF-C and recovered residua. TL estimated from viscosities at 140 F, along with viscosities at 275 F on RTF-C or recovered residua, show no correlation with measured TL. Resistance to low-temperature thermally induced cracking should not be implied on diverse types of asphalts from high-temperature viscosity measurements. Ductilities at 45 F show no correlation with TL. A modified asphalt test data chart that permits the low temperature stiffness of asphalts to be determined from normal ASTM penetration tests is given.

RECORD No.: 25.
AUTHOR : Schmidt, R. J.
TITLE : Use of ASTM Tests to Predict Low-Temperature Stiffness of Asphalt Mixes
JOURNAL : Transportation Research Record
VOLUME No.: 544
PUBLISHER : 1975
YEAR : 35-45
PAGES : Transportation Research Board
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cements, stiffness modulus, asphalt concrete mixtures, low temperature cracking, field tests
ABSTRACT :

The investigation described tested the reliability of ASTM tests to predict low-temperature stiffness of mixes made with a wide variety of asphalts. Mix stiffnesses obtained from creep tests performed with a new low-cost nondestructive method on ordinary Marshall or Hveem specimens were compared with ASTM stiffnesses. The relationship reported between thermally induced pavement cracking and the temperature at which the 10,000-sec asphalt stiffness is 20,000 psi is qualitatively supported by field tests. 25 refs.

RECORD No.: 26.
AUTHOR : M. F. Clark, R. W. Culley
TITLE : Use of Air-Blown Asphalt Cements to Reduce Thermal Cracking
JOURNAL : Proceedings, Canadian Technical Asphalt Association
VOLUME No.: XIX
PUBLISHER : 1974
YEAR : 5-24
PAGES : Canadian Technical Asphalt Association
ABSTRACTOR: PTI
KEYWORDS : Asphalt cements, thermal cracking, test road, air-blown, penetration, cracking, rutting, stripping, oxidative hardening

ABSTRACT :

Studies have indicated that air-blown asphalt cements might have the thermal and structural characteristics that would not crack at low temperatures and would not extensively deform at high temperatures. A full scale test section was constructed in central Saskatchewan in 1973 to evaluate the performance of air-blown asphalt cements in full-depth structures. A 400-pen stock asphalt was air-blown to provide 100-pen and 150-pen asphalts to be used in comparison with a standard 200-pen Saskatchewan AC-5 asphalt in 7 1/2 inch full-depth structure. As part of the evaluation, a wide range of properties were measured at pre- and post-pugmilling stages and at 1 week, 4 weeks, and 6 months after paving. The test section was monitored to observe cracking, stripping, and rutting. The hardening of asphalts was also measured for a number of years. Results at 6-months indicated only a single transverse crack in a block where the 100-pen blown asphalt was used. Loss in penetration caused by pugmilling was not as severe as that by the thin film oven test.

RECORD No.: 27.
AUTHOR : T. R. J. Fabb
TITLE : The Influence of Mix Composition, Binder Properties and Cooling Rate on Asphalt Cracking at Low Temperatures
JOURNAL : Proceedings, Association of Asphalt Paving Technologists
VOLUME No.: 43
PUBLISHER : 1974
YEAR : 285-331
PAGES : Association of Asphalt Paving Technologists
ABSTRACTOR: PTI
KEYWORDS : Asphalt, asphalt pavement mixes, viscosity, temperature, susceptibility, shear susceptibility, cracking, cooling rate, aggregate grading
ABSTRACT :

This study evaluated the influence of the rheological properties of bitumen, aggregate grading, rate of cooling, binder content, filler content, and polymer additives on the thermal cracking tendency of asphalt pavement mixes. A new testing apparatus was developed in which beam test specimens of compacted mix measuring 300 by 25 by 25 mm can be maintained at constant length while cooling the specimen at the desired rate. The setup allows the stress induced in the specimen to be measured while the specimen is cooled in a cooling bath. The induced stress versus temperature can be obtained until fracture occurs. A 2(MT) x 2(BC) x 3(BR) factorial experiment was conducted in which MT denotes mix type (dense graded or gap graded), BC denotes bitumen consistency (50/70 penetration or 80/100 penetration), and BR denotes the rheological character of bitumen (shear susceptibility and temperature susceptibility). In addition to this factorial experiment, nine other dense asphalt mixes incorporating seven different asphalts were tested. Based on the analysis of experimental results, the following conclusions are drawn: (a) the thermal failure temperature for a given asphalt mix is usually influenced by the properties of the asphalt binder used and can be related to the low temperature stiffness of the asphalt calculated from viscosity at 25 C, shear susceptibility, and temperature susceptibility of the original asphalts. Low Newtonian Viscosity, low temperature susceptibility, and high shear susceptibility of the asphalt binder are all factors conducive to reducing asphalt failure temperature; (b) variations in aggregate grading and properties have little or no effect on the resistance of asphalt mixes to thermally-induced fracture; (c) increasing the binder content of asphalt mixes within practicable limits only slightly reduces its thermal fracture susceptibility; (d) the failure temperature of asphalt mixes is independent of the rate of cooling. From this it is deduced that failure occurs when the bitumen attains a critical physical state, rather than when incremental stresses accumulate to exceed the fracture strength of the asphalt; (e) the addition of synthetic polymers to asphalt can reduce asphalt mix fracture susceptibility, but their use for this purpose is likely to be small until better cost-effective species are identified.

RECORD No.: 28.
AUTHOR : R. A. Burgess, O. Kopvilliem, and F. D. Young
TITLE : St. Anne Test Road - Flexible Pavement Design to Resist Low Temperature Cracking
JOURNAL : Proceedings, 3rd Int. Conf. on Structural Design of Asphalt Pavements
VOLUME No.: I
PUBLISHER : 1972
YEAR : 27-41
PAGES : University of Michigan, Ann Arbor
ABSTRACTOR: PTI
KEYWORDS : Asphalts, low-temperature cracking, stiffness, predicted fracture temperature, penetration, tensile strength
ABSTRACT :

In 1967, a test road was constructed at St. Anne, Manitoba for the investigation of low temperature transverse cracking of bituminous pavements. After 5 yr of service, it was concluded that pavements incorporating high viscosity type asphalts and softer grade asphalts exhibit the greatest resistance to transverse cracking. This paper reports on a laboratory study conducted in conjunction with the field program to investigate the possibility of correlating laboratory-predicted fracture temperatures with the actual field performance of the St. Anne test sections. Predicted fracture temperatures of the compacted mixes were determined by calculating the temperature at which accumulated thermal stresses, exceed the tensile strength thermal stresses may be calculated based on stiffness of the mix (as measured by the constant load tensile creep test), rate of cooling, and the average linear thermal contraction. Tensile strength was determined by letting a number of mix specimens go to failure at each test temperature and at several loading times. The stress of break at one-half hour loading time is then determined from a plot of tensile strength versus loading time. Since the tensile properties of an asphalt binder are proportional to those of a mix made with that binder, the possibility of predicting pavement field performance by a knowledge of binder properties alone was investigated. Binder stiffness values were calculated at one-half hour loading time over the appropriate temperature range by the use of Van der Poel's nomograph, using the corrected softening point temperature and the P.I. values obtained from plotting the penetration (100 gm, 5 sec) values at three different temperatures on the bitumen test data chart, and from penetration at 25 C. Binder tensile strength values were then obtained from the relationship previously shown between stiffness and tensile (breaking) strength versus temperature. These values were used to predict the cracking temperatures of both binders and mixes. Comparison of the laboratory and field results revealed that there is an excellent correlation between the laboratory-predicted fracture temperatures of the binder and mix and the temperature of initial cracking of the asphaltic pavement in the field. For practical purposes, therefore, the tendency of an asphaltic pavement to crack can be predicted by a knowledge of the binder stiffness modulus at low temperatures and long loading time. Conversely, the binder, or mix, stiffness parameter may be used as a pavement design criterion to alleviate the transverse cracking problem. Binder type and low temperature susceptibility may be considered the major factors affecting the pavement's cracking tendency. Soft grade should be a beneficial property. Field observations indicated that subgrade type has an effect and that the pavement surface temperature is crucial with respect to cracking.

RECORD No.: 29.
AUTHOR : H. J. Fromm and W. A. Phang
TITLE : A Study of Transverse Cracking of Bituminous Pavements
JOURNAL : Proceedings of Association of Asphalt Paving Technologists
VOLUME No.: 41
PUBLISHER : 1972
YEAR : 383-423
PAGES : Association of Asphalt Paving Technologists
ABSTRACTOR: PTI
KEYWORDS : Asphalt, cracking, temperature, consistency, stiffness, temperature sensitivity, filler content
ABSTRACT :

An investigation to survey existing pavements where contrasting types of transverse cracking occurred is reported. The objective is to identify the factors that differed within the pavement and caused the cracking. A total of 33 contracts located near Ontario, Canada were investigated. Cracks were sorted into four categories and crack frequency diagrams showing each quantity of each of four types were obtained selected length of the contracts. 18-in square samples were cut from the outer wheel track in an uncracked portion of each pavement and the thickness and moisture content of the base courses were measured. Each asphalt concrete sample was subjected to a number of regular quality control tests. Asphalt content, aggregate gradation, and specific gravity were measured. Materials recovered were recompacted and tested by the modified Marshall procedure. A modified Abson procedure was used to extract the asphalt binder, which was tested for penetration at 77 F and at 39.2 F, kinematic viscosity at 275 F, sliding plate microviscosity at 60 F, and ring and ball softening temperature. The recovered asphalts were also split into four fractions; asphaltenes, saturates, and light and heavy aromatics by column chromatographic analysis. A total of 179 samples were obtained. In addition to the mentioned routine tests, the critical temperature of asphalt concrete (the temperature at which the viscous flow under creep test loading in 1 hr equals the thermal shrinkage in 1 hr) was determined using a 1 1/2-in square beam, 8-in long, loaded in tension with a 100-lb weight at a temperature drop rate of 10 F per hour. The freezing index was used as a measure of the temperature regime of the different areas where the pavements were located. The coefficient of expansion of the asphalt mixes was measured using 2 by 2 by 11.2 in samples. Statistical analysis methods were followed to determine levels of correlation between cracking index and 40 different variables. Many of the variables were found to be interrelated. A detailed discussion of these interrelations and of the correlation with the cracking index is presented. A general regression model, a model for the southern areas, and a model for northern areas are offered as final models for the regression analysis. Main conclusions of the analysis of the huge data are as follows: (a) transverse cracking is largely due to the effects of lower temperature. This was shown by the prominent part the freezing index plays in the models; (b) viscosity ratio (viscosity at 60 F/viscosity at 275 C) and critical temperature have large effects on the cracking potential; (c)

there was a tendency for the crack frequency to increase with decreasing filler (passing No. 200) content of the mixes; (d) there is a positive correlation between stripping potential (measured by visual inspection of pavement samples and by a special rating procedure) and cracking tendency. The tensile strength of mixes is directly affected by the stripping rating; (e) although no clear relation could be found between stiffness modulus of mixes calculated by indirect ways and cracking index, it is recommended that lower stiffness and lower temperature sensitivity will result in the reduction of cracking tendencies; (f) throughout the investigation, a direct correlation between asphaltenes and the viscosity ratio of the asphalts was found. Asphalts of lower temperature sensitivity had higher asphaltene content; (g) increased void content resulted in decreased cracking indices. This was explained by the decreased stiffness values of the mixes due to increased voids, which appears to overcome the effect of more asphalt hardening; (h) asphalt penetration has an inverse relation with cracking index; (i) no correlation was observed between ductility measurements at 77 F and the cracking index.

RECORD No.: 30.
AUTHOR : Shahin, Mohamed Y.; McCullough, B. Frank
TITLE : Prediction of Low-Temperature and Thermal-Fatigue Cracking in Flexible Pavements
JOURNAL : Research Report
VOLUME No.: CFHR-1-8-69-123-14
PUBLISHER : 1972
YEAR : 223
PAGES : University of Austin, center for highway research
ABSTRACTOR: NTIS
KEYWORDS : Asphalt concrete mixtures, thermal cracking, models, stiffness, oxidative hardening, fatigue

ABSTRACT :
A system was developed to predict the amount of temperature cracking in asphalt concrete surfaces throughout their service lives using laboratory materials data and available weather information. Basically, four models were developed to form the system. In brief, the models are as follows: Model 1 - Simulation of bituminous pavement temperatures. Model 2 - (i) Estimation of asphalt concrete stiffness as a function of temperature and loading time. (ii) Prediction of in-service aging of asphalt. (iii) Estimation of thermal stresses. Model 3 - Prediction of low-temperature cracking. Model 4 - Prediction of thermal-fatigue cracking (Model IV) due to daily temperature cycling makes the system an improvement over other available techniques in this field.

RECORD No.: 31.
AUTHOR : Rader, L. F., Ochalek, R. T.
TITLE : Proposed Method for Testing the Physical Properties of Asphalt Paving Mixtures at Low Temperatures
JOURNAL : Preprints - Division of Petroleum Chemistry, American Chemical Society
VOLUME No.: 16, No. 1
PUBLISHER : 1971
YEAR : D126-D135
PAGES : American Chemical Society
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cement, asphalt concrete mxitures, thermal stresses, binder power, cracking, age hardening
ABSTRACT :

Study of the cracking of asphaltic concrete wearing surfaces by thermal stresses only. It is shown that the high modulus of elasticity indicates brittleness or inability of the pavement to withstand strain without cracking. The effect of a high E is noticeable in flexible pavements in which a hard asphalt has been used or in which the binding power of the cement has been destroyed by overheating or by age. 15 refs.

RECORD No.: 32.
AUTHOR : Fromm, H. J., Phang, W. A.
TITLE : Temperature-Susceptibility Control in Asphalt-Cement Specifications
JOURNAL : Highway Research Record
VOLUME No.: 350
PUBLISHER : 1971
YEAR : 30-45
PAGES : Highway Research Board
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cements, penetration, viscosity, low temperature, pavement performance, stiffness modulus
ABSTRACT :

Relationships are determined between penetration at 77 F and viscosities at 77, 140, and 275 F for asphalt cements currently supplied in Ontario. A new criterion for low-temperature performance and critical temperature is introduced. This is an indication of the low-temperature flow properties of the asphalt mix. A method is suggested or the selection of a suitable asphalt-cement grade for various low temperature environments by using stiffness modulus. 16 refs.

RECORD No.: 33.
AUTHOR : Culley, R. W.
TITLE : Relationships Between Hardening of Asphalt Cements and Transverse Cracking of Pavements in Saskatchewan
JOURNAL : Proceedings, Association of Asphalt Paving Technologists
VOLUME No.: 38
PUBLISHER : 1969
YEAR : 629-659
PAGES : Association of Asphalt Paving Technologists
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cements, viscosity, penetration, temperature susceptibility, shear susceptibility
ABSTRACT :

Research program was carried out to determine if asphalts produced under the new specification based on tighter viscosity limits for asphalt cements, still resulted in a significantly different transverse cracking patterns. Program consisted of measuring penetration and viscosity changes and temperature and shear susceptibilities of asphalt sampled at various locations in the transition from storage tank, to 12 mo service on five projects. The results of investigation are reported.

RECORD No.: 34.
AUTHOR : K. O. Anderson, W. P. Hahn
TITLE : Design and Evaluation of Asphalt Concrete with Respect to Thermal Cracking
JOURNAL : Proceedings, Association of Asphalt Paving Technologists
VOLUME No.: 37
PUBLISHER : 1968
YEAR : 1-31
PAGES : Association of Asphalt Paving Technologists
ABSTRACTOR: PTI
KEYWORDS : Asphalt cement, mixtures, indirect tension test, cracking, penetration, ductility, failure strain

ABSTRACT :
The tensile splitting test is investigated as a possible approach to evaluating the tensile stress-strain characteristics of asphalt concrete at low temperature. Cylindrical specimens can be prepared by the Marshall method load applied, and strain at the center of specimen can be measured by specially developed equipment. Three sources of 200 to 300 penetration grade asphalt cement were used with one type of aggregate to prepare specimens that duplicate as closely as possible mixes aged in the paving of a section of four-lane divided freeway in central Alberta. For each type of asphalt cement eighteen specimens were tested to plot the tensile stress versus strain at 0 F and a loading rate of 0.056 in/min. The source of asphalt cement is found to affect significantly the tensile properties and the occurrence of cracking. The occurrence of cracking from field observations was found to increase as the failure strain decreases. (Failure strain is defined as the strain corresponding to the point at which the slope of the load deformation trace first reaches zero.) Failure strain appears to be a function of the asphalt source when the same aggregate subgrade of asphalt cement is used. Penetration is not found to be a true indicator of failure strain. Different sources give different relations between penetration and failure strain at 0 F. Ductility measurements were not used because in previous studies they were not found to be meaningful (most were 150 plus cm).

RECORD No.: 35.
AUTHOR : G. M. Jones, M. I. Darter, and G. L. Littlefield
TITLE : Thermal Expansion - Contraction of Asphalt Concrete
JOURNAL : Proceedings, Association of Asphalt Paving Technologists
VOLUME No.: 37
PUBLISHER : 1968
YEAR : 56-100
PAGES : Association of Asphalt Paving Technologists
ABSTRACTOR: PTI
KEYWORDS : Asphalt cement, asphalt concrete mixes, coefficients of thermal expansion and contraction, asphalt content, transition temperature
ABSTRACT :

An investigation of the basic aspects of thermal expansion and contraction of asphaltic concrete was conducted. Asphaltic concrete exhibits two different thermal coefficients of expansion and contraction similar to asphalt cement. These are called the solid and fluid thermal coefficients. A transition temperature, Tac, for asphaltic concrete mix was found to range from 70 F to 86 F, depending on asphaltic content. The greater the asphalt content the smaller the Tac. Mixes above Tac exhibit their fluid coefficient, while mixes below Tac exhibit their solid coefficients. The particular asphalt source used exhibited a glass transition temperature Tg of -27 F. The difference between Tac and Tg (about 100 F) is explained by the presence of mineral filler. Asphalt content was found to be a major contributor to the thermal expansion-contraction of asphaltic concrete. The greater the asphalt content the greater the thermal expansion and contraction. An increase of one percent asphalt caused an increase of 25 percent in the thermal expansion and contraction coefficients in the solid state. A relationship was derived that predicts the cubic thermal coefficient of expansion-contraction of asphaltic concrete in the solid state from the knowledge of the cubic thermal coefficient and volume of the asphalt and aggregate. The linear thermal coefficient may be determined by assuming that the asphalt concrete exhibits isotropic properties (X=B/3). Using a dilatometer, asphaltic concrete was found to exhibit a different thermal coefficient in expansion than in contraction, particularly in the fluid state. The expansion coefficient was 4 percent greater than the contraction coefficient in the solid state, and it was 5 to 43 percent greater in the fluid state under free movement conditions. In expansion, the air voids exert pressure and cause viso-elastic creep of the asphalt binder. Permanent length changes were observed in the asphaltic concrete specimens when subjected to temperature cycles in the fluid state. For free movement conditions, the specimens increased in length from their original length. For friction conditions the specimens decreased in length from their original lengths for every temperature cycle in the fluid state. This phenomenon was attributed to absorption of asphalt into the aggregates and to a densification of the asphaltic concrete mixture caused by an irreversible process of expansion and contraction of asphalt cement into the air voids.

RECORD No.: 36.
AUTHOR : G. Littlefield
TITLE : Thermal Expansion and Contraction Characteristics, Utah Asphaltic Concretes
JOURNAL : Proceedings of Association of Asphalt Paving Technologists
VOLUME No.: 36
PUBLISHER : 1967
YEAR : 673-702
PAGES : Association of Asphalt Paving Technologists
ABSTRACTOR: PTI
KEYWORDS : Asphalts, asphalt concrete, expansion, contraction, viscosity, penetration, temperature, cracking

ABSTRACT :

This paper reports the thermal expansion and contraction characteristics of asphaltic concrete in an attempt to determine whether asphaltic concrete surfaces made with different grades and sources of asphalt result in different amounts of expansion and contraction, and whether this could have significant influence on surface cracking. One source and gradation of aggregate was mixed with the different asphalt cements (60-70, 85-100, 120-150) used by the Utah Department of Highways. One grade of tar was also used. Beams 3 by 3 by 16 in were made using each of these bituminous materials and using Marshall optimum percent asphalt and percent voids as guides. These beams were subjected to heating and cooling over different temperature ranges between 0 F and 130 F, and length-temperature curves were drawn. Some of the conclusions drawn from these curves may be as follows: (a) different asphalts produce different amounts of expansion and contraction when the beams are heated or cooled between 0 F and 130 F. Within each grade, the results show that the source with highest viscosity has the least expansion from 0 F. However, this correlation is lost in the shrinkage phase. There is no correlation between the expansion or shrinkage values and penetration values of these asphalts; (b) variation of expansion with temperature is a straight line from 0 F up to about 50-60 F, after which a sharp decrease in rate of expansion is observed. After this point of curvature there can be zero expansion, a small amount of expansion, or even shrinkage with increasing temperature. Asphalt type, curing degree, and other factors will influence the range at which temperature-expansion relation changes; (c) the thermal coefficient of expansion should not be reported without including the temperature range, grade, and source of the asphalt; (d) considering a summer night-day-night cycle of heating and cooling, the amount of shrinkage during cooling is more than the amount of expansion during heating; (e) the heating-cooling-heating-cooling cycles may cause densification of the beams; (f) the magnitude of expansions and contractions of the asphaltic concretes tested could cause cracking.

RECORD No.: 37.
AUTHOR : Lamb, Donald R.; Scott, William G.; Gietz, Robert H.; Armigo, Joe D
TITLE : Summary Roadway Failure Study No. ii. Lateral Cracking of Asphaltic Concrete
JOURNAL : Final report on highway engineering research
VOLUME No.: PB-174 323
PUBLISHER : 1967
YEAR : 36
PAGES : Wyoming Universitry, Laramie. Natural Resources Research Inst.
ABSTRACTOR: NTIS
KEYWORDS : Asphalt concrete mixtures, cracking, oxidative hardening, test road, thermal stresses, asphalt cement, coefficient of expansion, tensile strength, composition, fillers
ABSTRACT :

The report summarizes the major accomplishments in the two phases of the study. The purpose of the "Lateral Cracking of Asphaltic Concrete" phase was to examine the relationship of asphalt aging to the alteration of mix properties and to the variation in frequency of lateral cracking of asphaltic concrete pavements. At three field test sites, temperature differentials of 11 F per inch of pavement thickness were observed during the winter period. The width of artificial joints increased with decrease of pavement tmeperature. Artificial joints or weakness planes, at 5-ft spacing, were effective in controlling lateral cracking during the year of observations. At one site, subgrade friction tests were documented by measuring the horizontal force necessary to cause movement of the pavement on the subgrade. In laboratory tests, elastic modulus, ultimate strength in tension and linear thermal expansion coefficient were determined on initial and aged pavement specimens. Laboratory tests were also conducted to determine the characteristics of mixtures and asphalts recovered from pavements after varying periods of service and varying service performance. Asphalt composition changed with increasing age in pavement areas having lateral cracking. Higher degrees of hardening of asphalts occurred in pavements with high air void contents. Differences in pavement performance were related to asphalt stiffness and filler concentration. Laboratory investigations were made to characterize the temperature - dependent consistency of asphalts in combination with various concentrations of mineral fillers. Increased filler content produced increased stiffness of the resulting mixutres. (Author)

RECORD No.: 38.
AUTHOR : C. L. Monismith, G. A. Secor, and K. E. Secor
TITLE : Temperature Induced Stresses and Deformations in Asphalt Concrete
JOURNAL : Proceedings of Association of Asphalt Paving Technologists
VOLUME No.: 34
PUBLISHER : 1965
YEAR : 248-285
PAGES : Association of Asphalt Paving Technologists
ABSTRACTOR: PTI
KEYWORDS : Asphalt cement, asphalt concrete, thermal stresses, cracking, creep compliance, viscoelasticity

ABSTRACT :

In the northern section and in some desert areas of the western United States, transverse cracks have appeared in asphalt pavements, which have been attributed, at least in part, to thermal stresses that exceed the breaking strength of the asphalt concrete surface. The research study reported herein was an attempt to investigate the development of thermal stresses and deformations in asphalt concrete under controlled conditions in the laboratory and to ascertain under what circumstances, if any, the development of thermal stresses might indicate possible cracking of idealized representations of actual pavements. Utilizing the creep compliance measured for a range of temperatures from -40 F to +110 F for a particular asphalt concrete, stresses and deformations under conditions of restrained deformation and creep for varying temperatures were predicted using viscoelastic theory. Measured stresses and deformations appeared to agree reasonably well with the predicted values. Thus, the theory was extended to predict thermal stresses due to temperature changes at the surface in a slab of the same material. For temperature changes below 0 F, computed stresses at the surface of an idealized representation of an asphalt concrete pavement considerably exceeded the breaking strength for the material. Thus, it might be concluded that temperature changes, particularly in the range below 0 F, might contribute to the cracking of asphalt concrete pavements.

RECORD No.: 39.
AUTHOR : Edward M. Barrall, II, Robert J. Schmidt, and Julian F. Johnson
TITLE : Asphalt Transition at Low Temperatures: Measurements Using a Thermal Expansion Apparatus
JOURNAL : Division of Petroleum Chemistry, ACS
VOLUME No.: Preprint 9, No. 1
PUBLISHER : 1964
YEAR : B-27
PAGES : American Chemical Society
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, coefficient of thermal expansion, penetration, compositions, glass transition temperature, wax content
ABSTRACT :

An extremely sensitive and stable automatic instrument for the measurement of small changes in sample length 10-4 to 10-7 in was constructed and the design details given. The thermal expansion characteristics of three typical asphalt systems were studied with this instrument in the temperature range of -100 C to 20 C. The temperature at which the asphalt changes expansion coefficient, Tgsp, for the three asphalt systems was evaluated for five different penetration grades of each material and the expansion coefficient below Tgsp was calculated. A log-linear correlation between Tgsp (previously given by some authors as a glass transition temperature, Tg) and penetration pen number has been found for two asphalts of low wax content. The intercept of this relationship is characteristic of each system and is determined basically by the maltene type. The high wax asphalt did not follow such a relationship--presumably due to the formation of an immiscible phase at Tgsp. A linear relationship between Tgsp and asphaltene content was found for each low wax system. The Tgsp was applied to the Williams-Landel-Ferry (WLF) equation with good agreement between calculated and experimental viscosity points. This fit indicates that Tgsp and Tg are identical under certain conditions. On the basis of the WLF equation, the Tgsp or Tg is proposed as a satisfactory temperature of corresponding states for asphalt systems.

RECORD No.: 40.
AUTHOR : Task force 5 of ASTM Committee D-8 Subcommittee XV on Rheological Properties
TITLE : Measuring the Temperature Susceptibility of Asphalt Bitumens
JOURNAL : Materials Research and Standards
VOLUME No.: 1
PUBLISHER : 1961
YEAR : 981
PAGES : American Society for Testing and Materials
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, temperature susceptibility, penetration
ABSTRACT :

It is proposed to determine the ASTM penetration using 100 gms and 5 secs at 3 temperatures (e.g., 54, 77 and 100 F). Penetration values are plotted on a logarithmic scale and temperature on an arithmetic scale (semi-log paper). The slope of the smooth plot is calculated.

RECORD No.: 41.
AUTHOR : C. L. Monismith
TITLE : Effect of Temperature on the Flexibility Characteristics of Asphalt Paving Mixtures
JOURNAL : ASTM
VOLUME No.: STP277
PUBLISHER : 1960
YEAR : 89-108
PAGES : American Society for Testing and Materials
ABSTRACTOR: PTI
KEYWORDS : Ductility, viscosity, temperature susceptibility, flexibility, modules of rupture, fatigue
ABSTRACT :

This paper is concerned with the effect of variation in type, amount, and temperature of asphalt on the behavior of dense-graded paving mixtures in repeated flexure. Two 85 to 100 penetration asphalt cements: one was a paving asphalt conforming to the recently adopted uniform asphalt specifications of the Pacific Coast, the other was an air-blown asphalt that has low temperature susceptibility. The asphalts had significantly different physical properties. One aggregate was used to prepare beam specimens (3 by 12 by 2 in) with both asphalts by a kneacting compactor. To measure the property of flexibility, a flexure test using a special apparatus consisting of a spring base and a device to apply repeated loadings of short duration was developed. The load applied and the temperature of the test were varied. Data collected show that for the loadings investigated, there appears to be little difference in the behavior of mixtures prepared with two asphalts of significantly different physical properties. At 75 F, specimens prepared with the air-blown asphalt performed slightly better at the higher asphalt contents than the specimens prepared with the asphalt conforming to the recently adopted uniform specifications of the Pacific Coast. At 40 F, however, the reverse was true. The effectiveness of ductility as a criteria for flexibility, at least as measured by the particular test, is questioned. Also, since the asphalt with greater temperature susceptibility performed better than the asphalt with lower susceptibility, the requirement for the temperature susceptibility test may be questioned. Other results indicate that for dense-graded mixtures, the effect of asphalt content is pronounced, and that the deformation (strain) induced in a paving mixture would be a better criterion for determining the behavior of a paving mixture in repeated flexure than deflection alone.

RECORD No.: 42.
AUTHOR : J. Huet
TITLE : Study of the Thermal Susceptibility of the Viscosity of Bitumens
JOURNAL : Centre de Recherches Routieres (Brussels), Rapport de Recherche
VOLUME No.:
PUBLISHER : 1958
YEAR : 55 pp.
PAGES : Centre de Recherches Routieres (Brussels)
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, viscosity, temperature susceptibility, molecular theory, collidal structure
ABSTRACT :

The dependence between the coefficient of viscosity of bitumens and the temperature was experimentally examined over a range of temperatures from 50 to 150 C and for materials from the same or different origin. On the results are based a critical examination of some viscosity-temperature relationships generally accepted to represent this dependence. Two equations are finally retained: the first is a relation between the log log of the dynamical viscosity and the log of the absolute temperature, and the second is based on a plot of the log of the dynamical viscosity versus the reciprocal of the absolute temperature raised to the fourth power. These two viscosity-temperature relationships are then theoretically interpreted in terms of qualitative molecular theories of flow for concentrated solutions of polymer chains. A close examination of the data represented by the use of a plot of log log viscosity versus log absolute temperature shows that the use of two straight lines with slightly different slopes is required to give a really accurate representation. A point of intersection is observed between 75 and 100 C and suggests some change in the mechanism of flow. The slopes increase with decreasing temperature, and the observed deviations confirm, for bitumen, the hypothesis of a structure of a colloidal solution where the constituents are macromolecular particles associated by strong interactions. The lowest numerical value of the slope is obtained for the bitumen whose viscosity is the least susceptible to change with temperature. It is also shown that the thermal susceptibility of the viscosity decreases with decreasing viscosity (or increasing penetration), and this relation is true not only for bitumens from the same origin but also for bitumens from different origins.

RECORD No.: 43.
AUTHOR : S. L. Neppe
TITLE : Classification of Bitumen in Asphalt Technology by Certain Rheological Properties. Part V-Experimental and Graphical Studies Involving Changes in Penetration and Ductility with Temperature
JOURNAL : Journal of Institute Petroleum
VOLUME No.: 38
PUBLISHER : 1952
YEAR : 532
PAGES : Institute of Petroleum
ABSTRACTOR: HRB
KEYWORDS : Asphalt cement, penetration, ductility, temperature susceptibility, softening point
ABSTRACT :

Analytical data on the effect of temperature on bitumen penetration and ductility were obtained from numerous samples of progressively decreasing hardness and covering six different series of materials, viz., severely cracked, slightly cracked, and natural bitumens, each class being either steam-refined or air-blown. A new "penetration susceptibility factor" was adopted to cover the temperature range over which penetration changes from 100 to 10, while "ductility susceptibility factor" is defined as the temperature range over which ductility changes from 100 to 1. Both factors are approximately proportional to softening point number, but differ essentially from the author's other classification methods in that they are materially affected by the consistency of the bitumen. These factors should accordingly be regarded only as supplementary to softening point number of related indices. The effect of air-blowing on the natural group of bitumens is shown to be considerably more pronounced than on cracked types. Whereas log ductility is normally directly proportional to log penetration, a characteristic sharp break occurs in the curve for air-blown natural bitumens, giving two independent straight lines above and below a definite degree of hardness. Composite diagrams show simultaneously the relationship of penetration, ductility, and softening-point properties to temperature. Once the characteristics have been established for any class of material, the relevant chart can be used directly for deducing the penetration or ductility of any member of that series at any temperature. The author also establishes that there is an independent characteristic mathematical relationship for the penetration at the softening-point temperature for each series of bitumen.

RECORD No.: 44.
AUTHOR : D. C. Broome
TITLE : Temperature Susceptibility of Asphaltic Bitumen
JOURNAL : Petroleum
VOLUME No.: 1
PUBLISHER : 1940
YEAR : 126
PAGES :
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, temperature susceptibility, penetration, penetration index, Fraass breaking point, viscosity
ABSTRACT :

Reference is made to the number of methods in existence for measuring the temperature susceptibility of asphaltic bitumens, and their relative values are discussed. The American methods, based on penetrations at different temperatures, using different times and weights, are considered unsound because of the varying stresses, since many bitumens are of plastic nature. The Pfeiffer and van Doormal penetration index is based on an assumption that the penetration of the ring and ball melting point is 800, which is frequently not the case. The effect of stress is shown by a series of ductility figures carried out on different rates of pull. The Continental method of determining the plastic range by the temperature difference between the breaking point (e.g., Fraass) and the softening point is of practical value. Abraham's method, based on the penetration at 32 F and 115 F and the softening point, and Kelly's float test index suffer also from the difficulty of reconciling figures obtained at varying stresses. Considerably sounder theoretically are the number of methods based on rate of change of viscosity with absolute temperature, since it is emphasized that the viscosity determinations should be carried out at the same rate of shear. The susceptibility of bitumens is reduced by the presence of a high asphaltene content, or by mineral matter, and increased by the presence of oily constituents. The temperature susceptibility is low over the medium range for oxidized bitumens, but they frequently tend to be brittle at low temperatures and exceptionally fluid at high temperatures.

RECORD No.: 45.
AUTHOR : R. Vokac
TITLE : Some Factors Affecting the Thermal Susceptibility of Asphaltic Paving Mixtures
JOURNAL : Proceedings, American Society for Testing and Materials
VOLUME No.: 39
PUBLISHER : 1939
YEAR : 1153-1157
PAGES : American Society for Testing and Materials,
ABSTRACTOR: HRB
KEYWORDS : Asphalt concrete mixtures, temperature susceptibility, asphalt cements
ABSTRACT :

The compression test was used to measure the strength or stability of asphaltic bitumen paving mixtures because of the correlation obtained with the service performance of mixtures. Values were obtained at various temperatures with various mixtures, using a hydraulic Baldwin-Southwark compression tester. Data are given showing the influence of mixture composition on the susceptibility of compressive strength to change in temperature and in asphalt cement. Although additional filler decreases the susceptibility of a given mixture, the effect is not so evident at low temperatures, and is also markedly influenced by the source of the asphaltic bitumen. It is therefore concluded that, if bitumens from different sources are used, in order to obtain mixtures having very similar physical characteristics, such as susceptibility, strength, etc., the mixtures must be made up to suit the individual characteristics of each bitumen.

RECORD No.: 46.
AUTHOR : Gilbert, Juge-Boirard
TITLE : Logarithmic Relation Between Viscosity and Temperature
JOURNAL : Second World Petroleum Congress, Proceedings
VOLUME No.:
PUBLISHER : 1937
YEAR : 961
PAGES : World Petroleum Congresses, London
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, temperature susceptibility, viscosity
ABSTRACT :

In all temperature scales there is a linear logarithmic relation between the absolute (poises) or kinematic (stokes) viscosities and the temperature. The viscosity being represented by n, we have:

$$\log n^t = A^t \log \frac{t + C^t}{t^1 + C^t} + \log n^1$$

in the centesimal scale, symbolized by t, C^t being a constant owing to the studied sample, which is calculated by resolving graphically the equation

$$\frac{\log n^1 - \log n^2}{\log (t^1 + C^t) - \log (t^2 + C^t)} = \frac{\log n^2 - \log n^3}{\log (t^2 + C^t) - \log (t^3 + C^t)}$$

where C^t is the independent variable. In the Fahrenheit scale, symbolized by f,

$$\log n^f = A^f \log \frac{f + C^f}{f^1 + C^f} + \log n^1$$

with

$$C^f = \frac{9}{5} C^t - 32$$

In the absolute scale, symbolize by T,

$$\log n^T = A^T \log \frac{T + C}{T^1 + C} + \log n^1$$

with

C = C^T - 273

RECORD No.: 47.
AUTHOR : Lloyd F. Rader
TITLE : Correlation of Low Temperature Tests with Resistance to Cracking of Sheet Asphalt Pavements
JOURNAL : Proceedings, Association of Asphalt Paving Technologists
VOLUME No.: 29
PUBLISHER : 1936
YEAR : 29
PAGES : Association of Asphalt Paving Technologists
ABSTRACTOR: HRB
KEYWORDS : Asphalt concrete mixtures, test road, stability, modulus, cracking, penetration
ABSTRACT :

Two sheet asphalt pavements in Ann Arbor, Michigan, were selected for this study. One pavement has shown considerable resistance to cracking, while the other one has cracked badly. Laboratory tests conducted on these paving mixtures at low temperatures include modulus of rupture, modulus of elasticity in flexure, and toughness. Stability of each mixture at 140 F was also obtained by means of the Hubbard-Field Asphalt Stability Machine. Asphalt was recovered from the mixtures by means of the Abson Method. The asphalt in the pavement with resistance to cracking had an original penetration of 56 and a recovered penetration of 34. The asphalt in the cracked pavement had an original penetration of 42 and a recovered penetration of 13. Correlation of the results of low temperature tests conducted in this investigation with actual resistance to cracking of the pavements in service is indicated.

RECORD No.: 48.
AUTHOR : I. Bencowitz and E. S. Boe
TITLE : Change of Penetration with Temperature of Various Asphalts
JOURNAL : Industrial and Engineering Chem.
VOLUME No.: 8
PUBLISHER : 1936
YEAR : 157
PAGES : American Chemical Society, Easton, PA
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, temperature susceptibility, penetration
ABSTRACT :

In this investigation a simple equation, p= A + B + C^T, was found to express the variation of the penetration of 13 asphalts with the temperature. Several sources and methods of processing are represented in the asphalts that were studied. The equation can be solved when three penetrations obtained with the same weight and for the same period of time at different temperatures are known. By means of this equation, a simple index, P2-P1, was found to represent adequately the order and the relative magnitude of the temperature susceptibility of the thirteen asphalts.

RECORD No.: 49.
AUTHOR : A. Holmes, J. O. Collins, and W. C. Childs
TITLE : Measuring the Susceptibility of Asphalts to Temperature Changes
JOURNAL : Industrial and Engineering Chem.
VOLUME No.: 8
PUBLISHER : 1936
YEAR : 100
PAGES : American Chemical Society, Easton, PA
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, temperature susceptibility, penetration, softening point

ABSTRACT :

The need for some suitable means of expressing the change in consistency of asphalts over the wide range of temperature usually encountered in actual service is demonstrated. While no single factor has been developed which will adequately serve to measure the temperature susceptibility over the entire range of conditions, three methods are suggested which can be used in conjunction with one another for this purpose. The softening point-penetration index indicates the susceptibility over a narrow range of normal atmospheric temperatures, the ratio of the penetration at 25 deg C (77 deg F) to the penetration at 0 deg C (32 deg F) at subnormal and the fluidity index at elevated temperatures.

RECORD No.: 50.
AUTHOR : H. E. Schweyer, C. E. Coombs, and R. N. Traxler
TITLE : The Susceptibility of Asphalts to Temperature Change
JOURNAL : Proceedings, American Society for Testing and Materials
VOLUME No.: 26
PUBLISHER : 1936
YEAR : 531
PAGES : American Society for Testing and Materials
ABSTRACTOR: HRB
KEYWORDS : Asphalt cement, viscosity, temperature susceptibility
ABSTRACT :

The viscosity-temperature relationships of asphaltic materials are complex, and no type of equation has been found that is of practical value over a wide temperature range. However, at processing temperatures, where asphalts have viscosities ranging from 1 to 5 poises, and at service temperatures (59 to 95 deg F), a log-viscosity versus temperature plot is a straight line. For these reasons a new, simple, and logical way of expressing susceptibility based on the percentage change of viscosity for a 1 deg C rise in temperature is proposed and is called the Asphalt Viscosity Index. The indices of the various asphalts tested are greatly different in magnitude for the two temperature ranges, and the relative order of susceptibility may change.

RECORD No.: 51.
AUTHOR : L. R. Rader
TITLE : Investigations of the Physical Properties of Asphaltic Mixtures at Low Temperatures
JOURNAL : Proceedings, American Society for Testing and Materials
VOLUME No.: 35
PUBLISHER : 1935
YEAR : 559
PAGES : American Society for Testing and Materials
ABSTRACTOR: HRB
KEYWORDS : Asphalt concrete mixtures, asphalt cements, temperature susceptibility, cracking, asphalt content, compaction, penetration

ABSTRACT :

This paper describes equipment and methods of tests developed for determining modulus of rupture, modulus of elasticity in flexure, and toughness of asphaltic mixtures chilled to low temperatures. Modulus of rupture and modulus of elasticity in flexure are determined by testing a chilled beam of compressed asphaltic mixture on a 6-in span. The toughness test is conducted by testing a chilled briquet in the standard Page impact machine. The specimens are chilled using solid carbon dioxide as the refrigerant. The test results show the influence of the following variables upon the physical properties of the asphaltic mixtures at low temperatures: (a) chilling temperatures, (b) compaction of mixture, (c) percentage of asphalt, (d) origin of asphalts, (e) method of manufacture, (f) penetrations, and (g) temperature susceptibility characteristics. The stability at 140 deg F of each mixture is given. The behavior of asphaltic mixtures under load when chilled to a low temperature is discussed with respect to the cracking of asphalt pavements. Among the conclusions, it is pointed out that: (a) sheet asphalt mixtures chilled to low temperatures are brittle materials having definite load deflection curves, (b) the mixtures become stiffer and more brittle with decrease in temperature, (c) compaction is important to develop tensile strength at low temperature, (d) the use of low normal penetration bitumen tends to make mixtures stiff at low temperatures, and (e) advantageous use of low-temperature physical tests of mixtures may be made in designing asphaltic mixtures. The effect of the character, consistency and percentage of asphalt cement are as follows: (a) asphalts of high susceptibility to temperature change produce mixtures that are least resistant to cracking at low temperatures, as indicated by their high modulus of elasticity, low modulus of rupture, and low toughness; (b) source and method of refining and consistency appeared to have little relation to cracking of sheet asphalt paving mixtures, except that oxidized asphalts in general developed a somewhat higher toughness that should be advantageous from the standpoint of resistance to impact failure; (c) other factors being equal, it would appear that those mixtures containing the highest penetration asphalt and the highest percentage of asphalt consistent with the necessary stability should prove most resistant to cracking at low temperature.

IV. Moisture Damage Studies

RECORD No.: 1.
AUTHOR : P. E. Graf
TITLE : Factors Affecting Moisture Susceptibility of Asphalt Concrete Mixes
JOURNAL : Proceedings, Association of Asphalt Paving Technologists
VOLUME No.: 55
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1986
PAGES : 175-212
ABSTRACTOR: PTI
KEYWORDS : Moisture susceptibility, temperature susceptibility, pedestal tests, aggregate type, air voids, mixing temperature, additives, indirect tensile test
ABSTRACT :

Factors affecting the moisture susceptibility of asphalt aggregate mixes were examined using the freeze-thaw pedestal testing resilient modulus, and indirect tensile testing of water-conditioned laboratory-made cores. Major factors affecting performance in the pedestal test (no. of cycles to failure) include aggregate type, void content, lime addition, mixing temperature, and hot-mix storage time. Aggregate chemistry and physical properties were found to be important, but no simple correlations were found. Increased void content was found to result in sharply decreasing pedestal test life. Lime markedly improved performance when enough (at least 0.5 percent to aggregate, or <0.5 percent to asphalt) was added. Improving asphalt netting by raising temperature, holding the mix longer before compacting, or preceding the aggregates was found to help. Over 30 different asphalts were used in the tests. The asphalts were taken from 12 different sources with some at several penetrating grades. The 25 C (77 F) penetrations ranged from 18 to 220. Acid numbers also ranged widely from nil to 36. The results indicated that no obvious correlations between asphalt properties (penetration) and pedestal test cycle lives were observed. Within the same asphalt type, there is a trend toward increased cycle life with increased hardness, but the effect is minor. There is no correlation with acid number. The two poorest asphalts, in fact, have the widest difference in acid number. The best systems did have low acid numbers between nil and 0.2, but this was also true for many asphalts in the average group. The better performing asphalts have one unique feature which in some way accounts for their outstanding pedestal test performance. Their viscosity temperature plots show a marked upturn at high temperatures. The slope between 60 C (140 F) and 135 C (275 F) is much less than the slope between 25 C (77 F) and 60 C (140 F). This pattern indicates structural changes in the asphalt as the temperature is raised. Waxy asphalts have this quality, however, results indicated that not all waxy asphalts show good performance. The discontinuity in viscosity temperature behavior can be duplicated by adding 5 to 10 percent of certain polymers to a soft asphalt. The result is a several fold gain in pedestal test life. Resilient modulus and indirect tensile values were determined for mixes that had shown wide differences in the pedestal test. Retained straights confirmed the benefits of low void contents and higher mixing temperatures. However they do not duplicate the compositional

effects seen in the pedestal test. The differences are apparently due to the role of the application of leads in the two different tests. The rate is much faster in the indirect tensile test than the pedestal test.

RECORD No.: 2.
AUTHOR : Busching, Herbert W.; Corley, Gregg C.; Burati, James L. Jr.; Amirkhanian, Serji N.; Alewine, Jerry M.
TITLE : Statewide Program to Identify and Prevent Stripping Damage
JOURNAL : ASTM Special Technical Publication
VOLUME No.: 899
PUBLISHER : American Standard for Testing and Materials
YEAR : 1985
PAGES : 7-21
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cements, stripping, asphalt concrete mixes, field performance aggregates, traffic
ABSTRACT :

A statewide pavement coring and testing program was conducted in South Carolina to determine the extent and severity of asphalt pavement stripping. Information from extensive and intensive coring and testing programs identified causes of stripping so that effective measures could be developed to eliminate or minimize future damage. Stripping frequency was related to the following factors: highway, aggregate source, mix type, cross-section type, traffic group, pavement age, and presence of open-graded friction courses. Stripping was pervasive but of varying severity in all soil provinces. Results of findings from indirect tensile strength tests of pavement core layers and a visual examination are given. Strength retention of moisture-conditioned pavement core layers was measured for specimen cores obtained from the outer wheel path. (Author abstract) 9 refs.

RECORD No.: 3.
AUTHOR : Ruth, Byron E. (Ed.)
TITLE : Evaluation and Prevention of Water Damage to Asphalt Pavement Materials
JOURNAL : ASTM Special Technical Publication
VOLUME No.: 899
PUBLISHER : American Standard for Testing and Materials
YEAR : 1985
PAGES : 154
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt concrete mixtures, moisture damage, additives, evaluation methods
ABSTRACT :

This conference proceedings on 'Water Damage to Asphalt Pavement Materials' consists of 8 pages. They provide an insight into the severity of stripping, test methods of evaluation and relative effectiveness of using antistripping additives to minimize in-service stripping potential. The papers presented have been organized into three major topics: 1) Methods for identification and evaluation of stripping in highway Pavement Systems; 2) Laboratory evaluation of the effects of moisture, antistripping, additives and environmental conditioning; & 3) Recommendations for the evaluation and use of lime additives. Although test techniques and objectives are varied, there are numerous substantiating statements regarding the clauses of water damage, the methods of evaluation and the recommendations for corrective action.

RECORD No.: 4.
AUTHOR : Choquet, F.
TITLE : Characterization and Properties of Modified or Straight Bitumens for Waterproof Pavements
JOURNAL : Cent Rech Routieres Rep CR (Brussels)
VOLUME No.: 23
PUBLISHER : Cent Resch Routieres, Brussels
YEAR : 1984
PAGES : 171
ABSTRACTOR: Compendex Plus
KEYWORDS : Water proofing courses, fillers, asphalt cements, softening point, modifiers

ABSTRACT :
This study is a contribution to the problem of remedying the intrinsic causes of deterioration observed in certain waterproofing courses in mastic asphalt, particularly those which are intended as substrates for relatively horizontal layers (bridge decks and footways). To this end the characteristics have been examined of about fifty representative products used in the construction of this type of course (modified or unmodified hydrocarbon binders, polymers used in modified binders and bituminous mortars). Of twenty hydrocarbon binders, only three met the only specification currently imposed, namely that the temperature of the ring and ball softening point should be between 70 and 80 degree C. It has been demonstrated that the polymers employed play only a limited or non-existent role in the adhesion between binder and filler in waterproofing courses. This is linked to the dilution of the polymer in the maltene phase of the bitumen. 29 refs. In French.

RECORD No.: 5.
AUTHOR : Kim, Ok-Kee; Bell, C. A.; Hicks, R. G.
TITLE : Effect of Mix Conditioning on Properties of Asphaltic Mixtures
JOURNAL : Transportation Research Record
VOLUME No.: 968
PUBLISHER : Transportation Research Board
YEAR : 1984
PAGES : 86-92
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt concrete mixtures, water damage, resilient modulus, fatigue life, air voids, aggregate quality
ABSTRACT :

Recently, water-induced damage of asphalt mixtures has caused serious distress, reduced performance, and increased maintenance for pavements in Oregon. The information from tests performed at Oregon State University concerning three projects built between 1978 and 1980 was used to determine relationships between asphalt concrete pavement performance as indicated by resilient modulus, indirect tensile strength, fatigue life, and mix level of compaction for both as-compacted and conditioned samples. It was found that the rate of water-induced damage of asphalt mixtures was strongly related to aggregate quality and air void content of the mixture - the higher the air void content and the poorer the aggregate, the larger the loss of strength. 10 refs.

RECORD No.: 6.
AUTHOR : Ramaswamy, S. D.; Aziz, M. A.
TITLE : Assessment of Effect of Filler on the Stripping of Bituminous Mix
JOURNAL : Proceedings, Fourth Conference of the Road Engineering Assoc of Asia & Australasia
VOLUME No.: 3: (Material/Equipment)
PUBLISHER : Road Engineering of Asia and Australia, Kuala Lumpur, Malays
YEAR : 1983
PAGES : 159-170
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt concrete mixtures, stripping, fillers, adhesion, asphalt cement, sulphurs, Portland cement

ABSTRACT :

Road engineers have been concerned with the stripping of bituminous coating from the surface of aggregates in bituminous pavements. An investigation was carried out to determine the relative effects of different fillers in the control of the stripping. The filler used for this purpose must be able to increase the adhesive bond between the aggaregate and the bitumen and also be able to strengthen the bituminous film so that it can take more deformation before breaking. The paper describes the details of the investigation and discusses the results, emphasizing the point that filters do play an important influence on stripping problem. The study has indicated that among the various fillers used in the investigation, cement is found an effective control, whereas sulphur is found to encourage the stripping action. Refs.

RECORD No.: 7.
AUTHOR : J. A. N. Scott
TITLE : Adhesion and Disbonding Mechanisms of Asphalts Used in Highway Construction and Maintenance
JOURNAL : Proceedings of Association of Asphalt Paving Technologists
VOLUME No.: 47
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1979
PAGES : 19-48
ABSTRACTOR: PTI
KEYWORDS : Adhesion, disbonding, asphalt, mineral powders, interfacial tension, temperature, adhesion additives
ABSTRACT :

In this work the asphalt adhesion and disbonding mechanisms are considered from a chemical viewpoint, with the object of relating the observed physical phenomena to the constitutions of the participating substances and to the nature of their mutual interactions. It is postulated that these mechanisms can be usefully studied by investigating phenomena at the asphalt-stone, asphalt-water, and stone-water interfaces. Two types of asphalt were used in an experimental program to study adsorption phenomena on the surfaces of various types of mineral powders including quartz filler, limestone filler, and high surface area silicas. Toluene-diluted and undiluted asphalts were mixed with the powders at various temperatures and times. The desorbed fractions of asphalts recovered from the powders were characterized using differential infrared spectrometry, UV-visible spectrophotometry, and in some cases, vapor phase osmometry, elemental analysis, and simple gel permeation chromatography. Interfacial tension measurements were made with diluted asphalts (with toluene or kerosene) using a standard du Nouyving tensiometer. Electrophoresis was measured in a Rank MKII instrument using the flat cell, the pH value of the mineral powders/water systems were measured and the surface conductivity of thin layers deposited on glass plates was investigated. Various adsorption conditions such as powders, dehydration temperatures, and adhesion additives were studied for their effects on the adhesion-disbonding mechanisms. Analysis of results led to the following conclusions: 1. Oxygen-containing groups from asphaltene fraction molecules predominate in the asphalt fractions adsorbed on the mineral surface. The exact composition is determined by both asphalt and the mineral, together with the adsorption conditions. 2. The interaction between many types of minerals and water is frequently extensive enough to alter the pH of the surrounding water layer by several units. In turn, pH changes in microscopic water accumulations at the mineral surface can alter the type of polar groups adsorbed from the surrounding asphalt as well as their state of ionization/dissociation. 3. Disbonding of asphalt from mineral aggregate is probably due to a combination of these effects. Changes in the adsorption environment create changes in the adsorbate, leading to desorption and buildup of opposing negatively-charged electrical double layers on the mineral and asphalt surfaces. The drive to reach equilibrium leads to the uptake of more water and the physical separation

of asphalt from the mineral. 4. Adhesion additives can delay but not prevent loss of adhesion on water-sensitive surfaces. The extent of the role of additives will depend on asphalt, mineral, and contact conditions. 5. The best practical protection from adhesion loss remains the use of a good wetting agent or the addition of a material (e.g., hydrated lime) to control the adsorption of oxidized asphalt components on the water-sensitive stone.

RECORD No.: 8.
AUTHOR : Ciplijauskas, L.; Piggott, Michael R.; Woodhams, Raymond T.
TITLE : CHEMICALLY MODIFIED ASPHALTS FOR IMPROVED WET STRENGTH RETENTION.
JOURNAL : Industrial & Engineering Chemistry, Product Research and Development
VOLUME No.: 18, No. 2
PUBLISHER : American Chemical Society, Easton, PA
YEAR : 1979
PAGES : 86-91
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cements, moisture damage, modifiers, asphalt concrete mixtures, tensile strength, bending strength
ABSTRACT :

Many asphaltic paving surfaces lose most of their tensile or flexural strength when exposed to moisture for a prolonged period of time as a result of the attendant loss of adhesion between the asphaltic binder and the aggregate, a well known phenomenon frequently referred to as "water stripping". Chemical modification of the asphalt (or a portion thereof) by maleation or sulfonation attaches acidic substituents which may be subsequently neutralized by basic metal oxides such as lime or magnesium oxide. The resulting insoluble bituminous salts have been shown to impart full wet strength retention even when laboratory samples have been fully immersed in water for several months. Examples are given for compositions of chemically modified asphalts containing sand or traprock, two common aggregate types employed in the design of wear-resistant pavements. 21 refs.

RECORD No.: 9.
AUTHOR : Lehdrich, J.
TITLE : Adhesion Phenomena in Bituminous Concrete
JOURNAL : Strassen- und Tiefbau
VOLUME No.: 33, No.4
PUBLISHER :
YEAR : 1979
PAGES : 8-14
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt concrete mixtures, indirect tenstion test, aggregate types
ABSTRACT :

The splitting test has been adapted for testing asphalt concrete formulations with various types of aggregate to evaluate the adhesive strength of bitumen films to mineral matter. The results, presented in graphs and tables, allow the conclusion that there is no room for differentiation of good from bad aggregate. 11 refs. In German with English abstract.

RECORD No.: 10.
AUTHOR : H. J. Fromm
TITLE : The Mechanisms of Asphalt Stripping from Aggregate Surfaces
JOURNAL : Proceedings, Association of Asphalt Paving Technologists
VOLUME No.: 43
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1974
PAGES : 191-223
ABSTRACTOR: PTI
KEYWORDS : Asphalt cements, stripping, additives, treated surfaces, emulsification, asphalt penetration, asphalt composition
ABSTRACT :

This report describes a laboratory investigation conducted to determine how water penetrates asphalt films. Two mechanisms were studied that proved to affect stripping. One is spontaneous emulsion formation, by which water droplets migrate through the asphalt film to the base material. The other is rapture of the film by interfacial tension at an air-water-asphalt interface. A series of 11 asphalt cements that differ in their composition as well as penetration grade are used in the investigation. Since it is difficult to properly observe the stripping mechanisms in regular asphaltic concrete samples, larger surfaces were used. For this purpose, 3/4-in (20 mm) stone particles, microscope slides, and teflon strips were selected. The investigation includes using boiled and unboiled tap water, salt solutions, different additives, and pretreated glass slides. The primary results indicate that lighter asphalts (higher penetration values) had a greater tendency to strip by "roll-back" than the heavier asphalts; also, the rate of first appearance of the emulsion on the surface was dependent on the nature of the asphalt (composition) rather than the value of its consistency. There was no difference in appearance after 8 to 10 days, between samples immersed in salt water and those immersed in plain tap water, or between those on teflon and those on glass. Additive tests indicate that pretreatment of the glass slides could improve adhesion in some cases but could also be responsible for pinhole formation. The main improvement against stripping occurred when a soluble iron compound was dissolved in the asphalt. This improved adhesion, reduced stripping by "roll-back," and retarded emulsion formation. Three commercial anti-stripping additives which were tested actually increased emulsion formation. These additives enabled a better coating to be placed on the aggregate particles initially, but could lead to accelerated stripping later as the emulsion developed and penetrated the asphalt coating. Emulsion formation is a mechanism by which asphalt stripping occurs. It depends on the nature of asphalt and it can be retarded or prevented using different additives. Interfacial pulling of the asphalt, by which asphalt film may be penetrated by water, is the other mechanism. Pulling and breaking of the asphalt film at an air-water-asphalt interface was found to result in making the asphalt more vulnerable to stripping. No method was found to prevent this phenomenon.

RECORD No.: 11.
AUTHOR : Jimenez, R. A.
TITLE : TESTING FOR DEBONDING OF ASPHALT FROM AGGREGATES.
JOURNAL : Transportation Research Record
VOLUME No.: 515
PUBLISHER : Transportation Research Board
YEAR : 1974
PAGES : 1-17
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt concrete mixture, moisture damage, pore pressure, double-punch test
ABSTRACT :

This paper presents the development of new apparatus and procedure for the measurement of stripping susceptibility of asphaltic concrete. In the new method a regular Hveem specimen was water saturated at 50. 0 C. Then the specimen was subjected to repeated pore water pressure. The effect of the exposure on tensile strength was expressed as retained strength determined with a double punch procedure. The work showed that the method responded to variations in type of aggregate, cleanliness of aggregate, and asphalt content in a direction dictated by experience. 15 refs.

RECORD No.: 12.
AUTHOR : Jimenez, R. A.
TITLE : Characteristics of and Factors Influencing Bituminous Materials and Mixtures
JOURNAL : Transportation Research Record
VOLUME No.: 515
PUBLISHER : Transportation Research Board
YEAR : 1974
PAGES : 166p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt concrete mixtures, moisture damage, temperature, resilient modulus, asphalt-aggregate interaction, fatigue
ABSTRACT :

Contents: Testing for debonding of asphalt from aggregates; A laboratory test system for prediction of asphalt concrete moisture damage; Effect of temperature, freeze-thaw, and various moisture conditions on the resilient modulus of asphalt-treated mixes; Quantitative evaluation of stripping by the surface reaction test; Changes in asphalt concrete mixture, properties as affected by absorption, hardening, and temperature; Molecular interactions of asphalt in the asphalt-aggregate interface region; Storage of asphalt concrete; Service behavior of asphalt concrete: a 10-year study; Laboratory evaluation of rheological behavior of an asphalt concrete containing an SBR elastomer; Methods for predicting moduli and fatigue laws of bituminous road mixes under repeated bending; Highway materials as aggregate-binder composites; Tentative mix-design criteria for gap-graded bituminous surfaces; Mechanical properties of gap-graded asphalt concretes; Consideration of particle orientation in the compaction of asphalt concrete.

RECORD No.: 13.
AUTHOR : Oakes, D. T.; McCain, Jr, W. D.
TITLE : Improvement in the Durability of Asphaltic Pavement
JOURNAL : Mississippi State Univ., State College. Dept. of Petroleum Engineering (Final Report)
VOLUME No.: RR-8; EIRS-PTE-73-1; MSHD-RD-74-39
PUBLISHER : Mississippi State University
YEAR : 1974
PAGES : 33p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt concrete mixtures, aggregates, temperature, moisture damage, pore pressure, tensile strength, compressive strength, elasticity
ABSTRACT :

The report is a formalization of several oral and written reports to representatives of the Mississippi State Highway Department and the Federal Highway Administration over the past year. Conclusions strongly suggest that degradation of asphalt concrete is dependent on: (1) The wettability of the solid substrate (aggregate as it affects the strength of the asphalt-aggregate) bond, particularly in the presence of water, and (2) temperature as it affects both the internal pore pressure of the system and the redistribution of the asphaltic binder within the system, again the presence of water. Further, it is suggested that: Field modification of existing asphalt hot-mix plants is technically feasible and would require relatively small additional capital to apply the process in the field. It is further suggested that the deletorious effects of wettability, water, and temperature can largely be obviated by treating the surface of the aggregate to render it oleophilic (asphaltophilic). This results in a practical means of producing more durable asphalt concrete pavements. Improvement in yield value, ultimate unconfined compressive strength, elasticity and tensile strength are demonstrated.

RECORD No.: 14.
AUTHOR : E. K. Ensley
TITLE : A Study of Asphalt-Aggregate Interactions and Asphalt Molecular Interactions by Microcalorimetric Methods: Postulated Interaction Mechanism
JOURNAL : Journal of Institute of Petroleum
VOLUME No.: 59
PUBLISHER : Institute of Petroleum
YEAR : 1973
PAGES : 279-289
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, asphalt concrete mixtures, moisture damage, heat of immersion, composition, aggregates
ABSTRACT :

The interaction energies between several asphalts and aggregates were obtained by measuring the energy released when -35 + 48 mesh aggregate particles were immersed into molten asphalt. The energy released in the slow, exothermic interaction process was measured with a sensitive microcalorimeter. The paper includes typical immersion curves and a table presenting data for 40 immersion studies. Data were obtained at 130 and 150 C. The data show the effects of: temperature on asphalt-aggregate interactions, doping of the asphalt with an antistripping agent, surface treatment of the aggregate, and the presence of atmospheric oxygen. The difference in intermolecular energy of an asphalt at 150 C and at 200 C was measured using the microcalorimeter. The difference was attributed to greater association in the asphalt at 150 C than at 200 C. The report concludes with a proposed mechanism for asphalt-aggregate interactions and for asphalt-intermolecular interactions.

RECORD No.: 15.
AUTHOR : R. J. Peters
TITLE : Asphalt Cement Durability and Aggregate Interactions
JOURNAL : Report, Administration D330-282, Final Report
VOLUME No.: No.4
PUBLISHER : Arizona Highway Department, Research Division
YEAR : 1973
PAGES :
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, asphalt concrete mixtures, moisture damage, viscosity, oxidative hardening, composition
ABSTRACT :

A laboratory study of adhesion and durability of road mixes is reported. Adhesion was evaluated by measuring the effect of water on properties of compacted bituminous mixtures; durability was evaluated by measuring the effect of heat and air on moving films of asphalt. The research indicated, among other things, that (1) asphalts can be blended together to achieve practically any desirable viscosity or aging index or combination of both; (2) viscosity of asphalts alone did not improve adhesive qualities; (3) the second accidifin fraction (Rostler A fraction) of an asphalt is the most important fraction in the improvement of durability; and (4) asphaltenes contribute the most towards structural strength.

RECORD No.: 16.
AUTHOR : Jimenez, R. A.
TITLE : Testing for Debonding of Asphalt from Aggregates
JOURNAL : Arizona State Highway Dept., Phoenix Research Division (Final Report)
VOLUME No.: AHD-RD-10-123
PUBLISHER : Arizona State Highway Department
YEAR : 1973
PAGES : 59p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt concrete mixtures, moisutre damage, pore water pressure, tensile strength, asphalt content, aggregate type

ABSTRACT :
The report presents the development of new apparatus and procedure for the measurement of stripping susceptibility of asphaltic concrete. In the new method a regular Hveem specimen was water saturated at 122F. Then the specimen was subjected to repeated pore water pressure. The effects of the exposure on tensile strength was expressed as retained strength determined with a double punch procedure. The work showed that the method responded to variations in type of aggregate, cleanliness of aggregate, and asphalt content in a direction dictated by experience. Comparative results with the immersion compression test are presented.

RECORD No.: 17.
AUTHOR : E. C. Brown, and R. A. Kuntze
TITLE : A Study of Stripping in Asphalt Pavements
JOURNAL : Ontario Research Foundation for Ontario Department of Transportation and Communications
VOLUME No.: DTC Report No. RR177
PUBLISHER : Ontario Research Foundation
YEAR : 1972
PAGES : 36
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, asphalt concrete mixtures, peeling, moisture damage, detachment, interfacial tension, differential thermal analysis, adhesion

ABSTRACT :

Stripping of asphalt from surfaces was investigated using the following techniques: 1) peeling of asphalt films from the substrate, 2) water stripping of asphalt films between glass plates, 3) rate of detachment of asphalt from aggregate chips by water action, 4) bond strength measurements of lap joints of asphalt-substrate systems, 5) visual and attenuated total reflectance spectroscopic examination of asphalt surfaces previously in contact with Teflon tape and aged under various aqueous solutions, 6) measurement of asphalt-water and aggregate-water interfacial tension using the Wilhelmy plate method, and 7) differential thermal analysis of asphalt-aggregate mixtures and stripped asphalt residues. From this diverse attack on asphalt-aggregate interactions, several conclusions were drawn: a) thinner asphalt films appeared to increase slightly in peeling strength until the thickness was reduced to about 10 microns (a critical thickness, below which their peeling resistance decreased rapidly as they became thinner); b) smooth substrate surfaces water stripped more slowly and healed more rapidly than rough ones; c) heavy or transition metal salts, especially those of iron, chromium, lead, and zinc, decreased stripping rates; d) substrate surface treatment, i.e. with chromium or iron ions, could be beneficial; e) commercial wetting agents in the asphalts decreased stripping rates, but not appreciably; and f) stripping is decreased somewhat by additives with high molecular weights and polar substituents, and by the removal of low molecular weight components with vacuum pre-treatment of the asphalt.

RECORD No.: 18.
AUTHOR : C. Crawford
TITLE : Facing the Facts about Adhesion
JOURNAL : Openbare Werke Paaie en Vervoer/Roads and Transport
VOLUME No.:
PUBLISHER :
YEAR : 1972
PAGES : 15-17
ABSTRACTOR: HRB
KEYWORDS : Asphalt concretes, moisture damage, adhesion, sonic, ultrasonic, aggregates
ABSTRACT :

This article is mainly devoted to adhesion tests. Three types of destructive tests (the plaque test, the Reidel and Weber test, and the NIRR Cc/10 test) are described and compared. Nondestructive sonic and ultrasonic tests are briefly mentioned, the mechanism of adhesion agents is discussed, and the need for dry, dust-free aggregates is emphasized.

RECORD No.: 19.
AUTHOR : E. K. Ensley, and H. A. Scholz
TITLE : A Study of Asphalt-Aggregate Interactions by Heat of Immersion
JOURNAL : Journal of Institute of Petroleum
VOLUME No.: 58, No. 560
PUBLISHER : Institute of Petroleum
YEAR : 1972
PAGES : 95-101
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, heat of immersion, interaction, adhesion
ABSTRACT :

A microcalorimeter was used to study the heat of immersion of aggregates into asphalts. The rate of energy released from the asphalt-aggregate interaction reaches a maximum within 10 minutes after immersion and gradually decreases until a steady flow results. The energy released is many times greater than that which would be predicted on the basis of immersion data of known systems. A comparison of results obtained in this work with reported strip test data suggests a correlation between heat of immersion and adhesive performance. Two mechanisms are proposed in an attempt to interpret the immersion curves.

RECORD No.: 20.
AUTHOR : D. W. McGlashan
TITLE : Asphalt Durability and Its Relation to Pavement Performance Adhesion
JOURNAL : Montana College of Mineral Science and Technology, NCHRP Contract HR9-2, Terminal Report
VOLUME No.:
PUBLISHER : Montana College of Mineral Science and Technology
YEAR : 1972
PAGES : 111-120
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, moisture damage, aggregate interaction, pressure flows, temperature adhesion
ABSTRACT :

Asphalt-aggregate interactions were studied by streaming potential measurements. Asphalts were pressure-flowed through aggregate plugs over a wide pressure and temperature range and curves of streaming potential (E)/flow pressure (P) vs. temperature (T) were plotted. Although little theoretical discussion is presented supporting the type of plot used, the compatibility of asphalts and aggregates was evaluated from the maxima in the E/P vs. T curves. It was postulated that those with highest maxima formed strongest asphalt-aggregate bonds. Of particular importance was one study which showed an E/P vs. T curve to be highly time-dependent.

RECORD No.: 21.
AUTHOR : Schmidt, R. J.; Graf, P. E.
TITLE : The Effect of Water on the Resilient Modulus of Asphalt-Treated Mixes
JOURNAL : Proceedings, Association of Asphalt Paving Technologists
VOLUME No.: 41
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1972
PAGES : 118-162
ABSTRACTOR: HRB
KEYWORDS : Asphalt concrete mixture, moisture damage, asphalt cements, penetration, resilient modulus, asphalt content
ABSTRACT :

The effects of water on the resilient modulus of a number of asphalt-aggregate systems were investigated by measuring strain displacements in a nondestructive test using a diametrical resilient modulus testing device. Other variables considered in the study included temperature, exposure time, percent asphalt, asphalt and aggregate types, and asphalt and aggregate pretreatments. With all aggregates tested except pure silica and pure calcite, large drops in modulus were seen on exposure to moisture. Most asphalts behaved similarly in the presence of moisture. Mixes with higher asphalt content showed less change in resilient modulus on exposure to moisture. Both the rate and magnitude of decrease of resilient modulus of mixes in the presence of moisture increased with an increase in temperature. Lime slurry pre-treatment (1 percent or more) was effective in increasing resilient modulus and reducing effects of moisture on modulus.

RECORD No.: 22.
AUTHOR : H. Kunath
TITLE : Critical Consideration of the Accepted Methods of Evaluating the Adhesion of Bituminous Binders
JOURNAL : Strasse - Berlin
VOLUME No.: 11, No. 4
PUBLISHER :
YEAR : 1971
PAGES : 190-194
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, adhesion, moisture damage, test methods
ABSTRACT :

Details are given of the results of tests carried out at the University of Dresden into the accuracy of the two standard methods of test currently used in the German Democratic Republic to evaluate the adhesion of bituminous binders. It was established that the present standards could be improved by slight modifications, but that more research is required before the effect of water on bituminous mixtures can be accurately established.

RECORD No.: 23.
AUTHOR : R. P. Lottman
TITLE : Debonding Within Water-Saturated Asphalt Concrete Due to Cyclic Effects
JOURNAL : American Chemical Society, Preprints, Division of Petroleum Chemistry
VOLUME No.: 16, No. 1
PUBLISHER : American Chemical Society
YEAR : 1971
PAGES : 146-155
ABSTRACTOR: HRB
KEYWORDS : Asphalt concrete, mixture, moisture damage, thermal stresses, pressure, adhesion
ABSTRACT :

The asphalt-aggregate interfacial bond strength is a function of both the characteristics of the asphalt and aggregate when the asphalt concrete is water-saturated. Current research implies that standard tests do not detect the moderately weak interfaces in the presence of water. Therefore, the purpose of the paper is to present test observations from current research and probable mechanisms for the destructions of the moderately weak interfacial bond. Observations indicate that the differential thermal expansions produced by temperature change produce pressures in the void water of asphalt concrete leading to interfacial failure. External cyclic stresses also produce interfacial failure.

RECORD No.: 24.
AUTHOR : J. Schmidt, and A. Schniering
TITLE : The Adhesion of Bituminous Binders to Aggregates Under Hydrodynamic Stress, and Ultrasonic Testing in Solutions of De-Icing Salt
JOURNAL : Str. Verkehrstechnik, Godesberg
VOLUME No.: 22, No. 12
PUBLISHER :
YEAR : 1971
PAGES : 550-554
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, moisture damage, de-icing salt, ultrasonic
ABSTRACT :

A laboratory method is described which enables the determination of the decrease in binder content after hydrodynamic stress. A bituminous sample is placed in a solution of de-icing salt and exposed to ultrasonic waves. This causes particles of the binder to dissolve. Two interesting results are: 1) the amount of binder which dissolves increases as the salt concentration increases; and 2) the increase in the dissolving of the binder is significantly different for each of the binders used.

RECORD No.: 25.
AUTHOR : Lottman, Robert P.
TITLE : The Moisture Mechanism that Causes Asphalt Stripping in Asphaltic Pavement Mixtures
JOURNAL : Research Report
VOLUME No.: Final Report
PUBLISHER : Idaho University, Moscow. Engineering Experiment Station.
YEAR : 1971
PAGES : 154p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt concrete mixtures, moisture damage, tensile strength, temperatures, rate of deformation, fatigue testing pressure
ABSTRACT :

The report shows a laboratory test method for the prediction of stripping (asphalt-aggregate debonding) in saturated asphalt concrete mixtures. The method utilizes 4-inch diameter field cores or laboratory specimens, and consists of evaluating split cylinder test results (tensile strengths) on pair-groups of specimens in which some specimens from the same group are thermal cycled in a saturated condition (to duplicate field stripping conditions) and others are maintained in a dry state before testing. The report also includes the development of an optimum set of split cylinder test conditions: rate of deformation and temperature. In addition, a 'tensile strength ratio,' called TSR, was used to quantify the amount of stripping and to rank mixtures. The report summarizes the first work done in the study including fatigue tests on saturated laboratory specimens, static tests under free water and high humidity conditions, supplementary tests to determine internal pressures from temperature change, and an approach to pressure-force relationships for adhesion breakdown. (Author)

RECORD No.: 26.
AUTHOR : E. K. Averbakh, A. R. Darydova, and E. D. Yakhnin
TITLE : Adhesion of Aggregate Particles to Bitumens
JOURNAL : Tr. Gos. Vses. Dorozh, Nauch
VOLUME No.: 46
PUBLISHER :
YEAR : 1970
PAGES : 115-123
ABSTRACTOR: HRB
KEYWORDS : Asphalt cement, adhesion, centrifugal testing, time effects
ABSTRACT :

Centrifugal force was used to characterize the adhesion force between glass or marble beams and bitumen. The adhesion force increased with the time that the asphalt was in contact with the beads prior to centrifugal testing. Even after a contact time of 15 days the adhesion force had not reached a final value.

RECORD No.: 27.
AUTHOR : P. D. Cratin
TITLE : Interfacial Behavior of Asphaltenes
JOURNAL : Highway Research Record
VOLUME No.: No. 340
PUBLISHER : Highway Research Board
YEAR : 1970
PAGES : 29-37
ABSTRACTOR: HRB
KEYWORDS : Asphalt cement, adhesion, asphaltenes, composition, interfacial tension, pH value
ABSTRACT :

Interfacial tension measurements were made at an interface between an aqueous phase and an organic phase containing dissolved asphaltenes. The interfacial tension was determined over a wide range of pH values of the aqueous phase. It was observed that the interfacial tension is highest in the pH range 4-8 and falls off drastically on both sides of the pH. From the data it was concluded that the asphaltenes have amphoteric characteristics.

RECORD No.: 28.
AUTHOR : E. K. Ensley, and A. H. Scholz
TITLE : An Investigation of Asphalt-Aggregate Adhesion by Measurements of Heats of Immersion
JOURNAL : Highway Research Record
VOLUME No.: No. 340
PUBLISHER : Highway Research Board
YEAR : 1970
PAGES : 38-44
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, adhesion, heat of immersion, aggregates, composition
ABSTRACT :

The problems of studying asphalt-aggregate adhesion and the relation between adhesion and heats of immersion are discussed. The construction of a microcalorimeter and its application in measuring the energy of interaction between road asphalts and aggregates are described. Experimental heat of immersion curves are presented on quartz, calcite, a phosphate slag, and four Montana aggregates used with a commercial asphalt. The effect of an antistripping agent on heats of immersion was evaluated.

RECORD No.: 29.
AUTHOR : D. McNeil
TITLE : Tar-Bitumen Mixtures as Surface Dressing Binders
JOURNAL : Road Tar
VOLUME No.: 24, No. 2
PUBLISHER : British Road Tar Association
YEAR : 1970
PAGES : 4-7
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, aggregates, adhesion, temperature, impact tests, tars, oxidative hardening, viscoelastic properties
ABSTRACT :

The energy required to break the bond between stone and tar or bitumen at various temperatures was investigated using sharp impact tests. Results indicate the viscoelastic properties of bitumen are less temperature sensitive than tar. It was found that mixtures of tar and bitumen combine the superior viscoelastic properties of bitumen with the superior wetting, antistripping, and weathering characteristics of tar to produce a strong bond.

RECORD No.: 30.
AUTHOR : J. E. Lukens
TITLE : A Theoretical Analysis of the Asphalt-Water-Aggregate System and Explanation for the Stripping Problem
JOURNAL : Dissertation Abstracts International
VOLUME No.: 30
PUBLISHER : Cornell University
YEAR : 1969
PAGES : 636-B
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, aggregates, adhesion, thermodynamics, contact angle
ABSTRACT :

This thesis is an investigation of the physicochemical nature of asphalt-aggregate adhesion and draws heavily on interfacial energy investigations from 1927 by F. E. Bartell and co-workers. It is reported that the contact angle, Owo; was constant for all organic liquids which formed a constant angle with water on any given solid surface, and that Owo was found constant for kerosine, crude oil, and by extension, for asphalt. Each mineral aggregate possesses its characteristic value for Owo, which reportedly is related to stripping resistance. The effects of antistripping agents are discussed.

RECORD No.: 31.
AUTHOR : Majidzadeh, K.
TITLE : Rheological Aspects of Aging-2
JOURNAL : Nat Acad Sciences-Nat Research Council-Highway Research Rec
VOLUME No.: 273
PUBLISHER : HRB
YEAR : 1969
PAGES : 28-41
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cements, oxidative hardening, viscoelastic model parameters, creep compliance, asphalt-sand mixes, activation energy
ABSTRACT :

Effect of aging of asphaltic binder on rheological response of sand-asphalt mixtures is studied; experiment and method of analysis follow procedures outlined in earlier report indexed in Engineering Index 1968 p 2651; Creep response of sand-asphalts at various temperatures and aging were analyzed, and viscoelastic model parameter and overall response were related to asphalt aging index; analysis of activation energy was carried out. 14 refs.

RECORD No.: 32.
AUTHOR : K. Majidzadeh and F. M. Brovold
TITLE : State of the Art: Effect of Water on Bitumen-Aggregate Mixtures
JOURNAL : Highway Research Record
VOLUME No.: Special Report No. 98
PUBLISHER : Highway Research Board
YEAR : 1968
PAGES : 77
ABSTRACTOR: HRB
KEYWORDS : Asphalt cement, asphalt concrete mixture, moisture damage, adhesion, peeling tests, rheology, ultrasonic, sonic, review
ABSTRACT :

This paper presents a comprehensive review and evaluation of the literature on the effects of water and moisture on bituminous mixes, covering the period prior to 1966.

RECORD No.: 33.
AUTHOR : F. C. Gzemski, D. W. McGlashan, W. L. Dolch
TITLE : Thermodynamic Aspects of the Stripping Problem
JOURNAL : Highway Research Circular
VOLUME No.: No. 78
PUBLISHER : HRB
YEAR : 1968
PAGES : 77
ABSTRACTOR: PTI
KEYWORDS : Asphalt concrete, stripping, moisture damage, thermodynamics, interfacial tension
ABSTRACT :

The report presents a review of the literature on the question of stripping of binder from aggregates in bituminous mixtures. The information concerns mostly the thermodynamic approach to the stripping problem. Axiomatic to the usual concept of stripping is the presence of a three-phase interface, consisting of aggregate, bitumen, and water. This report is concerned chiefly with the processes that occur once the three-phase interface is formed. The binder can be spontaneously removed from the aggregate surface by a "roll-back" mechanism or a lift-off mechanism. Apparently, according to experience, the roll-back mechanism is the one usually encountered. Whenever unit area of a surface or interface is created, the system absorbs energy equal to the free surface energy or surface tension of the interface in question. When an interface is destroyed, the corresponding energy is released by the system. For unit change in the aggregate-water interfaces depicted above, the free energy changes are as follows. For the roll back: For the lift-off case: where the 's are the appropriate interfacial tensions, A=aggregate, W=water, and B=bitumen, and C is the area of bitumen-water interface destroyed per unit change of the area of the other two interfaces and is smaller than 1. f the free energy changes given in (1) and (2) are negative, the process can occur spontaneously. Whether it will occur or not involves rate questions. Equations (1) and (2) show that, other things being equal, the roll-back case of stripping is more likely than the lift-off case. Thus, a chief problem in the thermodynamic approach is the accurate knowledge of the interfacial tensions involved. Among the difficulties in measuring the interfacial tensions is the slowness of liquids of such high viscosity as bituminous materials to assume equilibrium. Some workers, to circumvent this difficulty, have used hydrocarbon liquids of lower viscosities and assumed their other properties to be equivalent to those of the substituted bitumens. The accuracy of this assumption is debatable. Studies measuring the surface tension of bitumen indicate that the same general sort of hydrocarbon structure is presented at the surface by molecular orientation in asphalts that have considerable compositional variability. This is the same conclusion that has been reached for lower hydrocarbons. For the bitumen-water, aggregate-water, and aggregate-bitumen interfacial tensions there is less agreement on their values. While the measurement of the interfacial tensions themselves is difficult, it is easier and relatively unambiguous to determine the difference between the AW and AB interfacial tensions. The classical equation of Young is where is the equilibrium contact angle at the three-phase interface. However this contact angle is notoriously hard to measure accurately. Of the various methods available, the tilting plate and sessile drop seem to be well adapted to the problem. Surface roughness is also important to the stripping problem. It affects the thermodynamic considerations of stripping. Partial wetting with failure to penetrate into surface crevices may be either a metastable or an equilibrium state. There has been considerable work done and some partial success with surface active additives introduced to prevent stripping. Their chief function seems to be to change the interfacial tensions by adsorption at the interfaces so as to make F more positive and, therefore, stripping less likely. Field experience has shown traffic to be an important variable in stripping. The exact role played by traffic is less clear. It may be a mechanical breaking away of films of binder already loosened from the aggregate surface by spontaneous stripping action. Also, it may prevent the self-healing of a pavement that would otherwise occur when it dries out. Pumping action by which tires cause movement of water in a wet pavement has also been considered an important effect of traffic. All that can be concluded here is that the extent to which the problem should be approached by thermodynamics and, alternately, by adhesion mechanics cannot be determined from current knowledge.

RECORD No.: 34.
AUTHOR : Majidzadeh, Kamran
TITLE : Stripping in Hot-Mixed Sand-Asphalt Mixtures
JOURNAL : Research Report.
VOLUME No.: Final Report
PUBLISHER : Ohio State University, Columbus. Transportation Research Center.
YEAR : 1968
PAGES : 45p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt-sand mixtures, moisture damage, adhesion, hydrostatic pressures, additives,air voids
ABSTRACT .:

The paper reviews the fundamental concepts relating to adhesion and the stripping phenomena in bituminous mixtures. In this study, saturated sand-asphalt mixtures are subjected to repeated trial and hydrostatic pressure and the reduction in the unconfined compressive strength due to the effect of water is investigated. The study shows the improved characteristics of the sand-asphalt mixture containing an antistripping agent and the mixture with less air voids. It is pointed out that reduction in void content either by compaction or by a change in mixture composition can be used as a preventive measure in the field. The study demonstrates an improved test and preconditioning procedure for the investigation of the effect of water or bituminous mixtures. (BPR Abstract)

RECORD No.: 35.
AUTHOR : Majidzadeh, Kamran; Stander, Jr, R. R.
TITLE : Stripping in Hot - Mixed Sand Asphalt Mixtures
JOURNAL : Research Report
VOLUME No.: 0997
PUBLISHER : Ohio State University, Columbus. Dept. of Civil Engineering
YEAR : 1967
PAGES : 49p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt-sand mixtures, moisture damage, stripping, creep response, dynamic conditioning, rheoloigcal models
ABSTRACT :

In the report an attempt is made to search for the causes of stripping observed in hot-mix sand-asphalt paving mixtures, and to develop a realistic hypothesis and testing procedure for evaluation of stripping characteristics in these mixtures. The investigation describes specific road failures related to the stripping phenomena and the shortcomings of standard laboratory tests as applied to these problems. To duplicate field conditions, a dynamic preconditioning method was devised in which samples were subjected to specified numbers of load repetitions prior to testing for compressive strength to be drastically reduced by dynamic preconditioning. The creep responses were less consistent due to differences in the strain history of creep samples. Further investigations are needed to develop acceptable rheological models for describing stripping phenomena. (Author)

RECORD No.: 36.
AUTHOR : J. J. Bikerman
TITLE : Adhesion of Asphalt to Stone
JOURNAL : Journal of Material
VOLUME No.: 1, No. 1
PUBLISHER :
YEAR : 1966
PAGES : 34-47
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, adhesion, peeling test, scraping test, rheology, steric hardening, oxidative hardening, water damage, aggregates

ABSTRACT :

A scraping test was used to determine conditions for forming a proper joint between asphalt and stone. A peeling test was used to show that the adhesion of composites of stone, asphalt and aluminum-foil ribbon follow the rheological theory of adhesion. The scraping test showed that adhesion was independent of application temperatures but strongly dependent on surface area. The peeling test showed that the peeling rate and the amount of asphalt left on the stone were dependent on peeling tension and temperature. A study of the effect of time on adhesion of asphalt to aggregate under water showed that there was very little adhesion initially, but that with aging adhesion increased and then leveled off. Rate of displacement appeared to be different for granite and marble.

RECORD No.: 37.
AUTHOR : R. P. Wellman
TITLE : Study of the Electro-Chemical Reactions in an Aggregate-Asphalt System; Final Report
JOURNAL : Research Report
VOLUME No.: Final Report
PUBLISHER : Montana State Highway Commission
YEAR : 1966
PAGES : 274 pp.
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, adhesion, composition, aggregates, viscosity, free energy of activation, dielectric constant, polarity

ABSTRACT :

Studies of asphalt composition and the adhesion of asphalt to aggregate are summarized. The studies were designed to develop an adhesion theory--based on hydrogen bonding and such related phenomena as viscosity, free energy of activation, and electric properties--and to explain the mechanism involved in adhesion and stripping in asphalt-aggregate systems. Average hydrogen-bonding energies were determined from viscosity data. Bonding energies for polar groups were determined from dielectric constant measurements. It was postulated that surface acidity and basicity were related to the activation energy of adsorption. Activation energy of adsorption was related to polarizability; this was investigated using a polarography. A good relationship was found between aggregate adsorption and stripping resistance, using the concept of Lewis acidity and basicity.

RECORD No.: 38.
AUTHOR : Wellman, Robert P.
TITLE : Study of the Electro-Chemical Reactions in an Aggregate-Asphalt System
JOURNAL : Materials Division (Final Report)
VOLUME No.: 847
PUBLISHER : Montana State Highway Department, Materials Division
YEAR : 1966
PAGES : 284p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt cements, adhesion, composition, viscosity, free energy of activiation, moisture damage, asphalt concrete mixtures, additives

ABSTRACT :

The report summarizes work done in several studies relating to asphalt composition and to the adhesion of asphalt to aggregate. The primary purpose of the studies was to develop an adhesion theory based on hydrogen bonding and related phenomena, such as viscosity, free energy of activation and dielectric properties, to explain the mechanism involved in adhesion and stripping in asphalt-aggregate systems. Also described is work done in attempting to develop a quantitative method for additives in asphalts from infra-red spectra. Average hydrogen bonding energies were estimated for 70/85 grade asphalts and for cutbacks in terms of Gibbs Free Energy of Activation determined from viscosity data using the Eyring Transport Theory. Bonding energy for polar groups in an SC-5 was determined from Dielectric Constant measurements over a range of temperatures. Infra-red analyses were made on asphalts and components of asphalts obtained by the Marcusson and by the Traxler-Schweyer fractionation methods. The results lead to the conclusion that adsorption measurements can serve to classify aggregate surfaces as to Lewis Acidity or Basicity. It was not possible to determine activation energies because of deficiencies in equipment and temperature control. Aggregate-asphalt interactions were studied by use of a standard stripping test and adsorption data in the light of the Lewis Acid concepts. A fairly good relation was found between aggregate adsorption and stripping resistance and with the acidity concepts, for the asphalts with and without additive. (Author)

RECORD No.: 39.
AUTHOR : Skog, J.
TITLE : Durability of Paving Asphalt. Part III. Evaluation of the Thelen Sphericity Test for Measuring the Adhesion Characteristics of Paving Grade Asphalts in the Presence of Water
JOURNAL : Resaerch Report
VOLUME No.: M/R-633134-3
PUBLISHER : California State Division of Highways, Material reseach Dept.
YEAR : 1966
PAGES : 26p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt cements, moisture damange, stripping, adhesion
ABSTRACT :

One of the tests developed for routine control of asphaltic binder susceptibility to stripping in the presence of water is the Thelen Sphericity Index. This test measures the degree of adhesion of an asphalt to pyrex glass in the presence of water. A tentative relation was found between the sphericity index, as measured by the test, and the percentage of stripping as measured by the dye stripping technique. The method did not provide satisfactory repeatability. Further studies of the various factors affecting the test repeatability were performed. However, these studies did not provide repeatable results and the adhesion test was abandoned.

RECORD No.: 40.
AUTHOR : P. J. Desio
TITLE : Further Tests of Asphalt-Stone Adhesion and Its Water Sensitivity
JOURNAL : Research Report, No. R65-49, Massachusetts Institute of Technology
VOLUME No.: R65-49
PUBLISHER : MIT, Department of Civil Engineering
YEAR : 1965
PAGES :
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, peeling test, adhesion, moisture damage
ABSTRACT :

This paper presents the details of a peeling test used to measure asphalt-stone adhesion and water sensitivity.

RECORD No.: 41.
AUTHOR : H. Karius and G. L. Dalton
TITLE : 'Detachment' of the Stone from the Binder Under the Influence of Water in Road Surface Dressings
JOURNAL : Journal of the Institute of Petroleum
VOLUME No.: Vol. 40, No. 481
PUBLISHER : Institute of Petroleum
YEAR : 1964
PAGES : 1-114
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, asphalt concrete mixtures, moisture damage, composition, adhesion, matter permeability, detachment test, additives

ABSTRACT :

Failures of bituminous surface dressings as a result of displacement of the binder from the stone can occur even when these surfacings have been laid under dry conditions and good initial adhesion is obtained, if rain falls shortly after laying. Diffusion of water through the binder film can also cause detachment of the binder from the stone even months or years after the surface is laid. Laboratory and road tests have indicated that the danger of water displacing the binder from the stone can be avoided or at least reduced by using adhesion agents in the binder, or by precoating the aggregate with various materials. The factors determining the adhesion of binder to stone in the presence of water are briefly discussed. Attempts to correlate the chemical composition of the binders and of the aggregates with their adhesion behavior have so far not been convincing. It does appear, however, that the total acid content of the bitumens may be of importance. A special detachment test, which has been developed to determine the efficacy of various agents in preventing detachment, is described. The performance of all the agents tested depends on the type of stone and the type of binder used. The efficacy of the various commercially available cationic adhesion agents varies considerably. Pre-coating the aggregate with solutions of tar, bitumen, silicones, and metal salts often improved adhesion as much as the use of cationic adhesion agents. Precoating the stone with 1 percent bitumen or tar at 250 degrees secured 100 percent adhesion with all types of aggregate. The heat stability of the cationic agents was tested using the immersion tray test. Results show the heat stability of the agents to depend to a large degree on the type of binder in which they are used. Details of road experiments are given, and the correlation between the detachment test results and road performance indicates that the detachment test may become a useful tool in choosing the best adhesion agent for a certain binder-stone combination to prevent subsequent displacement of the binder from the stone after laying in dry conditions.

RECORD No.: 42.
AUTHOR : R. I. Hughes, D. R. Lamb, and O. Pordes
TITLE : Adhesion in Bitumen Macadam
JOURNAL : Journal of Applied Chemistry
VOLUME No.: 10, Part 11
PUBLISHER : Society of Chemical Industry, London
YEAR : 1960
PAGES : 433-444
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, adhesion, cohesion, detachment, traffic, additives, aggregates

ABSTRACT :

Loss of adhesion between a bituminous binder and stone in the presence of water may take place by the retraction of the binder. It is suggested that this only occurs when the viscosity of the binder is low. When loss of cohesion occurs in a carpet, it more normally originates from the accumulation of water at the binder-stone interface leading to a condition in which the binder may be peeled cleanly away from the stone surface. (This detachment occurs equally with bitumens and tars. Under traffic stresses, this may lead to the loss of cohesion which, on rare occasions, sometimes leads to surface disintegration.) Pretreatment of the mineral surface with certain metal salts may delay the initial state of detachment for several months, whereas this state cannot be prevented or delayed for more than a few days by the addition of wetting additives to the binder. Such additives, however, may modify the subsequent degree of detachment and very much reduce the loss of cohesion which may follow under the action of traffic. Loss of cohesion in these circumstances can also be reduced by the presence in the binder of components which have no positive wetting tendency but confer a certain interfacial rigidity.

RECORD No.: 43.
AUTHOR : W. Riedel
TITLE : Adhesive Power of Bitumen Binders
JOURNAL : Bitumen, Terre, Asphalte, Peche
VOLUME No.: 10
PUBLISHER : Bitumen, Terre, Asphalte, Peche, Isevnhagen, Germany
YEAR : 1959
PAGES : 214
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, adhesion, cohesion, viscosity, ductility, water penetration, cleavage, temperature
ABSTRACT :

A binder which may conform to regulation may fail in practice through inadequate adhesive properties. Perfecting methods for estimating adhesive properties, chip-binding capacity, and fixing limit value and minimum requirements regarding these properties, is of considerable practical importance when new building materials are to be introduced. Various binder properties defined and discussed are: adhesion, cohesion, viscosity, and ductility. Resistance to water pen is important. Causes and effects of stresses taken up by binders are disclosed. Tar-bitumen mixtures in various ratios are taken as suitable for ductility and cleavage strength tests in relation to temperature. Results are presented in charts.

RECORD No.: 44.
AUTHOR : D. H. Mathews
TITLE : Adhesion in Bituminous Road Materials: A Survey of Present Knowledge
JOURNAL : Journal of Institute of Petroleum
VOLUME No.: 44
PUBLISHER : Institute of Petroleum
YEAR : 1958
PAGES : 423
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, adhesion, asphalt concrete mixtures, additives
ABSTRACT :

The extent of present knowledge on adhesion in bituminous materials is surveyed. Much of the material for the survey has been provided by the literature listed in Road Research Laboratory Library Bibliography No. 81, April 1957 (Road Research Laboratory, D.S.I.R., Harmondsworth, Middlesex), although some additional material is also reviewed. The subjects covered include adhesivity in the absence of water, factors affecting adhesion in bituminous road materials, the physico-chemical properties of the system water-stone-binder, adhesion tests, and the effect of additives on adhesion. The final section of the survey reviews those aspects of the subject on which further information is required to complete the general picture of adhesion in bituminous materials.

RECORD No.: 45.
AUTHOR : Anon
TITLE : Stripping Bitumen from Aggregate: Use of Plate Test
JOURNAL : Research Report
VOLUME No.: 20, No. 4
PUBLISHER : Department of Main Roads, New South Wales, Main Roads
YEAR : 1955
PAGES : 123
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, stripping, moisture damage, field performance, plate test additives, asphalt concrete mixtures

ABSTRACT :

Under the title "Stripping Bitumen from Aggregate," an article in the March 1952 issue of "Main Roads" gave particulars of the experience of the Department of Main Roads with the problem of bituminous binders being stripped from aggregate in the presence of water. Investigations up to that time had been based on the immersion-compression test developed by the Bureau of Public Roads in the United States. Details of this test were given and several tentative conclusions were listed. Shortly after this time some erratic results with certain aggregates indicated that, while the immersion-compression test seemed suitable for checking the hydrophilic properties of aggregates used in densely graded bituminous mixes, it was not wholly reliable for testing some aggregates used as surface dressings. This article describes difficulties encountered in using the immersion-compression test, the development of an alternative method of testing, and some particulars of recent experiences with the testing of various aggregate-bitumen combinations with and without the addition of antistripping agents. A plate test was developed which was based largely on procedures adopted by authorities in Australia and overseas. The procedure currently used by the Department of Main Roads for this test is fully described. It is difficult to obtain a precise correlation between the results of this test and field service, and until further information in this respect is available, the results can be regarded as indicative only. A few cases of failure, apparently due to hydrophilic action, have been closely investigated and in each instance the plate test showed good correlation with the field observations. Although the stage has not been reached where definite conclusions can be stated, work with the plate test confirms in a general way the following conclusions: (1) the "stripping" behavior of the various combinations of aggregate, bitumen and additive is so varied that the results of any particular combination cannot be predicted from tests of the others; (2) more than half the aggregate-bitumen combinations without additives showed a marked tendency to strip; (3) additives which reduce the tendency to strip with one type of stone may be ineffective or actually harmful with another type; (4) marked differences exist between the various bitumens alone and in their response to additives; and (5) for all but a few of the rock samples tested, there is a reasonably safe bitumen or bitumen-additive combination.

RECORD No.: 46.
AUTHOR : W. H. Goetz
TITLE : Sonic Testing of Bituminous Mixtures
JOURNAL : Proceedings, Association of Asphalt Paving Technologists
VOLUME No.: 24
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1955
PAGES : 332
ABSTRACTOR: HRB
KEYWORDS : Asphalt concrete mixtures, moisture damage, oxidative hardening, sonic testing
ABSTRACT :

The results of this study have established quite definitely that suitable specimens of bituminous-aggregate mixtures can be vibrated in their fundamental frequencies. Even though it is indicated that modulus of elasticity values calculated from fundamental frequency measurements with the aid of elastic theory may not be strictly valid, particularly at temperatures above 40 F, such measurements do provide valuable information concerning the elastic-plastic characteristics of bituminous-aggregate mixtures and appear to be sufficiently valid at lower temperatures to provide a measure of stiffness. Of special significance is the fact that the test data strongly indicate that the sonic method of determining modulus of elasticity has application potential in the field of bituminous-aggregate mixtures as a non-destructive test useful in following progressive changes caused by laboratory exposure to different types of accelerated weathering.

RECORD No.: 47.
AUTHOR : A. Scheurer
TITLE : Estimation of Adhesive Power and Progress of Hardening of Bituminous Road Building Binders
JOURNAL : Bitumen
VOLUME No.: 2
PUBLISHER :
YEAR : 1952
PAGES : 29
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, adhesion, testing age-hardening, viscosity, temperature
ABSTRACT :

The testing apparatus consisted essentially of the test unit operated by a crank and rack and pinion connected to a calibrated wheel balance. The machine is described in detail together with the test procedure. The films obtained in the adhesion test are transferred to white paper, copied with printer's ink, or photographed for visual observation. Details are given of comparative tests on a series of binders which determine the magnitude of adhesiveness down to zero. The apparatus is applied as described to determination of the firmness of unctuous materials, fluid and dry friction in lubrication, coefficient of friction, tendency to setting, inwardly progressing resinification, embrittlement of types of binders, and quantifiable estimation of scratch resistance of binder films as affected by light, air, heat, water, and chemicals. Whereas conventional viscometers operate with three outflow nozzles and at four temperatures, viscosity curves are obtained with a progressive temperature rise or fall. Photographs, charts, and tabulations of results are presented.

RECORD No.: 48.
AUTHOR : E. Neumann
TITLE : Investigation of the Adhesiveness of Bitumen to Stone Under the Action of Water
JOURNAL : Bitumen
VOLUME No.: 4
PUBLISHER :
YEAR : 1951
PAGES : 89
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, adhesion, moisture damage, surface tension, asphalt concrete mixtures, fillers, asphalt content
ABSTRACT :

The problem of the adhesiveness of bitumen to stone in road construction is studied with special reference to the effect of water. For physical testing, the Swedish Road Construction Institute, in its latest report No. 78, introduces a new apparatus as illustrated, in which the change in weight between bitumen and water at the surface of the stone is measured. Adhesion and surface-tension measurements show that the former depends on a combination of a definite binder with a definite stone. Heavy oils are superior to light oils, tar oils to the corresponding petrol oils. Four types of adhesion are discussed. Laboratory tests do not correlate well with road tests. Experiments carried out at Stuttgart Research Station with special attention to grain structure, filler content, and binder addition, especially to pore space, confirmed the detrimental influence of water, but by careful compounding of the masses and reducing the pore space to a minimum, this unfavorable influence can be cut out. Experiments carried out by the American Bureau of Public Roads, which simulate the conditions of those of the Stuttgart Research Institute, are described. Their value lies in the proposals for the special treatment of the masses, in the choice of a suitable procedure for water storage, and in the ascertaining of the varying behavior of different additions, fillers, and bitumen. The effect of water on the adhesiveness of the binder is important only for types of open construction. The pH of the water is important.

RECORD No.: 49.
AUTHOR : Brown, Bahngreel W.; Welby, Charles W.
TITLE : Improvement of Sands and Gravels for Use with Asphalt
JOURNAL : Research Report
VOLUME No.: 0418
PUBLISHER : Univerity of Southern Mississippi
YEAR : 1931
PAGES : 60p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt cements, adhesion, modifiers, contact angle
ABSTRACT :

The purpose of this investigation was to evaluate the effectiveness of various commercial surfactants as aids in improving the adhesion or bond strength of asphalt to Mississippi quartzose gravels. An air bubble technique to measure the contact angle on treated quartz was first tried. Hysteresis effects made the measurements to imprecise that a good estimate of the angle could not be obtained. An alternate method using sessile water drops was tried and preliminary tests indicated that it would provide a technique for rapid quantitative evaluation of surfactants. The authors conclude, from theoretical considerations, that amines will not solve the asphalt bonding problem and suggest that fluorocarbons would be useful. (Author)

RECORD No.: 50.
AUTHOR : Brown, Bahngreel W.; Welby, Charles W.
TITLE : qmprovement of Sands and Gravels for Use with Asphalt
JOURNAL : University of Southern Mississippi, Hattiesburg.
VOLUME No.: 0418
PUBLISHER :
YEAR : 1931
PAGES : 60p
ABSTRACTOR: NTIS
KEYWORDS :
ABSTRACT :

The purpose of this investigation was to evaluate the effectiveness of various commercial surfactants as aids in improving the adhesion or bond strength of asphalt to Mississippi quartzose gravels. An air bubble technique to measure the contact angle on treated quartz was first tried. Hysteresis effects made the measurements to imprecise that a good estimate of the angle could not be obtained. An alternate method using sessile water drops was tried and preliminary tests indicated that it would provide a technique for rapid quantitative evaluation of surfactants. The authors conclude, from theoretical considerations, that amines will not solve the asphalt bonding problem and suggest that fluorocarbons would be useful. (Author)

RECORD No.: 51.
AUTHOR : Desio, P. J.; McGarry, F. J.
TITLE : Adhesion of Asphalt to Stone
JOURNAL : Research Report
VOLUME No.: Final Report
PUBLISHER : Massachusetts Institute of Technology, Cambridge. Dept. of Civil Engineering
YEAR : 1930
PAGES : 34p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt cements, aggregates, temperature, adhesion, moisture damage, peel test
ABSTRACT :

The effects of methods of joint formation, type of stone (aggregate), type of asphalt, and test temperatures on asphalt-stone (aggregate) adhesion were measured by a 'peel test' applied to adhesive joint specimens in the form of stone-asphalt-aluminum foil sandwiches. The researchers concluded: (1) Exposure tests concerned with the effects of water on asphalt-stone adhesive joints reveal no harmful effects on joint strength. (2) At 140 F, peel tests of joints formed in air show higher peeling rates than at 77 F and the joints fail cohesively with a more symmetrical residual distribution of adhesive. (3) At 77 F, peel tests of joints formed under water with no clamped period reveal a lack of adhesion regardless of the type of stone or asphalt used. Joints formed under the same condition but tested at 140F show some adhesion but not to the extent observed for similar joints formed in air. (4) Joints formed and clamped under water for sixteen hours indicate that the contact interval is not sufficient for good adhesion, when tested at 77 F and 140 F.

RECORD No.: 52.
AUTHOR : Ensley, Keith; Schelz, Henry
TITLE : An Investigation of Aggregate-Asphalt Adhesion by Measurement of Heats of Immersion
JOURNAL : Research Report
VOLUME No.: Progress Report Phase I
PUBLISHER : Montana Coll. of Mineral Science and Technology
YEAR : 1928
PAGES : 26p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt cements, adhesion, heat of immersion, aggregates interface bond, cohesion
ABSTRACT :

The report is a summary of progress achieved during the first phase of a study of binding phenomena in aggregate-asphalt systems utilizing immersional thermodynamics principles mainly through measurements of heats of immersion by microcalorimetry. To date, a single aggregate-asphalt system consisting of an asphalt cement and a pure quartz, size 35M + 48M has been studied. Details are given of the accessory equipment, the microcalorimeter developed and the procedure used in measuring heat of immersion of the aggregate in the asphalt. Heat of immersion is expressed in microcalories, per second, per gram of aggregate. Heat of immersion curves are given for three test runs over three time periods. The curves show initial sharp peaks in the initial stages after immersion followed by a tailing off to low levels of energy release. It is claimed that the sharp initial peak represents the adhesion phenomenon and is proportional to the strength of the bond developed at the aggregate-asphalt interface. It is also contended that the tail portion of the curve reflects cohesion and is believed to be a function of the asphalt only.

V. Fatigue, Fracture, and Rutting Studies

RECORD No.: 1.
AUTHOR : Wolfgang Arand
TITLE : Influence of Bitumen Hardness of the Fatigue Behavior of Asphalt Pavements of Different Thickness Due to Bearing Capacity of Subbase Traffic Conditions and Temperature
JOURNAL : Proceedings, Sixth International Conference on the Structural Design of Asphalt Pavements
VOLUME No.: I
PUBLISHER : The University of Michigan, Ann Arbor
YEAR : 1987
PAGES : 65-71
ABSTRACTOR: PTI
KEYWORDS : Asphalt concrete mixtures, fatigue, temperature, asphalt cements, penetration, thermal stresses, pavement thickness, wheel load

ABSTRACT :

The most well know and worldwide used fatigue laws are based on the results of bending tests on specimens of bituminous materials. Using one of these fatigue laws it can be demonstrated that the number of load applications to failure increases with decreasing temperature. Asphalt pavements, however, show increasing tensile stresses with drop of temperature because of the restrained thermal contraction within a range of adequate low temperatures. Superposition of these thermal induced tensile stresses to the bending stresses will result in a small number of allowable load applications, if the pavement is kept below a certain temperature limit. The use of a harder bitumen type, for example, a bitumen pen 20 instead of bitumen pen 80 entails a shifting of the critical temperature of about 15 C in the direction of higher temperature. Therefore, the use of harder bitumen types of lower temperatures involves a significant reduction in fatigue life. Thickness of pavement and wheel load are found to affect the selection of type of bitumen is a complex way.

RECORD No.: 2.
AUTHOR : Zenewitz, Joseph A.; Kim Thanh Tran
TITLE : FURTHER STATISTICAL TREATMENT OF THE EXPANDED MONTANA ASPHALT QUALITY STUDY.
JOURNAL : Public Roads
VOLUME No.: 51, No. 3
PUBLISHER :
YEAR : 1987
PAGES : 72-81
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cements, molecular structure, rutting, composition, age hardening, cracking, pavement performance
ABSTRACT :

Journal Announcement: 8804 Large-sized molecule content (generally branch-chained compounds) relates to stiffness or hardness of an asphalt as compared to the small-sized molecule content, generally paraffinic (aliphatic), which contributes a softening effect or property to asphalts. The paraffins have been found to help resist oxidative hardening. Paving technologists in hot climatic areas would be apt to use harder-grade asphalts containing a greater than usual level of large molecules to prevent rutting, especially if the level of traffic warrant this. On the other hand, for cold areas, paving engineers would choose softer-grade asphalts with small molecules to avoid hardening and cracking. It also is expected that the level of traffic per day would affect the choice of asphalts. It was hopeful at the outset of affirming the foregoing a priori considerations and also hold liable any significant departures from average of the levels of large-size or small-size molecules in pavement asphalts for cracking of various types, rutting, and the rated condition of pavement with the help of a computer, STAT computer program. 2 refs.

RECORD No.: 3.
AUTHOR : G. A. Huber, G. H. Heiman
TITLE : Effect of Asphalt Concrete Parameters on Rutting Performances: A Field Investigation
JOURNAL : Proceedings, Association of Asphalt Paving Technologists
VOLUME No.: 56
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1987
PAGES : 33-61
ABSTRACTOR: PTI
KEYWORDS : Asphalt cements, asphalt concrete mixtures, rutting, penetration, viscosity, aggregates, fractured particles, air voids
ABSTRACT :

To determine the asphalt concrete mix properties which reduce the rate of rutting in the asphalt bound layers, cores from nine highway sections carrying similar traffic but exhibiting different rutting performance were tested. Age of the highways ranged between 2 to 14 years. AC types are AC1.5, AC6, and AC5. Sections with fast moving traffic and others with slow moving traffic were selected. The properties of AC, reçovered using the Abson process, was tested for penetration and viscosity, percentage of AC, gradation, percent of fractured particles were also determined and calculated.

Regression analysis on 12 mix parameters: ESAL's, AC content, percentage of fractured particles, air voids, VMA, percentage of aggregate, Hveem stability, Marshall stability, penetration, viscosity, voids filled, and flow, determined that rut depth could not be satisfactorily related to the traffic or any of the mix properties. Asphalt content and voids filled are the most basic parameters which affect rutting. Penetration and viscosity of the asphalt did not demonstrate a significant effect on rutting rate. Since an asphalt grade typically produces a similar penetration and viscosity after mixing, the study suggests that the asphalt grade used does not have any significant effect on rutting performance.

Discussion by G. Thenoux: No relation between penetration or viscosity, and rutting is expected because 1) flow properties of asphalt are dependentant loading time (shear rate), 2) tests were carried on recovered asphalts. Answers by G. Huber: I am sure speed has some impact but I am not certain of magnitude.

RECORD No.: 4.
AUTHOR : C. S. Hughes, G. W. Maupin, Jr.
TITLE : Experimental Bituminous Mixes to Minimize Pavement Rutting
JOURNAL : Proceedings, Association of Asphalt Paving Technologists
VOLUME No.: 56
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1987
PAGES : 1-32
ABSTRACTOR: PTI
KEYWORDS : Asphalt cements, asphalt concrete mixtures, rutting, additives, viscosity, test road, gradation, temperature, traffic, temperature susceptibility

ABSTRACT :

To study the effects of 1) asphalt type and 2) antistripping additive on rutting resistance and stripping, four sections in South bound lane of route I-95 were overlaid with 4 different mixes. Mix No. 1 used AC-30 (4.58%) and 6% ACRA-2000 antistripping additive; Mix No. 2 used AC-20 (4.48%) and 0.5% BA2000; Mix No. 3 used AC-20 (4.47%) and 1% lime; and Mix No. 4 used AC-30 (4.58%) and 1% lime. Dense graded granite from Chersterfield, Virginia, was used for all mixes. The AC came from West Bark Oil. Temperature susceptibility of both asphalts is the same.

Traffic was allowed after surface temperature was 150F or lower. Rut depth measured during the first 24 hours did not indicate any relation to type of binder or additive.

The average rut dephts at 1, 3, 6, and 12 months indicated that mixes 1 and 3 rated slight more than 2 and 4. A decrease in the rate of rutting occurred between 6 and 12 months.

Mixes 1 and 2 showed more stripping than mixes 3 and 4. The field observation stripping did not correlate well with Lohman modified tests on lab specimens.

Since no appreciable rutting occurred on any of the four mixes, the viscosity of the asphalt-binder combination does not appear as important as the gradation if sufficient interlock had not been obtained, binder viscosity would have been more important.

Early rutting appears to be influenced greatly by the temperature of the pavement when it is opened to traffic. Rutting during the first 12 months appears to be influenced by the density obtained during construction.

RECORD No.: 5.
AUTHOR : Khedr, Safwan A.
TITLE : DEFORMATION MECHANISM IN ASPHALTIC CONCRETE.
JOURNAL : Journal of Transportation Engineering
VOLUME No.: 112, No. 1
PUBLISHER : American Society of Civil Engineers
YEAR : 1986
PAGES : 29-45
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt concrete mixtures, permanent deformation, dynamic loading, rutting, model, resilient modulus
ABSTRACT :

Journal Announcement: 8603 A theoretical approach is presented to describe the permanent deformation mechanism in asphaltic concrete subjected to traffic simulated dynamic loading. The approach is based on mechanical energy concepts and leads to a better realization of the rutting mechanism in flexible highway pavements. A power relationship between the rate of permanent strain accumulation and the number of dynamic load repetitions was derived. Two parameters were introduced in this relationship: exponential parameter 'm' and intersection parameter 'A '. The first parameter, m, is dependent on the material type. Parameter A is a function of stress-strain pattern and intensity, stress level, and dissipated plastic strain energy during the dynamic loading. Parameter m was showed to be constant for all samples of the same material tested under various conditions. Regression analyses showed that 'A' was a function of the applied deviator stress and the resilient modulus. (Edited author abstract) 17 refs.

RECORD No.: 6.
AUTHOR : Tada, Hiroyuki
TITLE : STUDY ON THE PREVENTION OF PAVEMENT FLOW THROUGH ASPHALT VISCOSITY.
JOURNAL : Transactions of the Japan Society of Civil Engineers
VOLUME No.: 15
PUBLISHER : Japan Society of Civil engineers, Tokyo, Japan
YEAR : 1985
PAGES : 500-501
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cements, rutting, modifiers, traffic, pavement performance
ABSTRACT :

This paper describes the improvement of asphalt quality for the purpose of reducing the rutting caused by the flow of the asphalt pavement mixture. High-viscosity asphalts for road construction were developed and the applicability of these asphalts to heavy traffic roads was investigated. (Author abstract)

RECORD No.: 7.
AUTHOR : Loos, Heinz, Urban, Rolf
TITLE : Aging of Bitumen - Results of a Group Study
JOURNAL : Strasse und Autobahn
VOLUME No.: 35, No. 8
PUBLISHER :
YEAR : 1984
PAGES : 322-325
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt concrete mixtures, crack propogation, viscosity, age hardening
ABSTRACT :

The crack propagation on the bituminous pavements prompted a group study of 16 testing laboratories. The article describes and discusses the results of the statistical evaluation of the testing samples. In evaluation the method of Goodness of Fit was used. The aging process of bitumens was studied in order to established a method for the prediction of bituminous pavements durability. It states that asphalt viscosity alone cannot produce reliable results. 5 refs. In German.

RECORD No.: 8.
AUTHOR : Kortschot, M.; Woodhams, R. T.
TITLE : TORSIONAL BRAID ANALYSIS OF BITUMEN-LIQUID RUBBER MIXTURES.
JOURNAL : Polymer Engineering and Science
VOLUME No.: 24, No. 4
PUBLISHER :
YEAR : 1984
PAGES : 252-258
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cements, modifiers, low-temperature properites, fracture, Frass test, glass transition temperature
ABSTRACT :

Performance of liquid rubbers as low-temperature plasticizers for bitumen was evaluated by the torsional braid technique developed by J. K. Gillham. The low-temperature dynamic mechanical properties of bitumen-liquid rubber mixtures were measured from ambient to minus 100 degree C and compared with the corresponding fracture behavior using a modified Fraass test. The reduction in the brittle temperature of the bitumen is related to the glass-transition temperature of the added rubber, those rubbers having the lowest glass-transition temperatures being most efficient. Such modifications are necessary to reduce the tendency of asphaltic paving materials to crack in cold climates. 30 refs. materials to crack in cold climates. 30 refs.

RECORD No.: 9.
AUTHOR : Abdulshafi, A.; Majidzadeh, Kamran
TITLE : COMBO VISCOELASTIC-PLASTIC MODELING AND RUTTING OF ASPHALTIC MIXTURES.
JOURNAL : Transportation Research Record
VOLUME No.: 968
PUBLISHER : Transportation Research Board
YEAR : 1984
PAGES : 19-31
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt concrete mixtures, viscoelastic model, rutting, experimental evaluation
ABSTRACT :
In this paper a one-dimensional combo viscoelastic-plastic constitutive model composed of Burger-type mechanical elements connected in series with a friction slider is used. The friction slider is the mechanical representation of plasticity with a Drucker-Prager yield criterion. This model is solved under creep phase loading conditions, and the solution is used to develop a rutting model that incorporates a densification phase represented by a relaxing spring. Within the verification of the constitutive model a true yield line has been identified and used instead of the Mohr-Coloumb failure lines. The two developed models are supplemented by appropriate experimentation phases to identify and numerically evaluate the relevant parameters. 26 refs.

RECORD No.: 10.
AUTHOR : Walter, Jean; Hicks, R. G.; Mahoney, Joe P.; Wilson, J. E. Jr.
TITLE : EFFECT OF MIX VARIATIONS ON ASPHALT PAVEMENT LIFE: NORTH OAKLAND-SUTHERLIN PROJECT.
JOURNAL : Transportation Research Record
VOLUME No.: 843
PUBLISHER : TRB
YEAR : 1982
PAGES : 64-71
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt concrete mixtures, fatigue, permanent deformation, stiffness, asphalt content, fillers

ABSTRACT :
A laboratory study to determine the relationship between asphalt-concrete mix performance and mix compaction, asphalt content, and percent passing the 2-mm and 0.075-mm is described. Conventional and dynamic tests were run on laboratory-compacted samples to determine mix stiffness, fatigue life, and permanent deformation characteristics. By using the fatigue data generated as an example, pay-adjustment factors were developed by comparing the performance for mixes prepared at the design optimum with that of mixes from specifications. 11 refs.

RECORD No.: 11.
AUTHOR : J. B. Skog
TITLE : Effect of Changes in Asphalt Properties on Pavement Performance Zaca-Wigmore Test Road
JOURNAL : Proceedings of the Association of Asphalt Paving Technologists
VOLUME No.: 50
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1981
PAGES : 538-560
ABSTRACTOR: PTI
KEYWORDS : Asphalts, asphalt pavements, deflections, asphalt stiffness, Zaca-Wigmore test road, fatigue cracking, aging
ABSTRACT :

This paper is concerned with durability of paving grade asphalts and deflections as factors in pavement performance, as determined from long time studies on the Zaca-Wigmore test road. Pavement performance in this analysis is judged on the amount of development of fatigue type cracking in the outer wheel track of the travel lane. Recently W. H. Highter and M. E. Harr advanced the hypothesis that load associated cracking (fatigue cracking) is caused by a destructive factor (number of equivalent wheel loads for a given period multiplied by the average deflection in inches for the same period), and the change in asphalt properties. This hypothesis has already been tested in the laboratory by others and it is tested here using the records from the Zaca-Wigmore test roads. Data about traffic, deflection, and recovered asphalt properties for the period of May 1956 to March 1957 were used to calculate the destructive factor and the recovered asphalt stiffness at 77 F and 4 F (for a speed of 0.1 sec using van der Poel (memograph). Stepwise-multiple regression analysis was used to fit a model for the percent fatigue cracking in terms of destructive factor, penetration of recovered asphalt at 77 F, and stiffness at 77 and 40 F. The analysis indicated that with only the destructive factor included in the model a relatively poor correlation (0.67) is obtained. When stiffness at 77 F of the recovered asphalt was added the correlation is markedly improved to 0.86. Other variables did not add significant improvements in the model when added. Discussion of the results and statistical analysis stress the point that the use of only asphalt properties or deflections will not provide sufficient information on the reasons for fatigue cracking of a specific pavements. A number of investigations in California have disclosed pavements of very low recovered penetrations with no evidence of fatigue cracking. In this case the deflections have been consistently low. Therefore, analyzing both deflections and asphalt properties is important.

RECORD No.: 12.
AUTHOR : Monismith, Carl L.
TITLE : FATIGUE CHARACTERISTICS OF ASPHALT PAVING MIXTURES AND THEIR USE IN PAVEMENT DESIGN.
JOURNAL : Proc Paving Conf 18th, Univ of NM, Albuquerque, NM,
VOLUME No.:
PUBLISHER : University of NM, Albuquerque
YEAR : 1981
PAGES : 1-43
ABSTRACTOR: Compendex Plus
KEYWORDS : Aspahlt concrete mixtures, cracking, fatigue stiffness
ABSTRACT :

In the United States and elsewhere, cracking from repeated loading - termed fatigue - is considered to be one of the primary causes of distress. To estimate the potential for fatigue, the fatigue characteristics of the asphalt-bound layer must be available. The magnitude of either the tensile strain or stress repeatedly applied is a reasonable damage determinant in fatigue. Either of these parameters can be determined by structural analysis. To do so requires a knowledge of the stiffness of the asphalt bound layer (and the stiffnesses of the other pavement layers as well). This paper presents a summary of available information on both the stiffness and fatigue characteristics of asphalt-bound materials. The paper also illustrates how the use of such knowledge permits more effective design of asphalt mixtures to be accomplished and emphasizes that mix design and pavement design go hand in hand. 39 refs.

RECORD No.: 13.
AUTHOR : Jacobs, F. A.
TITLE : Hot Rolled Asphalt: Effect of Binder Properties on Resistance to Deformation
JOURNAL : TRRL Laboratory Report
VOLUME No.: 1003
PUBLISHER : TRRL, England
YEAR : 1981
PAGES : 19p
ABSTRACTOR: Coupendex Plus
KEYWORDS : Asphalt cement, mixtures, rutting, softening point, penetration

ABSTRACT :
Serious deformation has occurred in recent years on certain heavily trafficked roads with rolled asphalt surfacing. The performance of this material is dependent on many compositional factors with the rheological properties of the binder being among the most important. The report considers those properties of binders that most affect the resistance to deformation of rolled asphalt. Thirteen binders were studied and mixtures containing them were subjected to design tests from BS 594: 1973 and the Wheel-tracking Test. These laboratory mechanical tests show that, within the range of binders tested, significant improvements in resistance to deformation can be achieved over a range of high road temperatures by increasing the softening point of the binder, irrespective of its penetration at 25C.

RECORD No.: 14.
AUTHOR : B. E. Ruth, H. E. Schweyer, A. S. Davis, J. D. Maxfield
TITLE : Asphalt Viscosity: An Indicator of Low Temperature Fracture Strain in Asphalt Mixtures
JOURNAL : Proceedings, Association of Asphalt Paving Technologists
VOLUME No.: 48
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1979
PAGES : 221-237
ABSTRACTOR: PTI
KEYWORDS : Asphalt cements, asphalt concrete mixtures, rheological properties, temperature susceptibility, tension test, complex flow, fatigue, fracture, air voids

ABSTRACT :

The relation between asphalt rheological parameters and asphalt mixture parameters should be established to facilitate design of mixtures and pavements. Asphalt viscosity temperature behavior is recognized as the most important factor in low temperature cracking. This paper presents the results of fatigue tests for a variety of asphalts. The purpose of these tests was to determine if all asphalts produce the same viscosity-deformation relationships and to explore the time and temperature dependent strain recovery effect on fatigue of mixtures. Ten different asphalts were used to prepare indirect tensile test specimens. The low temperature complex flow and viscosity values for the original asphalts and the asphalts extracted from the mixtures by the Abson method were measured using the Schweyer-constant stress viscometer. Mixtures were prepared using same aggregate, 3-different asphalt contents, and were compacted using gyratory compaction to provide the equivalent densities produced by the 50-blow Marshall Compaction method. Test temperature (-5, 5, 15 C), and stress level (21 - 400 psi) were varied during testing. A haversine loading duration of 0.1 sec with 0.4 sec rest period was used in all tests. Test data collected from the different tests included load, horizontal elastic deformation (Sc), cumulative horizontal plastic deformation (Sp), and comparable values Ep and Ec from SR-4 strain guages mounted at center of some tests specimens. A series of specimens were also subjected to indirect tensile fatigue tests with different conditioning processes to determine if dynamic loads are cumulative. The analysis of results indicates that conventional fatigue concepts and Miner's hypothesis of cumulative damage does not apply to dynamic testing of mixtures in the laboratory. Fracture of asphalt mixtures subjected to dynamic loading has been shown to be related to cumulative creep strain and fracture strain which are primarily dependent upon the viscosity, complex flow, and strain (shear) rate of the asphalt. Aggregate type and gradation, density of the compacted mix, or asphalt content do not appear to significantly influence the fracture strain of the asphalt mixtures. However, these variables will significantly affect the stiffness modulus of mixtures which in turn influences the stress-strain response. It is desirable to use mixtures that are low in voids content to minimize in-service hardening of the asphalt and to maximize stiffness without using excessively hard asphalts.

Pavement cracking studies conducted in Florida have indicated that cracking and poor performance can be well correlated with the recovered asphalt viscosity measured with the Schweyer constant stress viscometer.

RECORD No.: 15.
AUTHOR : Smith, W.; Finn, F.; Kulkarni, R.; Saraf, C.; Nair, K.
TITLE : Bayesian Methodology for Verifying Recommendations to Minimize Asphalt Pavement Distress
JOURNAL : Research Report
VOLUME No.: TRB/NCHRP/REP-213;
PUBLISHER : TRB
YEAR : 1979
PAGES : 62p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt cement, asphalt concrete mixtures, test road, fatigue cracking, penetration, asphalt content, mix proportions, statistical model

ABSTRACT :
This report documents the development of a Bayesian methodology to quantify multiple regression models from personal interviews with experienced individuals. Procedures for combining this information with objective (measured) data were also demonstrated. Pilot implementation of the methodology was conducted in six states--Arizona, Colorado, Utah, Florida, Louisiana, and Virginia--to investigate the influence of designer-controlled variables on the occurrence of fatigue cracking. Four designer-controlled variables were considered: asphalt penetration, asphalt content, proportion of asphalt concrete, and base density. A multiple regression prediction model of fatigue cracking was defined in each state. In all six states it was found that the fatigue life cycle increased with increase of the asphalt penetration, asphalt content, proportion of asphalt concrete, and base density. The models allow prediction of the fatigue life cycle for any specified level of reliability and designer-controlled variable values. The results obtained were used as a basis to verify design recommendations made in a previous study, NCHRP 9-4, to minimize premature cracking. Only the recommendation to use harder grades of asphalts (lower penetrations) for thick asphalt concrete layers could not be verified. Further study is needed to resolve this difference.

RECORD No.: 16.
AUTHOR : Carpenter, Samuel H.; Lytton, Robert L.
TITLE : PROCEDURE FOR PREDICTING OCCURRENCE AND SPACING OF THERMAL-SUSCEPTIBILITY CRACKING IN FLEXIBLE PAVEMENTS.
JOURNAL : Transportation Research Record
VOLUME No.: 671
PUBLISHER : TRB
YEAR : 1978
PAGES : 39-46
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt concrete mixtures, cracking, viscoelastic properties, finite element, fracture mechanics, thermal stresses

ABSTRACT :
This paper presents the results of a study that attempted to quantify the mechanism of cracking and to predict crack spacings and the rate of crack appearance. The procedure used involves the combination of linear viscoelasticity and linear viscoelastic fracture mechanics. Crack spacings in the base course are calculated by using the results of a finite-element study of the frozen properties of the base course. The effect of these cracks (i. e., the rate at which they propagate reflection cracks through the asphalt surface layer) is determined by using a fracture mechanics approach. Intensity factors are calculated for the viscoelastic thermal stress in the asphalt caused by a temperature cycle and for the stress caused by the deformation of a crack in the base course caused by a freeze. 26 refs.

RECORD No.: 17.
AUTHOR : Barksdale, Richard D.; Miller, II, John H.
TITLE : Development of Equipment and Techniques for Evaluating Fatigue and Rutting Characteristics of Asphalt Concrete Mixes
JOURNAL : Research Report
VOLUME No.: SCEGIT-77/147; FHWA-RD-77-S0633
PUBLISHER : FHWA
YEAR : 1977
PAGES : 172p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt concrete mixture, fatigue, rutting, bonding, triaxial loading, air voids, asphalt content, fillers, viscosity, aggregates

ABSTRACT :
Fatigue and rutting characteristics are evaluated for a range of asphalt concrete base mixes. A rectangular beam on a rubber subgrade is used in the fatigue test. Tensile strain in the beam is measured by means of a strain gage bonded to the beam. Rutting characteristics are determined using both the Shell creep test and also a repeated load triaxial test. A temperature of 95F was used which is the mean pavement temperature for rutting in Georgia. The fatigue life of a mix was found to be primarily dependent upon the void and asphalt content of the mix. Fatigue life is inversely proportional to the air voids on a log-log plot with a small change in air voids having a large influence on fatigue life. For a long fatigue life the air void content should be between 2 and 4 or 5%. Going from an asphalt content of 4.5 to 4.75% approximately doubled the fatigue life. Other variables studied included mineral filler, asphalt cement viscosity, aggregate type and gradation, and 50 and 75 blow Marshall mixes. Rutting tests indicated that moderate changes in mix variables do not greatly affect rutting.

RECORD No.: 18.
AUTHOR : Majidzadeh, K.; Buranarom, C.; Karakouzian, M.
TITLE : Application of Fracture Mechanics for Improved Design of Bituminous Concrete. Volume 1. Plan of Research, State-of-the-Art, and Mathematical Investigations
JOURNAL : FHWA Report
VOLUME No.: FHWA/RD-76-91
PUBLISHER : FHWA
YEAR : 1976
PAGES : 211p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt concrete mixtures, fracture mechanics, fatigue, asphalt cement, filler, modifiers
ABSTRACT :

The effect of material constituents influencing the fatigue and fracture response of asphaltic mixtures are discussed. The sensitivity analysis included the effect of mixture constituents such as asphalt, filler and polymeric and fibrous additives. In this study, a number of fatigue models for asphaltic concrete were also investigated. In this volume, the State-of-the-Art of fatigue and fracture concepts and mathematical development of stress-intensity factor are reviewed. The mathematical relation between the normalized stress-intensity factor, crack length and beam on elastic foundation geometry are presented. Nomographs are developed to aid in solution of stress-intensity variation with crack length. The limits of analysis and restriction of the theory are discussed. Typical examples demonstrating the applicability of concepts developed are presented.

RECORD No.: 19.
AUTHOR : Majidzadeh, K.; Dat, M.; Makdisi-Ilyas, F.
TITLE : Application of Fracture Mechanics for Improved Design of Bituminous Concrete. Volume 2. Evaluation of Improved Mixture Formulations, and the Effect of Temperature Conditions on Fatigue Models
JOURNAL : FHWA Report
VOLUME No.: FHWA/RD-76-92
PUBLISHER : FHWA
YEAR : 1976
PAGES : 502p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt concrete mixtures, fatigue, fracture mechanics, asphalt cements, aggregates, fillers, modifiers, sensitivity analysis, models
ABSTRACT :
In this volume, a sensitivity analysis of mixture variables and a study of fatigue models as related to fracture mechanics is presented. The sensitivity analysis included the effect of mixture constituents, such as aggregate, asphalt and filler content as well as influence of mixture additives. Numerous polymeric and fiberous additives were investigated and effects of treatment levels and additive types on fatigue parameter A were evaluated. A number of fatigue models for asphaltic concrete were investigated. These models ranged from the simplest form to the most general form. Variation of the parameters in these models were studied. (Portions of this document are not fully legible).

RECORD No.: 20.
AUTHOR : Saraf, C. L.; Smith, W. S.; Finn, F. N.
TITLE : RUT DEPTH PREDICTION.
JOURNAL : Transportation Research Record
VOLUME No.: 616
PUBLISHER : TRB
YEAR : 1976
PAGES : 9-14
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt concrete mixtures, rutting, mechanistic-emperical model, pavement performance, stress levels

ABSTRACT :

This paper describes a method for the prediction of rut depth in asphalt pavements that is based on a combined mechanistic-empirical approach. Three methods, viscoelastic, elastoplastic and linear-elastic, were originally evaluated. This paper concentrates on linear-elastic procedures to relate the various mechanistic responses, stress, strain, and deformation to the rate of rutting observed on 32 sections at the AASHO Road Test. The rate of rutting was influenced by the season of the year and the number of years for which traffic is applied. Correlations with the surface deflection, the vertical compressive stress in the asphalt concrete, the vertical strain in the subgrade, and the traffic previously applied to the section were obtained. 13 refs.

RECORD No.: 21.
AUTHOR : P. J. Van de Loo
TITLE : A Practical Approach to the Prediction of Rutting in Asphalt Pavements - The Shell Method
JOURNAL : Transportation Research Record
VOLUME No.: No. 616
PUBLISHER : Transportation Research Board
YEAR : 1976
PAGES : 15-22
ABSTRACTOR: PTI
KEYWORDS : asphalt pavements, rutting, viscosity, stiffness temperature variation, equivalent number of strandard wheels

ABSTRACT :

This paper describes a true engineering method for predicting rut depth. It demonstrates how a mix design procedure based on creep testing can be used as a subsystem in an overall pavement management system. It is shown that reduction in asphalt concrete mix layer thickness (H) can be calculated as follows:

d = Cm*Ho*St(av)/Smix

where Cm = correction factor for the so-called dynamic effect, which takes account of differences between static (creep) and dynamic (rutting) behavior. The factor can be determined emperically. Ho= design thickness of asphalt layer, St(av) = average stess in the pavement under the moving wheel and is = Z*Sto where Z is a proportionality factor between the average stress and the contact stress between the tire and pavement (Sto). Smix = value of the stiffness of the mix at Sbit=Sbit, vis. Since it is assummed that permenant deformation or rutting is a function of only the viscous or nonelastic component of the bitumen stiffness (sbit, visc), the service life of a pavement may be expressed as

Sbit, visc = 3/SUM[N*to (1/V)av

where N=total number of standard wheel loads over the predefined period (e.g. one month), loading time of one wheelpass, and (1/V) av = average of the reciprocal viscosities (V) in that month. The latter should be calculated with consideration of temperature gradient through the layer and the mean monthly temperature. The lateral distribution of wheel loads over the traffic lane and the occurrence of lateral swelling is shown to result in rut depth values that are approximately equal to the reduction in layer thickness caused by the equivalent number of standard wheels in a single wheel path.

RECORD No.: 22.
AUTHOR : P. S. Pell and K. E. Cooper
TITLE : The Effect of Testing and Mix Variables on the Fatigue Performance of Bituminous Materials
JOURNAL : Proceedings of the Association of Asphalt Paving Technologists
VOLUME No.: 44
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1975
PAGES : 1-37
ABSTRACTOR: PTI
KEYWORDS : Asphalt, fatigue, controlled stress, temperature aggregate, fillers, softening point, asphalt content, air voids.

ABSTRACT :

The purpose of this paper is to summarize and briefly review an extensive laboratory investigation, lasting five years, mainly into the effect of mix variables on the fatigue strength of bituminous materials. Forty-eight test series have been carried out on a wide variety of base-course and wearing course mixes of both the gap graded and continuously graded type. The effects of binder type and content, aggregate type and grading, filler, and air void content have been investigated. Fatigue tests were performed under controlled stress conditions. A cylindrical specimen of variable diameter and depth has been used. The specimen was mounted as a vertical cantilever an a rotating shaft and a single point load was applied through a bearing at the top, resulting in a sinusoidal variation of bending stress throughout the specimen with a maximum stress amplitude at the neck. The specimens were immersed in a controlled temperature bath with a range of speeds from -5 C to +30 C and the machines were capable of speeds from 80 to 3000 rev/min. In order to examine the effects of confining stress on fatigue performance an axial fatigue machine was used, a cylindrical specimen, and the specimen was enclosed in a perspex triaxial cell. 7 asphalts (nonwaxy types), 3 tars, 4 types of coarse aggregate, 4 types of fine aggregate, and 3 types of fillers were used in making the samples. 50 types of mixes were tested by the cantilever rotating cylinder and 5 types with the triaxial loading configuration. Stress level and temperature were varied during the tests. Data collected were analyzed and the following conclusions were drawn: 1. Binder content is a primary factor influencing fatigue performance on the basis of applied dynamic strain longer lives being obtained for a given strain when the relative binder volume is increased. 2. Binder type is also a primary factor. A binder having a higher ring and ball softening point temperature will result in longer fatigue lives. Dynamic stiffness is also influenced but in a more complex way as speed of loading and temperature effects must be taken into account. 3. Aggregate type and gradation only influence fatigue performance insofar as they influence the relative binder content. Dynamic stiffness is influenced by these factors due to their affect on mix density. 4. Adding filler to a mix results in increasing the dynamic stiffness. However, there is no appreciable improvement in fatigue performance if the relative binder volume is kept constant. 5. Based on the limited triaxial loading tests,

the fatigue performance is independent of the effects of both confining stress and temperature. 6. When plotted on a logarithmic basis, the slope and position of the various strain-life relationships are such that they tend to interact at a point or focus. 7. The results of a regression analysis indicated that the following equation accounts for 88 percent of the variation in fatigue life at a strain of 1×10^{4} ($N_e = 10^{4}$): $\log N_e(10^{-4}) = 4.13 \log V_b + 6.95 \log T_{r\&b} - 11.13$ V_b = relative binder volume $T_{r\&b}$ = ring and ball softening point temperature in C. The equation may be used in conjunction with the "focus" to predict strain life relationship for laboratory fatigue performance.

RECORD No.: 23.
AUTHOR : Porter, Byron W.; Kennedy, Thomas W.
TITLE : Comparison of Fatigue Test Methods for Asphalt Materials
JOURNAL : Reseach Report
VOLUME No.: CFHR-3-9-72-183-4; FHWA/RD-76-S0449
PUBLISHER : University of Texas at Austin. Center for Highway Research
YEAR : 1975
PAGES : 122p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt concrete mixtures, fatigue, creep, testing, statistical model

ABSTRACT :

This report describes the results of an investigation comparing various commonly used fatigue tests and evaluating the relationship between creep and fatigue. It was found that the repeated-load indirect tensile test produces results comparable with other fatigue tests if the state of stress developed in the specimen is considered. A regression analysis was conducted and an equation was developed which can be used to relate fatigue results for a variety of mixtures and test methods. A comparison of creep and fatigue results indicated that a relationship probably exists between creep and fatigue deformation and that fatigue life can possibly be estimated from creep rupture time.

RECORD No.: 24.
AUTHOR : L. Francken, and J. Verstraeten
TITLE : Methods for Predicting Moduli and Fatigue Laws of Bituminous Road Mixes Under Repeated Bending
JOURNAL : Transportation Research Record
VOLUME No.: 515
PUBLISHER : Transportation Research Board
YEAR : 1974
PAGES : 114-123
ABSTRACTOR: PTI
KEYWORDS : Asphalt concrete mixtures, asphalt cement, fatigue, composition, penetration, mixes proportion, viscosity

ABSTRACT :

The use of modern pavement design methods to prevent cracking necessitates, among other things, determining the moduli and fatigue laws in bending of the bituminous road mixes (base courses and wearing courses). These determinations are now possible, but they involve sophisticated experiments that are not well adapted to practical purposes. The objective of this paper is to present an original contribution to the prediction of moduli and fatigue laws in sinusoidal bending (controlled stress tests) of bituminous mixes. The results obtained with a large variety of mixes having different bitumen, composition, and size distribution of the aggregates show that this prediction requires only the knowledge of the volumetric composition of the mix (aggregate volume content, bitumen volume content, and void content) and the knowledge of some characteristics of the bitumen used (asphaltene content and penetration). On the basis of the experimental results obtained, general formulas are presented to permit the prediction of the moduli and the fatigue law of a mix. Practical criteria for the selection of the bitumen are also proposed.

RECORD No.: 25.
AUTHOR : Shahin, Mohamed Y.; McCullough, B. F.
TITLE : DAMAGE MODEL FOR PREDICTING TEMPERATURE CRACKING IN FLEXIBLE PAVEMENTS.
JOURNAL : Transportation Research Record
VOLUME No.: 521
PUBLISHER : TRB
YEAR : 1974
PAGES : 30-46
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt concrete mixtures, thermal cracking, tensile strength, thermal fatigue, viscoelastic model

ABSTRACT :
A model for predicting temperature cracking has been developed. Temperature cracking as predicted by the model is the appropriate addition of low-temperature cracking, which occurs when the thermal tensile stress exceeds the asphalt concrete tensile strength; and thermal-fatigue cracking, which occurs when the thermal-fatigue distress due to daily temperature cycling exceeds the asphalt concrete fatigue resistance. During model development, stochastic variations in material properties were considered. 16 refs.

RECORD No.: 26.
AUTHOR : Cooper, K. E. ; Pell, P. S.
TITLE : The Effect of Mix Variables on the Fatigue Strength of Bituminous Materials
JOURNAL : Research Report
VOLUME No.: TRRL-LR-633
PUBLISHER : Tranportation and Road Research Laboratory, Crowthorne (England)
YEAR : 1974
PAGES : 73p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt concrete mxitures, fatigue, mix variables, stiffness, aggregate, asphalt cement, fillers, asphalt content
ABSTRACT :

The report covers work carried out to investigate the effect of mix variables on the fatigue properties of bitumen- and tar-bound road materials. Fatigue testing was carried out in controlled stress rotating bending machines. Measurements of dynamic stiffness were also made to enable the results to be analysed on the basis of applied strain. During the four years of testing, a considerable number of different mixes were investigated under a variety of test conditons. Both base course and wearing course mixes of the gap graded and continuously graded type were used. The effects of such mix variables as binder content, binder type, aggregate grading and aggregate type and the use of filler were studied.

RECORD No.: 27.
AUTHOR : Epps, J. A.; Monismith, C. L.
TITLE : FATIGUE OF ASPHALT CONCRETE MIXTURES -- SUMMARY OF EXISTING INFORMATION.
JOURNAL : ASTM Special Technical Publication
VOLUME No.: 508
PUBLISHER : American Society for Testing and Materials
YEAR : 1972
PAGES : 19-45
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt concrete mixtures, mixture variables, fatigue, asphalt cement, aggregate gradation, pavement performance, temperature

ABSTRACT :

Data are presented based on a review of the literature as well as the authors' research, which illustrate the effects of a number of mixture variables on fatigue response and include an indication of the influence of: mixture stiffness, air void content, aggregate gradation, aggregate type, asphalt content, and asphalt type. A literature review indicates the variation of air void content, aggregate gradation, and asphalt content to be expected on typical construction projects. This information together with the fatigue data presented previously allows the engineer to assess the relative importance of these mixture variables on predicting the performance of pavements. Asphalt content and test temperature appear to be more critical than the variation associated with aggregate gradation, asphalt hardness, and air void content. 56 refs.

RECORD No.: 28.
AUTHOR : Raithby, K. D.; Sterling, A. B.
TITLE : Some Effects of Loading History on the Fatigue Performance of Rolled Asphalt
JOURNAL : Research Report
VOLUME No.: TRRL-LR-496
PUBLISHER : Transportation and Road Research Laboratory, Crowthorne (England)
YEAR : 1972
PAGES : 32p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt concrete mixtures, fatigue, rest periods, temperature, stress

ABSTRACT :
Results are given of fatigue tests under direct stress axial loading conditions on a typical rolled asphalt base-course material, to investigate the significance of varying the load-time history. Rest periods between successive loading cycles had a beneficial effect on fatigue performance, both by increasing the resistance to cracking and by reducing the rate ofloss of dynamic stiffness due to repeated loading. Rest periods of the order of 1s increased the number of cycles to failure by a factor of up to 25, when compared with the life under continuous sinusoidal cyclic loading. The improvement in life was less at high temperatures; it also appeared to be affected somewhat by the magnitude of the applied cyclic stress, although this effect was not clearly established. (Author)

RECORD No.: 29.
AUTHOR : Coffman, Bonner S.; Ilves, George J.; Edwards, William F.
TITLE : The Fatigue of Flexible Pavements
JOURNAL : Research Report
VOLUME No.: EES-296B-1
PUBLISHER : Ohio State University, Columbus. Engineering Experiment Station
YEAR : 1971
PAGES : 279p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt cements, asphalt concrete mixtures, fatigue cracking, computer program, moduli
ABSTRACT :

Five asphaltic concrete pavement thicknesses, each of which measured 20x30 ft. and contained two test areas, were constructed on a 48 inch compacted clay subgrade. Certain of these pavement areas were fatigue loaded through concentric rings composed of truck tire rubber by superimposing one dynamic 10 Hz haversine pulse on a small static load every second to simulate a continuous line of wheel loads traveling in identical wheel paths 50 ft. apart at 40 MPH. Surface tangential strain, surface deflection and temperature sensors were placed at a number of radii from the load plate centerline and recorded periodically throughout each test. The fatigue of four of these pavements, as evidenced by visible cracking, was observed closely and noted in a log book. Asphalt and compacted subgrade samples were returned to the laboratory for the determination of structural strength and physical properties. The results of these tests were entered into the Chevron n-layer program along with a number of hypothetical moduli for the natural subgrade underlying these layers. (Author)

RECORD No.: 30.
AUTHOR : Kamran Majidzadeh, A. T. Chan, and D. V. Ramsamooj
TITLE : Fatigue and Fracture of a Bituminous Paving Mixture
JOURNAL : Transportation Research Record
VOLUME No.: 313
PUBLISHER : Transportation Research Board
YEAR : 1970
PAGES : 44-54
ABSTRACTOR: PTI
KEYWORDS : Asphalt concrete mixtures, asphalt cement, fatigue, fracture, stress intensity factor, prediction model
ABSTRACT :

The fatigue behavior of simply supported sand-asphalt beams is examined by using experimental and analytical methods of fracture mechanics. The fatigue crack growth rates correlate well with the stress-intensity factor in accordance with Paris's law that states that dc/dN = AK4, where dc/dN is the crack length per cycle, A is a constant of a material, and K is the stress-intensity factor, which is dependent on the load, geometry, and boundary conditions. It is postulated that in a material such as a sand-asphalt mixture, which is abundantly endowed with flaws, fatigue damage is initiated at the first loading cycle, so that the fatigue life is the number of cycles of repeated loading to propagate a "starter flaw," co, into a crack of critical size, df. The starter flaw is a material's constant but is subject to statistical variation and is believed to be principally responsible for the statistical variation of fatigue life. The crack reaches the critical stress-intensity factor, Kc, which is a constant for a given material. Kc is the failure criterion for both static fracture and fatigue. A formula for fatigue life, Nf, is given. Methods for determining these constants are presented, and the fatigue lives, determined experimentally are compared with those predicted from the formula and show good agreement.

RECORD No.: 31.
AUTHOR : Marek, C. R.
TITLE : Estimation of the Tensile Strength of Asphalt Cements in Thin Films
JOURNAL : Journal of Materials
VOLUME No.: 5, No. 1
PUBLISHER :
YEAR : 1970
PAGES : 3-17
ABSTRACTOR: Compendex Plus
KEYWORDS : Asphalt cements, tensile strength, thin films, strain rate, shift factor
ABSTRACT :

On the basis of data obtained in tests a technique was developed to enable estimation of the tensile strength-log//1//0 film thickness relationship for asphalt cements of normally used consistency, for normal temperatures above the glass transition temperature, and for rates of deformation ranging from 0.005 to 1.0 in. /min. The method requires knowledge of a "base curve" and a shift factor for each of the three varibles. 8 refs.

RECORD No.: 32.
AUTHOR : P. S. Pell and I. F. Taylor
TITLE : Asphaltic Road Materials in Fatigue
JOURNAL : Proceedings of Association of Asphalt Paving Technologists
VOLUME No.: 38
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1969
PAGES : 371-422
ABSTRACTOR: PTI
KEYWORDS : Asphalts, bitumen, fatigue, stiffness, penetration fillers, aggregate
ABSTRACT :

Previous works have shown that stiffness plays a predominant role in determining the fatigue behavior of asphalt mixes and maximum principal strain appears to be a major determinant of the fatigue life. It therefore follows that any mix variables which effect the stiffness (aggregate type and grading including filler, bitumen type, penetration and content, and air void content), are also going to effect the fatigue life. In this study a machine has been developed to measure the dynamic stiffness of specimens under loading and environmental conditions similar to those used in the fatigue tests. Mix variables in addition to testing condition variables of temperature, speed of loading, and stress level were investigated. Gap graded mixes, dense bitumen macadam, and mixes with some alteration to the specification of the first or second were the three types of mixes studied. Three grades of binder, two types of coarse aggregates, and three types of fillers were used in samples preparation. Fatigue testing was carried out under controlled stress conditions, and the testing was in the form of rotating bending cantilever set up. Temperatures were varied between -5 C to +30 C and the speed range of 80-300 rev/min. Hundreds of specimens were tested and the analysis of results and their comparison to results of other investigations lead to the following conclusions. 1. In general the relation between number of cycles to failure (Ns) and the amplitude of the applied stress level (stmax) can be represented as follows: log(Ns) = K - nlog (stmax), where K and N are constants. 2. The fatigue life is highly temperature dependent, a low temperature giving a longer life where other factors remain constant. 3. The addition of some filler to mixes normally containing no filler, results in longer fatigue life due to reduction in voids, and an increase in stiffness. Sufficient binder should be present. 4. Increasing bitumen content increases fatigue life up to an optimum above which any further increase in bitumen will result in reduced fatigue life. 5. Type or grading of coarse aggregate does not greatly influence fatigue life. 6. An increase in voids, or a decrease in speed of loading may result in reduced fatigue life. 7. The fatigue life is primarily controlled by the magnitude of the tensile strain. The type of behavior displayed by a mix has a profound influence upon the slope of the resulting stress-life or strain life fatigue lines. Fatigue results should be considered in two parts: one in which only linear mix behavior is displayed and the other in which non-linear behavior is displayed. 8. For

the linear conditions (i.e. stiffness independent of stress level), different grades of bitumen will not have a significant effect on slope of relations. Also the slope of stress-life fatigue lines will be the same as that of the strain-life fatigue lines. 9. For conditions where non-linear behavior (i.e. stiffness decreases as stress level is increased) is displayed over the entire range of stress levels used, it is suggested that bitumen grade will have a significant effect on the slope of strain-life lines. Steeper slopes are observed when using harder asphalts (lower penetration). 10. For testing conditions in which the mix displays linear and nonlinear behavior, the strain-life relationship may be curvilinear in the non-linear range the slopes are steeper. 11. Using softer grade bitumen, higher temperatures, less binder, less filler, and decrease in speed of loading result in lower and more non-linear stiffness values. 12. When measured values of stiffness are not available, Van der Poel nomograph may be used to estimate these values.

RECORD No.: 33.
AUTHOR : J. A. Epps and C. L. Monismith
TITLE : Influence of Mixture Variables on the Flexural Fatigue Properties of Asphalt Concrete
JOURNAL : Proceedings of Association of Asphalt Paving Technologists
VOLUME No.: 38
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1969
PAGES : 423-464
ABSTRACTOR: PTI
KEYWORDS : Asphalts, fatigue, stiffness, asphalt concrete, air voids, aggregates penetration, asphalt content

ABSTRACT :
The results of controlled-stress flexural fatigue tests on asphalt concrete mixtures are reported. Data are presented to illustrate the influence of: mixture stiffness, air void content, aggregate gradation, aggregate type, asphalt content, and asphalt type. Four aggregate types, four aggregate gradations, three grades of asphalt and a range in asphalt contents were examined. More than 300 specimen were tested under various stress levels and the relation between fatigue life and strain or stress were obtained. Considering the results obtained and other published information on fatigue the following findings were reported: 1. Air voids reduces both fatigue life and stiffness. The effect on fatigue life cannot wholly explained by the change in stiffness. The structure of the voids as well as voids content may have an influence. 2. The effect of aggregate type is not clear. Aggregate grading has little effect that cannot be explained by differences in asphalt or air content. 3. There exists a linear relationship between log of fatigue life and log of bending strain. 4. Asphalt type influences both stress and strain and fatigue regression lines relating both stress and strain and fatigue life. Mix containing the hardest asphalt, has the longest fatigue life and the flattest slope. The data indicate that a single relationship may be used however, provided the stiffness do not vary much and the asphalt contents are the same. 5. There appears to be an optimum asphalt content for best fatigue response. This optimum, however, depends on type and grading of aggregate.

RECORD No.: 34.
AUTHOR : L. E. Santucci, R. J. Schmit
TITLE : The Effect of Asphalt Properties on the Fatigue Resistance of Asphalt Paving Mixtures
JOURNAL : Proceedings, Association of Asphalt Paving Technologists
VOLUME No.: 38
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1969
PAGES : 65-97
ABSTRACTOR: PTI
KEYWORDS : Asphalt concrete mixtures, asphalt cements, fatigue, viscosity, oxidative hardening, penetration, softening point, oven tests
ABSTRACT :

The purpose of this investigation was to define those asphalt properties that best predict the durability of asphalt pavements in terms of fatigue resistance. Laboratory prepared asphalt concrete specimens containing test asphalt were stored in a sand bed for seven months at 140 F prior to measuring their fatigue resistance under a controlled strain mode of loading. A correlation between mixture fatigue resistance and asphalt viscosity projected from Rolling Thin Film (RTF) and original asphalt data proves significant at only 81.3 percent level. This relatively low significance level emphasize the danger of drawing conclusions on the long-term durability of certain asphalts based on their short-term hardening characteristics. Good correlations were found between recovered asphalt properties and mixture fatigue resistance. Recovered asphalt penetration, asphalt viscosity (calculated from recovered penetration and softening point), and viscosity measured at a constant shear rate (.05 1/sec) predict mixture fatigue behavior reasonably well. All of these correlations are significant at a level greater than 95 percent. Viscosity of recovered asphalt measured by a new constant stress (167g/cm^2) technique gives a correlation with mixture fatigue resistance significant at the 90 percent level. Three laboratory microfilm tests designed to simulate the long term durability of paving asphalts were examined for their suitability in predicting asphalt mixture fatigue resistance. An excellent correlation was found between constant shear rate asphalt viscosity (0.05 1/sec at 77 F) from the State of California's experimental Thin Film Plate (TFP) durability test and mixture fatigue resistance. Two new durability tests, the Rolling Microfilm (RMF) and Rolling Microfilm on Original Asphalt (RMFO) tests are introduced to eliminate many of the practical limitations of the TFP test and still retain its proven functionability. Correlations between TFP, RMF, and RMFO viscosities and mixture fatigue resistance are significant at a 95 percent level or higher. Asphalt viscosities in the RMF and RMFO durability tests are measured at a constant stress (167gm/cm^2). The improved repeatability and ease of testing of the RMFO durability test, as well as an acceptable correlation between RMFO viscosity and mixture fatigue resistance, support the proposal of this test as an alternate to the TFP durability test. A standard fatigue equation with consideration given to appropriate modes of loading can be used to predict mixture service life from asphalt

properties. For pure controlled strain testing, service life is inversely proportioned to asphalt viscosity at a given bending strain level and fixed mix characteristics. Deviations from pure controlled strain or controlled stress loading conditions, as occur in actual pavements, require sound engineering analyses prior to predicting fatigue response from asphalt at mix characteristics.

RECORD No.: 35.
AUTHOR : R. J. Schmidt, L. E. Santucci
TITLE : The Effect of Asphalt Properties on the Fatigue Cracking of Asphalt Concrete on the Zaca-Wigmore Test Project
JOURNAL : Proceedings, Association of Asphalt Paving Technologists
VOLUME No.: 38
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1969
PAGES : 39-64
ABSTRACTOR: PTI
KEYWORDS : Penetration, viscosity, hot mix hardening, long-term hardening, thin film oven tests, fatigue life, asphalt concrete mixtures, asphalt cements

ABSTRACT :

The paper presents two new durability test methods and compares their functionality and precision with two test methods now in use. Tests in common use today, Thin Film Oven (TFO) test and the Rolling Thin Film (RTF) test, can predict the hardening of asphalt during mixing with hot aggregates. The tests are commonly interpreted to indicate also the degree of long-term field hardening which might be expected to occur. However, no quantitative way of projecting the TFO or RTF hardening to long-term field hardening has been proposed. Based on the observation that the logarithm of the viscosity of an asphalt increases linearly with time exposed to high temperature oxidation. Two points on such a plot allow extrapolation or projection to longer exposure times. A fair correlation between actual 77 F viscosity calculated from recovered asphalt, of the Zaca-Wigmore project, and 77 F viscosity projected from penetrations of original asphalt and TFO residue was observed. Therefore, the TFO or RTF exposure is found to offer an interim way of distinguishing between the extremes of fatigue resistant and a fatigue-prone paving asphalt. Three recently developed microfilm durability tests: the Thin Film Plate Durability tests (TFP), the Rolling Microfilm (RMF), and the Rolling Microfilm on Original Asphalt (RMFO), appear to correlate equally well with the pavement life obtained on the Zaca-Wigmore test project. These correlations are shown to be slight, although statistically not significantly better than are obtained from projections of the TFO or the RTF. The RMFO test is found the most convenient, economical, and at the same time the most reliable of these three microfilm tests. Relation between fatigue life and viscosity of the asphalt has been studied. A low degree of dependency of the fatigue life on viscosity in the Zaca-Wigmore test project is found. The reason is probably because the test project approaches the condition somewhere between the controlled stress type fatigue resistance and controlled strain type fatigue resistance. The study shows that in structures containing thin asphalt concrete surfaces hardening resistance asphalts are, from the standpoint of fatigue resistance alone, clearly worthwhile to use. On the otherhand, more rapid-hardening asphalts may be advantageous in structures having very thick sections of asphalt concrete.

RECORD No.: 36.
AUTHOR : R. C. G. Haas, T. H. Topper
TITLE : Thermal Fracture Phenomena in Bituminous Surfaces
JOURNAL : Highway Research Board, Special Report
VOLUME No.: 101
PUBLISHER : Highway Research Board
YEAR : 1969
PAGES : 136-153
ABSTRACTOR: PTI
KEYWORDS : Asphalt cements, asphalt concrete mixtures, thermal cracking, fracture, stiffness
ABSTRACT :

This paper explores the phenomenon of thermally induced cracking in bituminous surfaces as a problem primarily associated with design. Low temperature effects on pavement performance are examined and the need for modifying current mixture design procedures is discussed. Since any such design requirements would be concerned with fracture susceptibility, an approximate procedure for calculating thermally induced stresses is presented which recognizes the probable stiffness and temperature gradients that occur in field service. A consideration of fundamental mechanisms involved is essential to adequately fulfilling design objectives; consequently, an hypothesis has been advanced to the effect that thermally induced cracking occurs in two main phases. These consist essentially of limited-depth cracking initiation, and subsequent full-depth propagation with rising air temperatures. The pertinent mechanics are explained and the hypothesis appears to be compatible with observed phenomena. Several practical implications of the hypothesis are discussed and these related primarily to the development of mix designs to mitigate or reduce cracking and to the possible use of "good" and "poor" asphalts in the same pavement structure. it is suggested that more efficient and economical uses of available materials may be possible in designing for the low-temperature cracking problem.

RECORD No.: 37.
AUTHOR : A. W. Sisko
TITLE : Tensile Strength of Asphalt Films and Road Life
JOURNAL : Highway Research Record
VOLUME No.: No. 231
PUBLISHER : Highway Research Board
YEAR : 1968
PAGES : 62-67
ABSTRACTOR: PTI
KEYWORDS : Asphalt cements, tensile strength, fracture, thin films, temperature, rate of loading, oxidative hardening
ABSTRACT :

The tensile strength of thin films of 12 asphalts in different conditions of aging-unaged, aged in the thin film oven test, and aged in roads for up to eleven years - increased by as much as 140 percent as the temperature decrease from 80 to 0 F. Experimental conditions insured failure by brittle fracture. At low temperatures, TFOT aging produced no significant differences in the tensile strength of the asphalts but road aging produced large differences. The tensile strength of road-aged asphalts appears unrelated to asphalt source or composition.

RECORD No.: 38.
AUTHOR : A. G. Bahgat, M. Herrin
TITLE : Brittle Fracture of Asphaltic Mixtures
JOURNAL : Proceeding, Association of Asphalt Paving Technologists
VOLUME No.: 37
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1968
PAGES : 32-55
ABSTRACTOR: PTI
KEYWORDS : Asphalt cements, asphalt concrete mixtures, fracture toughness, impact test, temperature, penetration, rate of loading
ABSTRACT :

All fracture mechanic concepts are based upon the assumptions that the materials are elastic and homogeneous in nature. The purpose of this investigation is to determine the applicability of modern fracture mechanics to heterogeneous asphalt-aggregate mixtures. For this study, the stress intensity analysis method as adapted by Bueckner is used due to its experimental suitability for determining the fracture toughness. Two types of tests: Notched Beam tests and an Izod type impact test are used to study the effects of test temperature, rate of loading, consistency of asphalt cement, asphalt content, and unit weight of the compacted specimen, on the brittle behavior of asphalt mixtures prepared with three different asphalt cements and one type of aggregate. The analysis of results indicates that brittle behavior is a direct function of the test temperature (TC) at and below which mixes behave in a brittle manner. TC appears to be a function of the consistency of asphalt cement. At low temperatures (<0 C), Griffith theory of brittle fracture is applicable to study the fracture behavior of asphaltic mixtures since no notch effect is observed upon brittle resistance of mixtures. The pseudo-fracture toughness is a measure of the brittle resistance of asphaltic mixtures and can be considered to be a mix property provided that the test environment and mix parameters are standardized. Mixes with softer asphalts (high penetration), greater asphalt contents, or higher unit weights have greater resistance to fracture. Higher pseudo-fracture toughness is observed with higher rates of deflection. Thus, at certain temperatures, asphalt roads with slow moving traffic may have less brittle resistance than similar roads with faster traffic.

RECORD No.: 39.
AUTHOR : B. A. Vallegra, F. N. Finn and R. G. Hicks
TITLE : Effect of Asphalt Aging on the Fatigue Properties of Asphalt Concrete
JOURNAL : Proceedings of 2nd International Conference on the Structural Design of Asphalt Pavements
VOLUME No.: III
PUBLISHER : University of Michigan, Ann Arbor
YEAR : 1967
PAGES : 595-617
ABSTRACTOR: PTI
KEYWORDS : Asphalts, aging, RTFOT, fatigue, stiffness, pavement structure, penetration

ABSTRACT :
A laboratory study of asphalt aging on the fatigue properties of asphalt concrete has been conducted. Fatigue tests using artificially aged asphalts with penetration values of 63, 53, 37 and 15 (after mixing), and refinery produced unaged asphalts with penetration values of 65, 48, 28 and 9 (after mixing) were carried out under constant bending stress-load conditions at one temperature and one rate of loading. The fatigue test results for each asphalt were interpreted with the aid of three-layered theory for three typical roadway structural sections. The variables included in this analysis were surface stiffness (E1) base stiffness (E2) and surface and base thickness. The weathered asphalt was produced in the Rolling Thin Film Oven developed by the California Division of Highways. The original use of the equipment was to simulate only the hot-mix hardening of asphalt for this study, however, the time in the oven was extended to obtain specific penetration levels. The most significant conclusions resulting from the interpretation of test data are the following: 1. For asphalt surfaces thicker than 3 inches, fatigue life increases with increasing stiffness for both the aged and unaged asphalts. 2. The aged asphalts out perform the unaged asphalts (of about same penetration) in terms of fatigue life for the range of stiffness moduli and materials investigated. 3. As E increases, fatigue life increases for both aged and unaged asphalts. 4. For equivalent pavement designs, as the thickness of the surface layer increases, the estimated fatigue life increases. 5. There are doubts as to the use of the Rolling Thin Film Oven to simulate aging beyond that of the mixing process.

RECORD No.: 40.
AUTHOR : Monismith, C. L.
TITLE : Asphalt Mixture Behavior in Repeated Flexure
JOURNAL : Research Report
VOLUME No.: TT-66-6
PUBLISHER : University of California-Berkeley. Soil Mechanics and Bituminous Materials Research Lab
YEAR : 1966
PAGES : 177p
ABSTRACTOR: NTIS
KEYWORDS : Asphalt cements, asphalt concrete mixtures, fatigue, stiffness, temperature, oxidative hardening

ABSTRACT :

The first phase of the study was concerned with defining the influence of asphalts from different sources and hardness and aggregate type on the fatigue characteristics of asphalt concrete using controlled-strain tests. The second continuing phase explores the application of laboratory fatigue data to predict the performance of in-service pavements. Controlled-stress fatigue tests were made on specimens sawed from the pavement courses and on laboratory-prepared specimens of the same components. Triaxial compression repeated load tests were made on recompacted granular and subgrade materials. Test procedures for controlled-strain, controlled-stress fatigue tests and repeated load triaxial tests are given. The report gives a comprehensive discussion of fatigue testing and approximate guides to assist in the selection of mode of loading depending on the pavement section under study. Stiffness of the mixture was used to assist in the interpretations of the fatigue data. The application of fatigue characteristics to the design of asphalt concrete pavements is discussed. A suggested procedure is presented in terms of stress in the asphalt concrete. Simplifying assumptions were made for temperature (influence on stiffness), lateral displacement of wheel loading and aging affects of asphalt aging. (Author)

RECORD No.: 41.
AUTHOR : Krenkler, K.
TITLE : Relationship Between Bitumen Structure and Strength Properties of Bituminous Layers
JOURNAL : Bitumen, Terre, Asphalte, Peche
VOLUME No.: No. 15
PUBLISHER : Bitumen, Terre, Asphalte, Peche, Isevnhagen, Germany
YEAR : 1964
PAGES : 447-456
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, fracture, ductility, plasticity, asphalt concrete, mixtures, Marshall stability, tensile strength

ABSTRACT :

Determination of the breaking point of untreated and heated bitumen is discussed, and a method for determining the solidification point by measuring penetration is described. The solidification point lies in the distribution range of measured breaking points. Measurement of plasticity span, which is the temperature between softening and breaking point, and of critical ductility are also discussed. Measurements show that the greater the plasticity span, the higher is the pressure resistance and the less the sensitivity of pressure resistance to temperature. Marshall stability between the 0 and 60 degree is greater if plasticity span is high, and less sensitive to temperature. Hammer resistance can show differences of 30 percent for different asphalts cements and depends largely on plasticity span and cold ductility. Tensile strength and deformation are also considered.

RECORD No.: 42.
AUTHOR : H. L. Speer, L. C. Burnstrum, A. W. Sisko, L. E. Ott R Evans and J. V. Evans
TITLE : Asphalt Viscosity as Related to Pavement Performance
JOURNAL : Proceedings of Association of Asphalt Paving Technologists
VOLUME No.: 32
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1963
PAGES : 236-246
ABSTRACTOR: PTI
KEYWORDS : Asphalts, rutting, viscosity, aging, temperature test track, aggregates
ABSTRACT :

Simulated severe traffic on a minature test track was used to determine the effect of asphalt properties on pavement performance. Eight types of commercially available asphalts, curshed limestone and uncrushed gravel, natural sand, and two sets of mixing and compaction procedures were used to construct 16 pavement tracks. The pavements were tested over temperatures from 60 to 140 F and the criteria for paving performance were the extent and rate of rutting at each temperature. In addition to routine aspahlt inspection tests, aspahlt viscosities were determined over a range of temperatures before and after the thin film oven test (TFOT). Parallel plate, cone and plate, vacuum capillary, kinematic and Furol viscometers were used at appropriate temperatures.

The traffic machine was operated at 42.4 rpm, giving a wheel speed of 21.4 mph. During the tests, wheel torque was varied in regular repeated cycles to simulate the effect of wheel braking and acceleration actions. Rut depth was determined by averaging the difference between the maximum and minimum elevation on transverse surface profiles at five equally spaced positions along each pavement.

The results indicated the following points:

1. Over the range of temperature used the viscosity-temperature data fitted the equation:

$$\log\log(100V + 0.8) = a - m*\log t \qquad 1$$

where V is the viscosity in poises. T is the absolute temperature on the Fahrenheit scale, and a and m are constants. Values for the constants on the original asphalts and on the residue from the TFOT showed that only the constant a changes as a result of aging.

2. Pavements made with uncrushed gravel rutted 6 times more rapidly than pavements made from crushed stone.

3. The major variable affecting rutting was asphalt viscosity at each operating temperature. The equation for the relationship between rutting depth in inches per million wheel passes (R) and viscosity (V) is:

$$R = k\ (V)^{-n} \qquad 2$$

The values of the constants are R = 9.51 and n = 0.552 for original

asphalts and R-285 and 0.552 for TFOT residue. Substituting equation 2 into 1 will give a relation between rutting, viscosity and temperature.

4. The viscosity at the highest temperature likely to be encountered in roads, say, 140 F, has a more direct bearing on pavement quality than either penetration at 77 F or viscosity at 275 F.

5. Rutting varies much less with temperature than does asphalt viscosity. A four fold increase in viscosity reduced rutting by one-half. Therefore, viscosity at 140 F need not be specified narrowly to effectively control rutting performance.

RECORD No.: 43.
AUTHOR : P. S. Pell
TITLE : Fatigue Characteristics of Bitumen and Bituminous Mixes
JOURNAL : Second International Conference of Structural Design of Asphalt Pavements
VOLUME No.: I
PUBLISHER : University of Michigan, Ann Arbor
YEAR : 1962
PAGES : 310
ABSTRACTOR: PTI
KEYWORDS : Asphalt cements, asphalt concrete mixtures, fatigue, stiffness, temperature, bending stresses, shear stresses, temperature, rate of loading

ABSTRACT :

Details are given of a laboratory investigation into the fundamental fatigue properties of bitumen and bituminous mixes. Tests were carried out in two different types of machine, rotating bending under constant stress amplitude, and oscillating torsion under constant strain amplitude, to investigate the effect of such factors as temperature, speed of loading, bitumen content of the mix, void content, surface finish, rest periods, and rate of crack propagation. Fatigue tests on sandsheet specimens carried out under constant amplitude bending stress at various temperatures between -13.5 degrees C and +25 degrees C show that the material exhibits fatigue properties over wide ranges of stress and that for a particular temperature and speed of loading the relationship between the logarithm of the stress and the logarithm of the number of cycles of loading to cause failure is linear between 104 and 108 cycles. The life under constant stress amplitude tests is highly dependent on the temperature, a low temperature giving a longer life at a particular stress; it is also dependent to some extent on the speed of loading. However, taking into account the stiffness of the materials which depends on temperature, speed of loading, rheological characteristics, and composition of the mix, it has been found that when the logarithm of the strain, calculated as the stress amplitude divided by the stiffness, is plotted against the logarithm of the number of cycles to failure, all experimental results at different speeds and temperatures for one mix lie with a certain amount of scatter about one straight line. It appears, therefore, that the fatigue life is primarily controlled by the magnitude of the applied strain and not by the stress, and that the effects of temperature and speed of loading can be accounted for by their effect on the stiffness of the specimen. The results of fatigue tests on sandsheet specimens under constant amplitude torsional strain at different temperatures between -20 degrees C and +40 degrees C confirmed the bending results, but at the higher temperatures under this type of loading the fatigue life includes a considerable crack propagation time, the rate of propagation depends on the stress at the tip of the crack: Examination of the fatigue cracks and failure surfaces showed that in nearly all cases failure originated on the principal tensile plane. Similar results have been obtained for mixes containing different amounts of aggregate but as the quantity of aggregate in the mix is reduced so the

life for a given strain increases, suggesting that the criterion of fatigue crack initiation in bituminous mixes may be one of tensile strain in the bitumen present in the mix. Tests on bitumen alone at various temperatures both in bending and shear also gave comparable results on the basis of tensile strain, but under certain conditions, particularly at low stresses, the measured fatigue life includes a considerable length of time necessary to propagate the crack or cracks sufficiently to terminate the test. Unlike sandsheet specimens, bitumen along showed beneficial effects of rest periods particularly at higher temperatures.

RECORD No.: 44.
AUTHOR : C. L. Monismith
TITLE : Effect of Temperature on the Flexibility Characteristics of Asphalt Paving Mixtures
JOURNAL : American Society for Testing and Materials Special Technical Publication
VOLUME No.: STP 277
PUBLISHER : American Society for Testing and Materials
YEAR : 1960
PAGES : 89-108
ABSTRACTOR: PTI
KEYWORDS : Ductility, viscosity, temperature susceptibility, repeated loading, flexibility, modulus of rupture

ABSTRACT :

This paper is concerned with the effect of variation in type, amount, and temperature of asphalt on the behavior of dense-graded paving mixtures in repeated flexure. Two 85-100 penetration asphalt cements: one is a paving asphalt conforming to the recently adopted uniform asphalt specifications of the Pacific Coast. The other is an air-blown asphalt which has low temperature susceptibility. The asphalts have significantly different physical properties. One aggregate was used to prepare beam specimens (3 x 12 x 2 inch) with both asphalts by a kneating compactor. To measure the property of flexibility, a flexure list using a special apparatus consisting of a spring base and a device to apply repeated loadings of short duration was developed. Load applied and temperature of test were varied. Data collected show that for the loadings investigated, there appears to be little difference in the behavior of mixtures prepared with two asphalts of significantly different physical properties. At 75 degrees F, specimens prepared with the air-blown asphalt performed slightly better at the higher asphalt contents than the specimens prepared with the asphalt conforming to the recently adopted uniform specifications of the Pacific Coast. At 40 degrees F, however, the reverse was true. The effectiveness of ductility, at least as measured by the particular test, as a criterion for flexibility is questioned. Also, since the asphalt with greater temperature susceptibility performed better than the asphalt with a lower susceptibility, the requirement for temperature susceptibility test may be questioned. Other results indicates that for dense-graded mixtures, the effect of asphalt content is pronounced, and that the deformation (strain) induced in a paving mixtures would be a better criterion for determining the behavior of a paving mixture in repeated flexure than deflection alone.

RECORD No.: 45.
AUTHOR : S. Pickles
TITLE : Improved Brittle Point Test for Tars
JOURNAL : Journal of Applied Chemistry
VOLUME No.: No. 9, Pt. 4
PUBLISHER : Society of Chemical Industry, London
YEAR : 1959
PAGES : 219-223
ABSTRACTOR: HRB
KEYWORDS : Asphalt cement, Fraass brittle point, fracture
ABSTRACT :

Test embodies principles of that devised by A. Fraass, with modifications.

RECORD No.: 46.
AUTHOR : R. N. J. Saal
TITLE : Mechanical Properties of Bitumen
JOURNAL : Erdol u Kohle
VOLUME No.: 7
PUBLISHER :
YEAR : 1954
PAGES : 70
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, fracture, viscoelastic properties, penetration, softening point

ABSTRACT :

Main properties of bitumen from standpoint of its use as a constructional material are rigidity and fracture resistance. Rigidity can be considered as modulus of elasticity comprising both elastic and viscous components and which is time-dependent; its maximum value (approximately 3.10 kg/cm^2) is independent, and at short loading has, for various types, maximum value of about 30 kg/cm^2. Bitumens of various types and hardness can be differentiated by rigidity-time curves for various temperature examples of which are given; these results are, broadly speaking, related to penetration and softening point (R and B).

RECORD No.: 47.
AUTHOR : S. L. Neppe
TITLE : The Influence of Rheological Characteristics of the Binder on Certain Mechanical Properties of Bitumen-Aggregate Mixes
JOURNAL : Proceedings, Association of Asphalt Paving Technologists
VOLUME No.: 22
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1953
PAGES : 428
ABSTRACTOR: HRB
KEYWORDS : Asphalt cement, asphalt concrete mixtures, rheological properties, penetration, temperature susceptibility, ductility
ABSTRACT :

The primary purpose of this work was to examine the relative propensities of different bituminous mixtures to fail under direct loading and under conditions of impact, and to evaluate the results in terms of the rheological properties of the binder, with special reference to softening point number as the characterization criterion. The same aggregate and grading were used as standard for all the mixtures, the only variables being the nature and proportions of bitumen. Unconfined direct compression tests were performed with a Wilson stabilometer at temperatures ranging from 77 to 140 F. A special impact machine was constructed based on the AFA standard hammer, and primary tests were made at a subzero temperature of 5 F followed by tests, starting at 77 F and higher. Secondary impact tests, starting at 77 F, were carried out on those samples where failures were recorded in the primary tests at 5 F. While mixtures prepared with bitumens of all classes gave adequate performance at normal temperatures in both types of test, drastic failures were liable to occur under impact stresses at subzero temperatures with binders of low softening point number. Again, at elevated temperatures, poor stability results were obtained for such low-index bitumens, whereas reasonably high compressive strengths were experienced with high-index binders. The great sensitivity to a change in the proportion of binder was striking in the case of mixtures with low-index bitumens. Diagrams are presented to show the effect of binder penetration, proportion and softening point number on both compressive strength and resistance to impact of bitumen-aggregate mixes. Among other observations, the dependence of mechanical stability of mixtures on the absolute viscosity of the binder at the temperature of test is clearly demonstrated. Attention is drawn to the importance of temperature susceptibility, with particular reference to fluidity characterization and ductility susceptibility factors.

RECORD No.: 48.
AUTHOR : Thelen, Edmund
TITLE : Physical Testing of Asphalts and Similar Materials
JOURNAL : Proceedings, Association of Asphalt Paving Technologists
VOLUME No.: 18
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1949
PAGES : 154-184
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, fatigue, fracture, impact, adhesion, shrinkage, aging
ABSTRACT :
In practice, it has been found that the failure of asphaltic materials to form a tight bond, at least to a smooth, dry, hard non-polar surface is almost always caused by too high a yield value or too low a mobility at pouring temperatures, rather than to poor wetting. Pouring temperature is more critical if the solid surface is rough, porous or highly heat conducting. A stormer viscosimeter was used to determine flow properties at various ambient temperatures. Cold flow was also measured. The sessile drop method was used to determine the work of adhesion and surface tension. Impact forces and breaking energies were measured. Resistance to failure caused by vibration was evaluated.

RECORD No.: 49.
AUTHOR : Edmund Thelen
TITLE : Physical Testing of Asphalts and Similar Materials
JOURNAL : Proceedings, Association of Asphalt Paving Technologists
VOLUME No.: 18
PUBLISHER : Association of Asphalt Paving Technologists
YEAR : 1949
PAGES : 154
ABSTRACTOR: HRB
KEYWORDS : Asphalt cements, adhesion, surface tension, composition, fracture, fatigue

ABSTRACT :

In practice, it has been found that the failure of asphaltic materials to form a tight bond, at least to a smooth, dry, hard non-polar surface is almost always at pouring temperatures, rather than to poor wetting. Pouring temperature is more critical if the solid surface is rough, porous or highly heat conducting. A stormer viscosimeter was used to determine flow properties at various ambient temperatures. Cold flow was also measured. The sessile drop method was used to determine the work of adhesion and surface tension. Impact forces and breaking energies were measured. Resistance to failure caused by vibration was evaluated.

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