DOT/FAA/AR-99/13
Office of Aviation Research
Washington, D.C. 20591

Evaluation of Strategic Highway Research Program (SHRP) Products for Application to Airport Pavements

October 2000

Final Report

U.S. Department of Transportation
Federal Aviation Administration

Notice

Technical Report Documentation Page

1. Report No. DOT/FAA/AR-99/13	**2. Government Accession No.**	**3. Recipient's Catalog No.**
4. Title and Subtitle EVALUATION OF STRATEGIC HIGHWAY RESEARCH PROGRAM (SHRP) PRODUCTS FOR APPLICATION TO AIRPORT PAVEMENTS		**5. Report Date** October 2000 **6. Performing Organization Code** CEWES-GP-Q
7. Author(s) J. Kent Newman and Reed B. Freeman		**8. Performing Organization Report No.**
9. Performing Organization Name and Address U.S. Army Engineer Waterways Experiment Station 3909 Halls Ferry Road Vicksburg, MS 39180-6199		**10. Work Unit No. (TRAIS)** DTFA03-94-X-00010 **11. Contract or Grant No.**
12. Sponsoring Agency Name and Address U.S. Department of Transportation Federal Aviation Administration Office of Aviation Research Washington, DC 20591		**13. Type of Report and Period Covered** Final Report **14. Sponsoring Agency Code** AAS-200
15. Supplementary Notes FAA William J. Hughes Technical Center COTR: Satish Agrawal		

16. Abstract

The Strategic Highway Research Program (SHRP) was a $150 million 5-year research program targeted toward four areas: asphalt, concrete, highway operations, and pavement engineering. This work resulted in 128 products, each of which may be a device, procedure, specification, etc. Many of these products and other aspects of the SHRP research have application to airfield pavements, but these technologies must be evaluated on an individual basis to determine their usefulness. These reviews have been organized into fact sheets that provide a brief description of the product and an evaluation of whether the technology has application to Federal Aviation Administration (FAA) pavements and the technical issues involved in their use. The SHRP asphalt mixture design system (SUPERPAVE®) has been evaluated in relation to current FAA asphalt mixture design. Asphalt mixture tests (repeated simple shear at constant height, flexural beam fatigue, and thermal stress restrain specimen test), utilized during SHRP, revealed no significant differences in performance-related material properties between heavy-duty SHRP and heavy-duty FAA laboratory-prepared specimens. Recommendations on the adoption and/or revision of aspects of the SHRP asphalt technologies for use by the FAA are included.

17. Key Words Asphalt, Concrete, Pavement engineering, SHRP, Performance, Grading, Airfield, Pavements		**18. Distribution Statement** This document is available to the public through the National Technical Information Service (NTIS), Springfield, VA 22161	
19. Security Classif. (of this report) Unclassified	**20. Security Classif. (of this page)** Unclassified	**21. No. of Pages** 237	**22. Price**

PREFACE

This research was sponsored by the U.S. Department of Transportation, Federal Aviation Administration (FAA), Airport Technology Branch, under Interagency Agreement DTFA03-94-X-00010 by the Airfields and Pavements Division (APD), Geotechnical Laboratory (GL), U.S. Army Engineer Waterways Experiment Station (WES), Vicksburg, MS. Dr. Xiaogong Lee, Airport Technology Branch, FAA, was technical monitor. Dr. Satish Agrawal is Manager, Airport Technology Branch, FAA.

This study was conducted under the direct supervision of Mr. T.W. Vollor, Chief, Materials Analysis Branch (MAB), APD, and under the general supervision of Dr. W. F. Marcuson III, Director, GL, and Dr. David W. Pittman, Chief, APD. Project principal investigator (PI) was Dr. J. Kent Newman, MAB. The authors of this report were Dr. J. Kent Newman and Dr. Reed B. Freeman, MAB. The PI would like to thank the following contributors to this work: Mr. Don R. Alexander for helpful discussions reviewing the falling weight deflection, ground pavement radar, and seismic pavement analyzer portion of the Strategic Highway Research Program (SHRP) technology; Dr. Randy Ahlrich for discussions of much of the SHRP mixture design and characterization work; and Dr. Ray Rollings for helpful discussions. Professor Carl Monismith at the University of California at Berkeley is gratefully acknowledged for providing technical direction and guidance. Professor Matthew Witczak at the University of Maryland is also acknowledged for several helpful discussions involving the future of asphalt pavements technology.

At the time of preparation of this report, the director of WES was Dr. Robert W. Whalin.

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EXECUTIVE SUMMARY

Many of the SHRP technologies can be directly used and/or adapted for use by Federal Aviation Administration (FAA) pavements personnel. All of the Strategic Highway Research Program (SHRP) products developed for highway technology have been reviewed and evaluated for application to FAA airport pavements. Fact sheets that describe and evaluate each product for FAA application are included in the appendices of this report. Technical issues relating to the application of each product are also addressed in the fact sheets.

The SHRP asphalt binder specifications should be adopted by the FAA for use in asphalt pavements. This specification represents a considerable improvement over current FAA asphalt binder specifications. It is recommended that a conservative approach to SHRP binder performance grade selection be adopted until sufficient data are available for making specific recommendations.

The SHRP asphalt binder grading system must be evaluated on a case-by-case basis when polymer-modified asphalts (PMA) are being tested. Several of the binder test procedures may not be applicable if the modifier phase separates during testing. In addition, the specifications limits are based on unmodified asphalts and may not accurately reflect the performance of some PMAs.

The SHRP asphalt mixture design results in laboratory samples similar in performance to those produced by current FAA design procedures. Some of the samples prepared using FAA specified materials did not meet SHRP mixture criteria for minimum compaction and the fines/effective asphalt ratio. Although the SHRP compactor is capable of producing heavy-duty laboratory mixtures with properties comparable to Marshall hammer samples, the SHRP mixture design system contains no measurement of properties of the compacted samples.

The original SHRP performance models were discontinued due a number of inconsistencies in the prediction routines. A further effort is underway by Dr. Matt Witczak at the University of Maryland to reformulate and generalize the models. The reformulated models are envisioned to account for variable static and dynamic loads as well as multiple-wheel configurations which would be applicable to FAA pavements technology.

INTRODUCTION

BACKGROUND.

The Strategic Highway Research Program (SHRP) was a $150 million effort targeted toward four general highway-related areas: asphalt, concrete, highway operations, and pavement engineering. The program was initiated to address, in part, growing concerns about the deterioration and aging of the nation's highway infrastructure. A number of task groups were formed consisting of industry and government representatives for identifying specific problem areas for targeted research action.

The results of these studies are a series of 128 products that may be a specification, mechanical device, process, report, or computer program for mitigation or solution of a specific problem area. These products may be of use to a number of different agencies, state Departments of Transportation (DOT), and businesses.

A major effort of the SHRP research was to address the problems occurring in asphalt pavements. Asphalt pavements are subject to permanent deformation, thermal cracking, fatigue cracking from traffic, and other problems related to poor adhesion of the asphalt binder to the aggregate portion of the asphalt concrete. Specific research efforts directed by SHRP were aimed at resolving three specific pavement distresses in asphalt pavements: permanent deformation (rutting), thermal cracking, and fatigue cracking. A number of new test methods, procedures, practices, and specifications (e.g., the Superior Performing Pavement (SUPERPAVE®) Mix Design System) have been developed or modified for characterization of asphalt binders, aggregates, and mixtures.

Discussions with Federal Highway Administration (FHWA) personnel and several of the SHRP researchers have revealed that the Level II and Level III portion (the performance prediction) of the SUPERPAVE® system will not be pursued further due to numerous technical problems. The SUPERPAVE® Level I volumetric mixture design (which includes the SUPERPAVE® binder specification) will be implemented at the state level. Many state highway agencies adopted the SHRP binder specification system during 1997, and it is expected that all of the states will be using SHRP performance-graded binders by the end of 1998. Much of the driving force for the binder specification implementation is coming from asphalt producers.

A significant research effort for a complete overhaul of the SUPERPAVE® performance prediction system is currently underway at the University of Maryland and is being led by Dr. Matthew Witzcak. The performance models will be refined and the system is intended to be capable of designing any type of asphalt pavement regardless of the load magnitude, traffic volume, and wheel configuration. This software would have application to Federal Aviation Administration (FAA) pavements technology. However, this vision is years from completion and is estimated to not be available before 2007.

Much of the SHRP asphalt technology will not be discussed in detail. Specific information is available in the SHRP reports listed in the reference section.

OBJECTIVE.

The objectives of this project entail three major goals:

1. Provide a complete and detailed description of each product of the SHRP research. There are currently 128 products of this research program which may have potential application for FAA pavements technology. These products will be classified into the following categories:

a. Not applicable. The SHRP product has no potential application or use for FAA pavement technology.

b. Applicable with major modifications. Significant changes are required in either the device, SHRP testing equipment, method, procedure, or specification. SHRP products in this category would require a substantial and timely effort for alteration of the product for use in FAA pavements technology.

c. Applicable with minor modifications. The product is useful to the FAA but requires a minor modification of some sort that involves only minimal changes to the device, SHRP testing equipment, method, procedure, or specification. These types of products would require only minimal effort to produce a product applicable to FAA pavements.

d. Directly applicable. In this case, the SHRP product can be employed by the FAA with no modification whatsoever before application or use of that product.

2. Discuss the basic assumptions and hypotheses employed in the development of the performance-based specifications and models for asphalt pavements. These assumptions and hypotheses will be evaluated for their relation to airfield pavements.

3. A laboratory investigation comparing current FAA and SUPERPAVE® asphalt and aggregate selection criteria and mix design procedures will be conducted to determine if SHRP asphalt mix design technologies are suitable for use in FAA asphalt pavements.

The objectives listed above will be accomplished by completing the following tasks:

- Task 1: Review and evaluation of all SHRP products.
- Task 2: Investigate the basic assumptions of SHRP specifications and test methods for asphalt pavements.
- Task 3: Develop a test plan for comparing FAA and SHRP asphalt concrete mix design procedures.
- Task 4: Conduct comparative laboratory testing.
- Task 5: Complete final report.

SCOPE.

This report is intended to be comprehensive and will include reviews of all SHRP products and the results of the laboratory investigation comparing current FAA asphalt mixture design procedures with those of the SUPERPAVE® mixture design.

PROBLEM STATEMENT.

This study is targeted toward determining the application of SHRP products, particularly the SHRP asphalt technology to FAA pavements. The SHRP SUPERPAVE® system of asphalt and asphalt mixture specification employs a different compaction method for laboratory design of asphalt pavements for roads and highways. These specifications are derived from studies based solely on highway-type mix designs.

Heavy-duty asphalt airfield pavements are typically composed of the same materials as highway pavements. However, there are significant differences. Of primary importance is the increased magnitude of the load and variable multiple-wheel configurations that result in different load distribution patterns on an airfield pavement than on a highway. This necessitates a stiffer asphalt mix and thicker asphalt layers to withstand the heavy aircraft loads. Stiffer mixes require higher compaction efforts that result in less asphalt binder to achieve the same air void level as a softer mix. Lower asphalt contents can result in lower durability of a mix and this is often observed in heavy-duty pavements.

Due to the substantial differences between a typical highway asphalt pavement structure and an airfield pavement, the types and levels of distresses observed on highway pavements vary from those of airfield pavements. The most significant distresses observed on airfield pavements are thermal cracking and weathering effects. Rutting is not a substantial problem and fatigue cracking is observed only occasionally in areas such as heavily used taxiways. However, in highway pavements, rutting, thermal cracking, and fatigue cracking are all significant forms of distress. Thus, the SHRP's focus was on load- and non-load-related distresses; whereas mainly non-load-related distresses are observed in airfield pavements. In addition, because the research studies leading to the validation of the asphalt specifications were conducted on highway pavements, portions of the specifications may need adjustment to correlate to airfield pavements.

The SHRP mix design and analysis procedures must be evaluated in detail and compared to current FAA design procedures to determine if these technologies are valid for light- or heavy-duty airfield pavements. In the near future, selection of an asphalt binder based on viscosity or penetration may not be available, having been replaced by the SHRP Performance Grade (PG) system. Thus, selection of an asphalt binder for an airfield paving job based on current FAA methodology may not be available, requiring some understanding of the PG system for asphalt selection.

APPLICABILITY OF SHRP PRODUCTS TO FAA PAVEMENTS

The results of the substantial research efforts undertaken during SHRP amounted to 128 products that respond to certain needs defined at the beginning of the program. The product may be a device, procedure, practice, specification, software program, test apparatus, etc., that advances the state of the art of some aspect of pavement technology. Many of these products have varying degrees of application to airfield pavement technology but each must be evaluated on an individual basis due to the differences in highway and airfield pavements.

Each of the SHRP products has been reviewed and evaluated for applicability to airfield pavements. The products have been classified into four categories:

- 0—Not applicable. The product has no current or future potential for use on airfield pavements. For example, SHRP product 3016 "Flashing Stop/Slow Paddle" has no application on an airfield.

- 1—Applicable with major modifications. This type of product has some potential for use or application to airfield pavements but would require a substantial effort to modify the product before use. An example of this is SHRP product 1012 "Superpave Mix Design System" that predicts performance of an asphalt pavement based on highway traffic loads. The entire prediction scheme could be retrofit to aircraft-type loads and pavements but would require significant effort at validation, test conditions, reworking performance models, and software changes to make the system applicable.

- 2—Applicable with minor modifications. The product has potential application for airfield pavements but requires a slight adjustment to apply the technology. An example of this is SHRP product 1001 "Binder Specification." The specification as written has been validated for use in highway pavements with highway test sections. Due to the differences in binder content, aggregate gradation, and compaction level of heavy-duty airfield pavements, portions of the specification or its method of application may need adjustment to meet more stringent aging and thermal cracking requirements for application to airfield pavements.

- 3—Directly applicable. The product can be used directly without any modification or changes. An example of this is SHRP product 1021 "Thermal Stress Retained Specimen Test" which can be conducted on any asphalt pavement sample regardless of the source.

- N/A. No information on the specifics of the product could be located; thus, no applicability rating could be established. A brief description of the product may be found in the fact sheet in the appendices.

The applicability ratings for each of the SHRP products are discussed in detail in fact sheets in appendices A-D. Each appendix contains fact sheets for each of the SHRP product categories; asphalt (appendix A), concrete (appendix B), highway operations (appendix C), and pavement engineering (appendix D). The fact sheets are presented in the order of their SHRP product number. The fact sheets contain a short description of each product, the applicability rating, a critical evaluation of the product, and the issues that accompany application of the product to airfield pavements. The SHRP product applicability ratings from appendices A-D are summarized in tables 1 through 4, respectively.

TABLE 1. ASPHALT PRODUCT APPLICABILITY RATINGS

SHRP Product Number	Product Title	Applicability Rating
1001	Binder Specification	2
1002	Bending Beam Rheometer	3
1003	Pressure Aging Vessel	3
1004	Asphalt Extraction and Recovery	3
1005	Low-Temperature Direct Tension Test	3
1006	High-Temperature Viscosity Test	3
1007	Dynamic Shear Rheometer	3
1009	Binder Chromatography	3
1010	Refiner's Guide	0
1011	Mix Specification	1
1012	Superpave Mix Design System	1
1013	Net Adsorption Test	3
1014	Gyratory Compactor and Method	2
1015	Rolling Steel Wheel Compaction Method	3
1017	Shear Test and Device	2
1019	Flexural Fatigue Life Test	2
1021	Thermal Stress Restrained Specimen Test	3
1024	Environmental Conditioning System	2
1025	Short-Term Aging	3
1026	Modified Rice Correction Test	3
1030	Long-Term Aging	2

TABLE 2. CONCRETE PRODUCT APPLICABILITY RATINGS

SHRP Product Number	Product Title	Applicability Rating
2001	Corrosion Rate Method	0
2002	Aggregate Durability Test	3
2003	Concrete Removal Manual	2
2004	Mitigation of D-Cracking	3
2005	Handbook for Mix Design	3
2006	Guide to Thermal Effects	3
2007	Permeability Laboratory Test	3
2008	Fluorescent Microscopy Manual	3
2009	Screening Reactive Aggregates Test	3
2010	Manual for ASR Detection	3
2011	ASR Mitigation in Existing Concrete	3
2012	Flaw Detection by Impact Echo Method	3
2013	Chemical Test for ASR Detection	3
2014	High-Performance Concrete Specifications	3
2015	Radar Method for Asphalt Decks	3
2016	Membrane Integrity Survey Method	0
2017	ASR-Safe Mix Designs	3
2018	Modified Freeze and Thaw Test	3
2019	Soundness Test for Concrete	3
2020	Air Entrainment Specifications	3
2021	PCC Aggregate Specifications	3
2022	Guide to Strength/Maturity	3
2023	Flexural Strength Test	3
2024	Compressive Strength Test	3
2025	Interfacial Bond Test	3
2026	Permeability Test—Electrical Resistance	3
2027	Fresh-Concrete Water Content Test	3
2028	Test for Consolidation	3

TABLE 2. CONCRETE PRODUCT APPLICABILITY RATINGS (Continued)

SHRP Product Number	Product Title	Applicability Rating
2029	Sealer Effectiveness Methods	3
2030	Chloride Content Test	0
2031	Permeability Test—Surface Air Flow	3
2032	Bridge Condition Evaluation Manual	0
2033	Manual on Chloride Removal	0
2034	Cathodic Protection Manual	0
2035	Manual on Rapid Repair of Bridge Decks	0
2036	Field Guide on Bridge Rehab and Protection Options	0
2037	Manual for Selecting Bridge Rehab and Protection Options	0
2038	Computer Program for Bridge Rehab and Protection Options	0
2039	HWYCON—Concrete Expert System	2
2040	Guidelines for Cathodic Protection	0
4001	Measuring Air Entrainment	3
4003	Monitoring Cathodic Protection	0
4009	Repairing Marine Structures	0

TABLE 3. HIGHWAY OPERATIONS PRODUCT APPLICABILITY RATINGS

SHRP Product Number	Product Title	Applicability Rating
3001	Snow Fence Guide	0
3003	Pavement Repair Materials Guidelines	2
3004	Robotic Crack-Filling Vehicle	2
3005	Robotic Pothole-Patching Vehicle	3
3008	Ultrasonic Intrusion Alarm	0
3009	Queue-Length Detector	0
3010	Infrared Intrusion Alarm	0
3011	Opposing Traffic Lane Divider	0
3012	Multidirectional Barricade Sign	0
3013	Remotely Driven Vehicle	0
3014	Portable Crash Cushion	0
3015	Portable Rumble Strip	0
3016	Flashing Stop/Slow Paddle	0
3017	Portable All-Terrain Sign Stand	0
3018	Radar for Pavement Subsurface Condition	2
3019	Seismic Pavement Analyzer Method	2
3020	Handbook on Deicer Test Methods	0
3021	Salt Spreader TMA	0
3022	Snowplow Cutting Edge	3
3023	Guide for Road Weather Information Systems	0
3024	Anti-Icing Operations Guide	0
3025	Snow Fence Engineering Design Manual	0
3026	Snowplow Scoop	3
3027	Snowplow Design Manual	3
3030	Anti-Icing Equipment Evaluation	0
3031	Anti-Icing Application Rates	0
3032	Anti-Icing Chemical Evaluation	0
3033	Manual on Rating Preventive Maintenance	2
3034	Specifications for Preventive Maintenance	2
3035	Epoxy-Core Test for Void Conditions	3
4006	Customized Weather Prediction System	0

TABLE 4. PAVEMENT ENGINEERING PRODUCT APPLICABILITY RATINGS

SHRP Product Number	Product Title	Applicability Rating
4002	Capacitance Strip Weigh-in-Motion Sensor	1
4008	Software for Measuring Pavement Layer Thickness	3
5001	LTPP Information Management Systems (IMS)	0
5003	FWD Relative Calibration	2
5004	FWD Reference Calibration	2
5005	FWDREFCL Program for Calibration	2
5006	FWDCAL Program for Calibration	2
5007	FWDCHECK Program for Quality Assurance	2
5008	FWDSCAN Program for Quality Assurance	2
5009	Manual for FWD Testing	2
5011	PROFCAL—Profile Quality Assurance	1
5012	PROFCHCK—Profile Quality Assurance	1
5013	PROFSCAN—Profile Quality Assurance	1
5014	Profile Measurement Manual	1
5015	Dipstick Profile Software	3
5016	Distress Identification Manual	2
5019	Resilient Modulus of Asphalt Pavement	2
5020	Resilient Modulus of Soils and Aggregates	2
5021	Guide to Field Sampling and Material Handling	3
5022	Examining Asphalt Pavement Cores	3
5023	Examining Concrete Cores	3
5024	Fine Aggregate Particle Shape Test	3
5025	Laboratory Guide for Test Pavement Samples	3
5026	Visual Examination of Asphalt Stripping	3
5028	Proficiency Testing for Modulus	3
5029	Proficiency Tests for Concrete Cores	3
5030	Proficiency Tests for Moisture Content	3
5031	Modified Georgia Faultmeter	3

TABLE 4. PAVEMENT ENGINEERING PRODUCT APPLICABILITY RATINGS
(Continued)

SHRP Product Number	Product Title	Applicability Rating
5032	Photographic Distress Surveys	3
5034	Traffic Monitoring Data Reduction Software	0
5035	LTPP Traffic Monitoring Database	0
5037	FWD Calibration Stations	2
5040	IMS Microcomputer Version	0

SHRP ASPHALT RESEARCH SUMMARY

The research program targeted four major areas: asphalt, concrete, highway operations, and pavement engineering. The major emphasis of the SHRP program was targeted toward asphalt technology due to the large volume of asphalt pavements in service and the varied problems observed in these types of pavements. The following discussion will focus solely on the asphalt technology investigated under SHRP. This summary is not intended to encompass all of the SHRP asphalt research but will focus primarily on those technologies of application to airfields. Level II and Level III mixture design technology is no longer being used as of March 1997; however, a discussion of these technologies will be included herein. There are several asphalt mixture tests that have applicability to airfield pavements characterization.

The asphalt research effort was separated into three major stages. In Stage I, empirical relationships between laboratory-measured binder properties and laboratory measurements of performance in asphalt mixtures were established. In this stage, measurements of expected performance were based on tests designed to simulate field conditions in the laboratory. Thus, key properties that relate to field performance could be established without the problems associated with field variability (SHRP 1993-94b).

In Stage II, a dual approach involving both empirical and mechanistic studies for establishing links between laboratory-measured properties and field performance was attempted. A reality of empirical studies is the variability of climatic conditions, materials, construction conditions, etc., that often cloud efforts to determine specific causes of pavement failures. It was discovered early in the SHRP program that specific links between some laboratory-measured properties and field performance was not possible within the limited time frame of the SHRP. This led to the adoption of a mechanistic approach in which models based on laboratory-measured properties are employed to predict the performance of the pavement for a given distress mode (rutting, thermal or fatigue cracking) (SHRP 1993-94q).

The third stage is the Long-Term Pavement Performance (LTPP) study in which a number of test sites across North America that encompass a variety of climatic regions are being investigated. The goal is to relate LTPP with the SHRP performance-based material properties. These studies may lead to refinements in the binder and/or mixture specifications for reducing pavement distresses over the long term. The LTPP program is an ongoing effort that is intended to provide performance data for various highway pavements under different traffic conditions and environments for many years.

BINDER PROPERTIES.

A principal goal of the SHRP asphalt research effort was targeted toward the development of performance-based specifications for asphalt binders. In the past, asphalt binders have been selected based solely on the viscosity or penetration of the asphalt or Rolling Thin-Film Oven Test (RTFOT/TFOT)-conditioned binder at 60 °C or 135 °C (American Association of State Highway and Transportation Officials (AASHTO) M20, M226 (AASHTO 1995) or American Society for Testing and Materials (ASTM) D 3381 (ASTM 1996c)). This method had been selected primarily for testing convenience and has limited ability for determining whether the asphalt will perform properly for the climate in which it is placed into service. In addition, this method has limited provisions for evaluation of asphalt durability. Softer asphalt grades have been employed in cold regions and stiffer grades in hotter climates, with the selection being primarily determined from past experience. The results of the Stage I and II programs indicated that a performance-based specification for the asphalt binder was a viable target, and that a rigorous testing protocol could identify binders with poor durability. For performance-based specifications, the asphalt or asphalt mixture is selected based on certain laboratory-measured properties that have been proven to have a link to field performance. This at least ensures that an asphalt binder for a given locale is based on criteria that satisfy some level of expected performance over a 5- to 10-year period (SHRP 1993-94a, o, r).

Several binder properties were identified that were linked to mixture performance. Complex modulus properties above 0 °C correlated somewhat with both fatigue and rutting as measured in the laboratory, although the correlations were weak for rutting and somewhat better for fatigue. It was noted that correlations for fatigue life, stiffness, and dissipated energy were found with complex modulus properties (G', G'', and δ). The phase angle, δ, is a measure of the degree of viscoelasticity of the material. A minimum value for G''($G^*/\sin\delta$) was established for the pressure aging vessel (PAV) residue to reject binders with poor viscoelastic properties after aging that may lead to fatigue cracking. The inclusion of the phase angle term, $\sin\delta$, is important for modified binders, which often cause significant changes in δ. The PAV test simulates 5 to 10 years of aging in the field dependent on the geographic location of the pavement. It is important to note here that significant correlations between binder properties and field data for fatigue were not clearly established (SHRP 1993-94q, b, p).

The correlation of binder complex modulus properties with permanent deformation of mixes was weak, but a consensus developed for a specification to reject binders that may have poor stiffness immediately after placement of an asphalt mix. Experiments revealed that in asphalt mixtures with poor aggregate interlock, complex modulus properties of the binder were important in resisting permanent deformation. The parameter $G^*/\sin\delta$ was selected because it includes modulus (stiffness) and phase angle. This allows the rejection of binders that have low modulus and/or a large viscous component of the complex modulus. Both the tank (original) and RTFOT-conditioned materials are tested to reject materials that may result in tender asphalt mixes. The RTFOT simulates the short-term aging of the mix from heating, mixing, and storage prior to compaction in the field. Again, as with fatigue, relationships between binder properties and field performance could not be clearly established (SHRP 1993-94q, b, p).

Strong correlations were observed with field performance as measured by the propensity toward thermal cracking for laboratory-measured low-temperature binder properties. The significant binder properties that correlate with field performance are stiffness, creep rate, and ultimate strain at failure for temperatures below 0°C. Correlations with field data were highest for laboratory-aged PAV binders. Mixtures containing binders that display high stiffness and low creep rates showed significantly higher tendencies toward thermal cracking as measured by the thermal stress restrained specimen test (TSRST). The TSRST correlates with the degree of thermal cracking observed in the field (SHRP 1993-94l, m, n). The ultimate strain at failure for binders is measured under direct tension at cold temperatures and exhibited strong correlations with the TSRST and with field data (SHRP 1993-94q, b).

In March 1997, a modification to the low pavement design temperature was made. Pavement temperatures are generally slightly warmer than the air surrounding the pavement, and this is reflected in the new design equation. Formerly, the yearly 1-day minimum air temperature for a G*/sin δ given locale was used as the low pavement temperature, but this has been proven to be inaccurate. The new procedure uses the lowest air temperature to estimate the low pavement temperature according to the following equation.

$$T_{\min} \square 0.859 T_{air} \square 1.7^{\circ} C$$

Application of the SHRP binder specifications to airfield pavements in Canada has been studied. These researchers concluded that the SHRP binder specification represents a considerable advancement in the state-of-the-art of binder selection but cautioned that the *G*/sin δ* specification is intended for highway loads and is not proven for use on airfields. For airfields with large, heavily loaded aircraft, a recommendation of a SHRP PG two grades above the minimum high temperature PG for that locale was offered. This recommendation was offered as being overly conservative and only an interim measure until sufficient data are available to judge reasonable values for *G*/sin δ*. The low temperature PG was accepted as reasonable using a minimum of 98% reliability in the selection (EBA Consultants Ltd., 1997).

MIXTURE PROPERTIES.

For asphalt mixtures, test methods were developed and/or refined during the SHRP that better characterize the response of these mixtures to certain types of loading and thermal stresses (SHRP 1994h). The relationship of asphalt adhesion to aggregate surfaces was studied in depth (SHRP 1993g). A significant effort was directed towards better characterization of water damage to asphalt concrete (SHRP 1994t). Relationships between laboratory compaction techniques, field compaction properties, and physical properties were established (Sousa, Harvey, Painter, Deacon, and Monismith 1990; Harvey and Monismith 1994; Harvey, Eriksen, Sousa, and Monismith 1994; and Scholz, Allen, Terrel, and Hicks 1994). Material properties were hypothesized to be linked to performance by employing analytical models to predict a particular aspect of performance (i.e., rutting, thermal cracking, and fatigue cracking). Many of the test methods were intended to be applicable to laboratory samples or field samples, and the results from many of the tests were to provide input to the performance prediction models. The performance predictions could then be used to quantify the differences between pavement mixtures and ultimately, accurate estimates of life-cycle costs (SHRP 1993-94q, b, e). Unfortunately, early in 1997, a decision was made to discontinue the performance prediction portion of SUPERPAVE® due to a number of inconsistencies and incorrect predictions that were discovered after generalized testing. However, many of the test methods and procedures developed by the SHRP are very useful for characterizing asphalt mixtures.

PERMANENT DEFORMATION. Asphalt mixtures can be subjected to a variety of uniaxial, triaxial, volumetric, indirect tensile, and shear tests that yield information on the compressive and shear properties. A significant effort was undertaken during the SHRP to develop models for prediction of permanent deformation in pavements. A model of a nonlinear viscoelastic material in parallel with an elastoplastic material was formulated. A suite of tests that included a linear viscoelastic frequency sweep, uniaxial strain, and hydrostatic measurements were needed to provide the materials parameters necessary to characterize asphalt concrete for the model. Although these models were unsuccessful at reliable predictions, significant empirical relationships were established that allow prediction of expected performance based on laboratory-measured shear properties. The importance of aggregate properties such as rough surface textures, gradation, angularity, and asphalt stiffness in reducing the susceptibility of an asphalt-aggregate mixture to permanent deformation is well known (SHRP 1991s). Under the middle portions of the tires, the pavement is in a state of compression and may result in slight compaction. However, the overwhelming majority of rutting was determined to arise in the upper asphalt layers (100 mm) from repetitive plastic shear strains concentrated under the edges of tires. Design of asphalt mixtures resistant to permanent deformations is predicated on the ability of the mixture to defy primarily shear forces as well as compression. Measurement of these properties in the laboratory provides indications of how materials should perform in actual pavements. A number of potential testing strategies such as simple and repetitive shear, confined repeated load compression (triaxial), and unconfined repeated load compression have been identified as being capable of yielding information that could be employed to predict rutting susceptibility of asphalt mixtures (SHRP 1994i).

Repeated load creep testing has been extensively utilized to evaluate asphalt mixtures for permanent deformation potential. The method involves application of repeated axial compression loads and measurement of the subsequent deformation response of the sample. The technique has been utilized both with and without pressure confinement (Mallick, Ahlrich, and Brown, 1994; Brown and Foo, 1994; and Ahlrich, 1996). Although the method gives an indication of the rutting potential of an asphalt mixture, it is primarily a measure of the compression characteristics and not shear. As such, this technique may not capture the true nature of the rutting phenomenon (SHRP 1994i).

Measurements of shear properties of mixtures studied during the SHRP were performed using a sophisticated testing device capable of simultaneous application of a shear, axial, and confining force. This device (known as the SHRP shear tester) can perform a variety of complex material characterization tests to provide information on the resistance of mixtures to compressive and shear forces. Tests such as uniaxial strain, volumetric strain, repetitive and constant simple shear with or without confinement, shear at constant height, and frequency sweeps can be performed (SHRP 1994i).

An empirical method for determining the reliability to permanent deformation of a pavement section was developed by researchers at the University of California at Berkeley using the repeated simple shear test at constant height (RSST-CH) test method developed during the SHRP (SHRP 1994i, j). The system has been used on actual highway pavement projects, accounts for field and laboratory variability, and allows the designer to select a reliability level dependent on the particular project. (Harvey, Lee, Sousa, Pak, and Monismith 1994; Harvey, Vallerga, and Monismith 1995; and Deacon, Leahy, and Monismith 1995). The system determines a N_{Supply} for an asphalt mixture that is the number of laboratory shear strain cycles that relate to a certain rut depth occurring in the field. A N_{Demand} value is determined that represents a laboratory equivalent of the number of 80 kN equivalent single axle loads (ESALs) traffic cycles expected on the pavement. This value of N_{Demand} is then adjusted by a reliability multiplier that accounts for the design reliability and the variability in N_{Supply} and N_{Demand} based on laboratory results. If $N_{Supply} > N_{Demand}$, the asphalt mixture should perform to the requirements set forth by the project engineer.

Initially, the pavement designer sets the design requirement, for example, a rut depth of 12.7 mm (0.5 inches). The critical temperature at which the pavement will undergo the largest amount of permanent deformation is selected based on local temperatures. This temperature is chosen to represent the maximum pavement temperature at approximately 50-mm pavement depths, where finite element studies predict maximum stress concentrations under wheel loading (SHRP 1994i). An estimate of the design traffic demand in 80 kN ESALs is used to determine the effective number of ESALs at the critical temperature, T_c, using the temperature conversion factor (TCF) (Deacon, Coplantz, Tayebali, and Monismith, 1994). A trial mix is designed and pavement samples prepared for RSST-CH testing. The samples should be prepared by Rolling Wheel Compaction (AASHTO PP3-94) to simulate as closely as possible actual field compaction conditions. The pavement sample is tested by RSST-CH at the critical temperature to define the relationship of repetitive shear cycles to plastic strain and define N_{Supply}. Using the following relation of rut depth to plastic strain, γ_p, the number of strain cycles (N_{Supply}) necessary to achieve a rut depth of 12.5 mm (0.5 inches) is determined based on the RSST-CH test. The strain is multiplied by a conversion factor K to account

$$RutDepth = K \bullet \gamma_p$$

for differences in the laboratory plastic strain and the strain occurring under field conditions. The K factor has been found to range from 254 to 279. A shift factor, SF, of 0.04, and TCF is used to convert the $ESALs$ at the critical temperature to determine the demand number of laboratory strain cycles, N_{Demand}.

$$N_{Demand} = ESALs \bullet TCF \bullet SF$$

This shift factor was determined from studies of SHRP General Pavement Studies (GPS) test sites. A reliability multiplier, M, is selected based on the sample size, variance of N_{Supply} and N_{Demand}, and the degree of reliability selected for a particular project. If $N_{Supply} \geq N_{Demand} \bullet M$, the mixture should perform to the project requirements.

The previously described system of performance prediction is entirely empirical, based on reliability, and has been correlated to highway pavements only. It is possible to apply a similar system to prediction of performance of airfield mixtures, but several critical points must be realized. The stress distribution patterns beneath the pavement of a multiple wheel aircraft load will be substantially different from that of a typical dual wheel truckload. Depending on the aircraft load and the wheel arrangement, critical stress concentrations between wheels will vary with depth. The mechanism that results in shear deformation at the edges of the wheels will be similar to those of a highway truckload, but the ratio of compressive to shear forces between the wheels of a multiple wheel aircraft load will be substantially different.

FATIGUE. Fatigue properties of asphalt mixtures are important for durable pavements, and failures can arise from a structural or material source or a combination of both. Fatigue results from repeated flexural strains that reduce the stiffness of a material with time. Microcrack formation leads to lower strength and eventually to macrocracks that are visible on the pavement surface. Fatigue failures occur due to fracture of materials and often cannot be easily related to the physical properties of the components that comprise the mixture. Fatigue testing of asphalt mixtures has been the focus of numerous studies that have utilized a variety of sample shapes, sizes, and testing apparatus (Tangella et al., 1990 and Matthews, 1993). The simplest, most reliable method of testing asphalt mixtures is the flexural beam fatigue test developed during the SHRP (SHRP 1994k).

The flexural beam fatigue test provides a measure of the laboratory fatigue life (number of cycles to failure). Samples are prepared using rolling wheel compaction to simulate actual field construction and subjected to a short-term aging step that simulates the aging effects of construction and up to two years of initial in-service aging (SHRP 1990c and 1994d). Testing at two strain levels allows the definition of the fatigue- life vs. strain- relationship according to the following, where *a* and *b* are the coefficients of a linear fit in a logarithmic relationship.

This allows the determination of N_{Supply} of the mixture for a given strain level. This strain level is computed using multilayer elastic theory using the structural design and properties of the pavement section. N_{Demand} is determined using the following relation.

$$N_{Demand} = \frac{ESALs \bullet TCF}{SF}$$

The expected traffic is defined in terms of *ESALs*. The Temperature Conversion Factor, *TCF*, is determined to equate the number of *ESALs* at a single temperature to the cumulative effects of *ESALs* over a range of temperatures (Deacon, Coplantz, Tayebali, and Monismith, 1994). The reliability multiplier, *M*, is determined based on the variability of N_{Supply} and N_{Demand}. The Shift Factor, *SF*, is strain dependent and is estimated according to

$$SF = 3.183 \times 10^{-5} \bullet \varepsilon_t^{-1.3759}$$

where ε_t, the simulated pavement strain from multilayer elastic theory is greater than 0.00004. The value for N_{Supply} must be greater than $N_{Demand} \bullet M$ to yield the expected performance of the mixture (SHRP 1994j, k; Harvey, Lee, Sousa, Pak, and Monismith 1994; Harvey, Deacon, Tsai, and Monismith 1995; and Harvey, Deacon, Tayebali, Leahy, and Monismith 1997). Although fatigue has been generally accepted as occurring more often in aged, brittle pavements, recent work has shown this may be a consequence of accumulated damage and not related to binder embrittlement (Harvey and Tsai, 1997).

Fatigue is typically not a widely observed distress on airfield pavements. Given that fatigue has both structural and material origins, this is not surprising. The structural design of airfields is much more critical and controlled than that of most highway pavements, resulting in a higher quality base for the asphalt surface. Airfield pavements are typically thicker than a highway pavement. However, the asphalt mixture designs employed for airfields result in very stiff asphalt mixtures which may be more susceptible to accumulated strain damage than a less stiff highway pavement.

THERMAL CRACKING. The thermal properties of asphalt mixtures can be evaluated using either the indirect tensile creep test (ITCT) developed during the SHRP (AASHTO TP9-94) or the TSRST (AASHTO TP10-93) that was utilized during the SHRP (SHRP 1990u). The TSRST is conducted on asphalt beams that are restrained at both ends. The sample is cooled while a strain feedback loop prevents the sample from contracting, allowing the stress to build. The thermal stress with temperature is recorded along with the fracture temperature (usually to -40°C) if the sample breaks. The results have shown strong correlation with field observations (SHRP 1993n and Vinson, Zubeck, and Zeng, 1996). The TSRST results can also be employed as a predictive tool (Vinson, and Zubeck, 1996). The ITCT is conducted on 6-inch (150-mm) -diameter specimens so that it can be performed on either laboratory specimens or pavement cores. The test is conducted using an indirect tensile creep arrangement and by insuring that the test is conducted within the linear viscoelastic region of response. The result of the test is a master creep compliance curve. The test was chosen by the SHRP researchers over the TSRST due to its simplicity, rapidity (compared to the TSRST), and ability to generate the input data necessary for the thermal cracking model (SHRP 1993-94q, b, e).

The thermal properties of an airfield asphalt mixture are likely to vary from that of a typical highway pavement due primarily to a lower asphalt content. Airfield mixtures are subjected to a high compactive effort which generally results in a lower asphalt content. A lower asphalt content often means a thinner asphalt film on the aggregate surface. The asphalt content (and film thickness) depend strongly on the voids in the mineral aggregate which are controlled by the aggregate source, porosity, surface texture, and shape. A thinner asphalt film results in less of the viscoelastic component (the asphalt binder) between aggregate particles. Thinner asphalt films are more susceptible to oxidation and water damage. This is one of the reasons that airfield pavements are observed to fail more often due to environmental rather than structural factors.

SUPERPAVE® MIX DESIGN OVERVIEW.

SUPERPAVE® is a complete methodology for the selection of materials and testing of binders, aggregates, and the resulting mixtures. The system is designed to yield an asphalt pavement with sufficient binder for durability, a proper aggregate skeleton for supporting loads, optimum air void content of 4 percent, and good mix workability. The aging characteristics of the binder and the mix prior to compaction are simulated using laboratory aging techniques. Binder selection is accomplished using the SHRP performance grading system and aggregates are selected based on a 0.45 power sieve chart to achieve a proper range of voids in the mineral aggregate (VMA). The SUPERPAVE system allows for three levels of mix design based on expected traffic levels for the service life of the pavement and are denoted as Level I, II, and III. The traffic levels are given as ESALs of 80 kN as shown in table 5.

TABLE 5. ORIGINAL TRAFFIC DESIGN LEVELS FOR SELECTION OF SUPERPAVE® MIXTURE DESIGN PROCEDURES

Design Level	Design Traffic (ESALs)
1 (low)	10^6
2 (intermediate)	10^7
3 (high)	$> 10^7$

In 1997, the three traffic levels of SHRP mere merged into a single level that is volumetric mix design only. The original Levels II and III were intended to incorporate different levels of performance prediction capabilities. However, due to inconsistencies in the prediction routines, Levels II and III were discontinued.

SHRP BINDER SPECIFICATION AND TEST METHODS.

The SHRP asphalt binder specification (AASHTO MP1-93) (AASHTO 1996) is based both on the maximum upper and minimum lower in-service pavement temperatures that the binder is expected to experience (table 6). For instance, with a proper aggregate material and gradation, a PG64-16 binder would be expected to perform adequately in a temperature regime between -16 and 64 C. The appropriate temperature regime is determined based on results from dynamic shear rheometry (DSR) and bending beam rheometry (BBR) on unaged and PAV-aged samples. In figure 1, the temperature range over which the binder is characterized is shown with the appropriate testing arrangement for that temperature (SHRP 1993-94e). The test method are reported in detail in SHRP-A-379 (SHRP 1993-94h) and in the 1995 edition of the AASHTO Provisional Standards. All of the binder tests were designed to be valid for modified binders as well as virgin binders. However, due to complex rheology and phase separation tendencies of some polymer modifiers, some of the test methods have been found to be unsuitable for proper materials characterization.

TABLE 6. PERFORMANCE-GRADED ASPHALT BINDER SPECIFICATION

	PG 46-			PG 52-							PG 58-					PG 64-						PG 70-						PG 76-					PG 82-				
Performance Grade	34	40	46	10	16	22	28	34	40	46	16	22	28	34	40	10	16	22	28	34	40	10	16	22	28	34	40	10	16	22	28	34	10	16	22	28	34
Average 7-day maximum pavement design temperature, °C[a]	<46			<52							<58					<64						<70						<76					<82				
Minimum pavement design temperature, °C[a]	>-34	>-40	>-46	>-10	>-16	>-22	>-28	>-34	>-40	>-46	>-16	>-22	>-28	>-34	>-40	>-10	>-16	>-22	>-28	>-34	>-40	>-10	>-16	>-22	>-28	>-34	>-40	>-10	>-16	>-22	>-28	>-34	>-10	>-16	>-22	>-28	>-34
Original Binder																																					
Flash point temperature, T48: Minimum °C	230																																				
Viscosity, ASTM D4402[b]: Maximum, 3 Pa·s Test temp, °C	135																																				
Dynamic shear, TP5[c]: $G^*/\sin\delta$, minimum, 1.00 kPa Test temp @ 10 rad/s, °C	46			52							58					64						70						76					82				
Rolling Thin-Film Oven (T240) or Thin-Film Oven (T179) Residue																																					
Mass loss, maximum, percent	1.00																																				
Dynamic shear, TP5: $G^*/\sin\delta$, minimum, 2.20 kPa Test temp @ 10 rad/s, °C	46			52							58					64						70						76					82				
Pressure Aging Vessel (PAV) Residue (PP1)																																					
PAV aging temperature, °C[d]	90			90							100					100						100(110)						100(110)					100(110)				
Dynamic shear, TP5: $G^*\sin\delta$, maximum, 5000kPa Test temp @ 10 rad/s, °C	10	7	4	25	22	19	16	13	10	7	25	22	19	16	13	31	28	25	22	19	16	34	31	28	25	22	19	37	34	31	28	25	40	37	34	31	28
Physical hardening[e]	Report																																				
Creep stiffness, TP1[f]: S, maximum, 300 MPa m-value, minimum, 0.300 Test temp @ 60s, °C	-24	-30	-36	0	-6	-12	-18	-24	-30	-36	-6	-12	-18	-24	-30	0	-6	-12	-18	-24	-30	0	-6	-12	-18	-24	-30	0	-6	-12	-18	-24	0	-6	-12	-18	-24
Direct tension, TP3[f]: Failure strain, minimum, 1.0% Test temp @ 1.0 mm/min, °C	-24	-30	-36	0	-6	-12	-18	-24	-30	-36	-6	-12	-18	-24	-30	0	-6	-12	-18	-24	-30	0	-6	-12	-18	-24	-30	0	-6	-12	-18	-24	0	-6	-12	-18	-24

[a] Pavement temperatures may be estimated for air temperatures using an algorithm contained in the SUPERPAVE software program provided by the specifying agency or found by following the procedures as outlined in PPX.
[b] This requirement may be waived at the discretion of the specifying agency if the supplier warrants that the asphalt binder can be adequately pumped and mixed at temperatures that meet all applicable safety standards.
[c] For quality control of unmodified asphalt cement production, measurement of the viscosity of the original asphalt cement may be substituted for dynamic shear measurements of $G^*/\sin\delta$ at test temperatures where the asphalt is a Newtonian fluid. Any suitable standard means of viscosity measurement may be used, including capillary or rotational viscometry (AASHTO T201 or T202).
[d] The PAV aging temperature is based on simulated climatic conditions and is one of three temperatures: 90°C, 100°C, or 110°C. The PAV aging temperature is 100°C for PG 58- and above, except for paving materials to be used in desert climates, where it is 110°C.
[e] Physical hardening—TP1 is performed on a set of asphalt beams according to section 13.1, except the conditioning time is extended to 24 hrs ± 10 minutes at 10°C above the minimum performance temperature. The 24-hour stiffness and m-value are reported for information purposes only.
[f] If the creep stiffness is below 300 MPa, the direct tension test is not required. If the creep stiffness is between 300 and 600 MPa, the direct tension failure strain requirement can be used in lieu of the creep stiffness requirement. The m-value requirement must be satisfied in both cases.

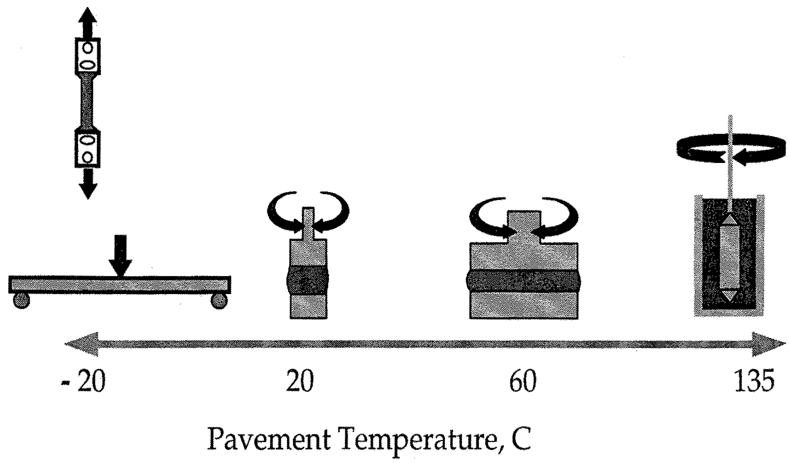


FIGURE 1. SHRP BINDER TEST AND TEMPERATURE RANGES APPROPRIATE FOR EACH TEST (Reprinted with permission from SHRP-A-410 (SHRP 1993-94o))

The following is a summary of the general procedure (AASHTO PP6-93) (AASHTO 1996) employed to determine the performance grade of asphalt binder.

1. The flash point of the binder is determined according to AASHTO T48 (AASHTO 1995).

2. The viscosity of the binder is determined at 135 C using rotational viscometry (AASHTO TP48-94) (AASHTO 1996). The maximum allowed value is 3 Pa·sec (3,000 cP) but may be waived if the binder manufacturer ensures adequate pumpability at the plant.

3. The virgin binder is tested according to AASHTO TP5-93 (AASHTO 1996) at temperatures ranging from 46 to 82 C listed in table 6. A minimum value for G^*/sin at 10 radians/sec of 1.0 kPa is specified to ensure a minimum stiffness to exclude the possibility of a tender mix.

4. The binder is aged by RTFOT (AASHTO T240) (AASHTO 1995) to simulate aging of the binder during the precompaction phase and the DSR test repeated. A minimum value for G^*/sin at 10 rad/sec of 2.2 kPa is specified to ensure a minimum strength at laydown, again, to exclude the possibility of a tender mix. The maximum temperature at which the specification is met is then designated as the maximum pavement service temperature.

5. The binder is PAV aged at the specified temperature, and the DSR test performed again at 10 rad/s but at the temperatures specified in table 6 (AASHTO PP1-93) (AASHTO 1996). A maximum value for G^*sin of 5,000 kPa is specified here to exclude binders with a tendency toward fatigue cracking due to rapid age hardening. This test is intended to simulate 5 to 10 years of aging depending on the geographic location of the pavement.

6. The binder is tested using BBR (AASHTO TP1-93) (AASHTO 1996) to determine the low temperature characteristics after PAV aging. A maximum value for the creep stiffness, S, of 300 MPa and a minimum value for the slope of the log-log plot of stiffness with time, m, of 0.3 is specified to prevent thermal cracking of the binder. In some isolated cases (generally involving modified binders), the stiffness criteria may not be met while the slope is. In these cases, the direct tension test is employed (AASHTO TP3-93) (AASHTO 1996). In this test, the sample is placed in tension and must meet a minimum of 1 percent strain prior to failure. The test temperatures are the same as that in the BBR test.

FLASH POINT TEST (AASHTO T48) (AASHTO 1995).

This test is the standard Cleveland Open Cup method that has been in use for some time for determination of minimum flash point. A minimum value of 230 C is required.

ROTATIONAL VISCOMETRY (AASHTO TP48-94) (AASHTO 1996).

This method has been adopted for the analysis of modified binders. Capillary viscometry of polymer-modified asphalts may have problems with shear thinning and crumb-rubber modified asphalts may clog the tube. The rotational technique obliterates these problems. The sample is placed in a container heated to 135 C. A spindle is lowered into the asphalt (figure 2). The spindle is attached to a torque detection device (Brookfield viscometer) and rotated at 20 rpm. The torque required to maintain 20 rpm is measured and translated into viscosity. A maximum viscosity of 3 Pa·sec is required.

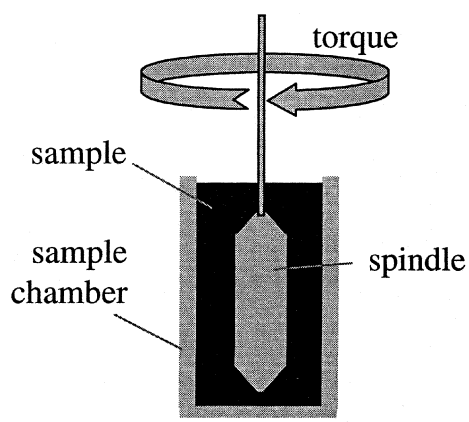


FIGURE 2. BROOKFIELD VISCOMETER TESTING ARRANGEMENT FOR ROTATIONAL VISCOMETRY AT 135 C (Reprinted with permission from SHRP-A-410 (SHRP 1993-94o))

DYNAMIC SHEAR RHEOMETRY (AASHTO TP5-93 (AASHTO 1996)).

This method measures the complex modulus characteristics of the asphalt binder in the linear viscoelastic regime. The sample is placed between two parallel plates (8 or 25 mm in diameter) and a sinusoidal oscillatory shear stress or strain applied at a frequency of 10 radians/sec and at a specified temperature. A schematic of the testing arrangement, applied torque, measured response for elastic, viscous, and viscoelastic responses of different materials, and the appropriate equations for determination of *G** and are shown in figure 3. The sinusoidal response of the sample is measured, and the time delay between the applied shear and the response is determined.

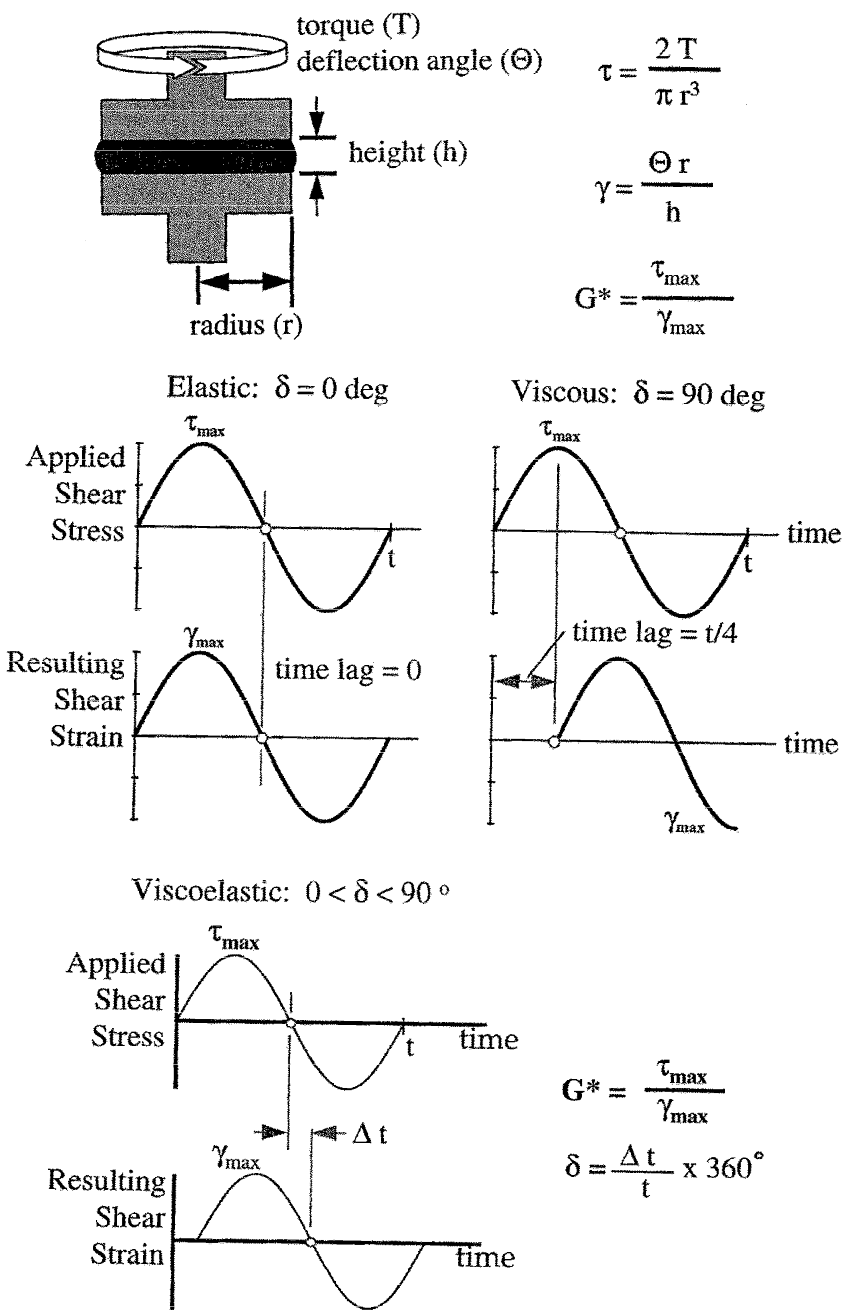


FIGURE 3. TESTING ARRANGEMENT AND EXAMPLES OF RESPONSE OF ELASTIC, VISCOUS, AND VISCOELASTIC MATERIALS (Reprinted with permission from SHRP-A-410 (SHRP 1993-94o))

This time delay is referred to as the phase angle between the applied shear and the response when expressing the sine wave in polar coordinates (figure 4). The complex modulus, G*, of the sample is determined from the applied torque, τ, and the shear strain, γ, applied to the sample as measured at the edge of the plate.

$$G \qquad \frac{\tau}{\gamma} \qquad \sqrt{(G\ )^2 \quad (G\ )^2}$$

The elastic, G , and viscous, G , components of the complex modulus can then be determined using δ and the following relations.

$$G \qquad G\ \cos\delta$$

$$G \qquad G\ \sin\delta$$

G is that portion of the modulus in which the phase angle is zero and G is that portion in which the phase angle is $\pi/2$ radians or 90 .

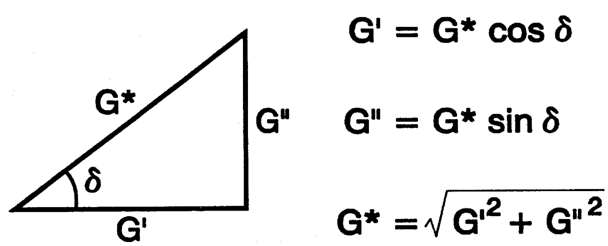


FIGURE 4. RELATIONSHIP AMONG COMPLEX MODULUS (G*), STORAGE MODULUS (G), LOSS MODULUS (G), AND THE PHASE ANGLE ( ) (Reprinted with permission from SHRP-A-369 (SHRP 1993-94a))

The SHRP DSR requirements for the binders are specified at a single frequency of 10 rad/sec. The specification values are a minimum for *G*/sin* of 1.0 kPa for the unaged (tank) binder and 2.2 kPa for the RTFOT or thin film oven test TFOT-aged binder. For the PAV-aged binder, a maximum value for *G*sin* of 5.0 MPa is specified. The minimum value for *G*/sin* ensures that enough elastic stiffness is present in the binder to resist permanent deformation immediately after laydown. The maximum value of *G* or *G*sin* provides for enough viscous flow in the sample to resist fracture of the binder due to repeated loadings that result in fatigue of the sample (SHRP-A-369) (SHRP 1993-94a).

BENDING BEAM RHEOMETRY (AASHTO TP1-93) (AASHTO 1996).

The BBR test is designed to measure stiffness and creep rate of aged asphalt binders at low pavement service temperatures (below 0 C). A schematic of the testing arrangement is shown in figure 5. The test measures the tendency of an asphalt binder toward thermal cracking. An asphalt beam approximately 125 mm long and 12.5 mm wide with a depth of 6.25 mm is subjected to a three-point

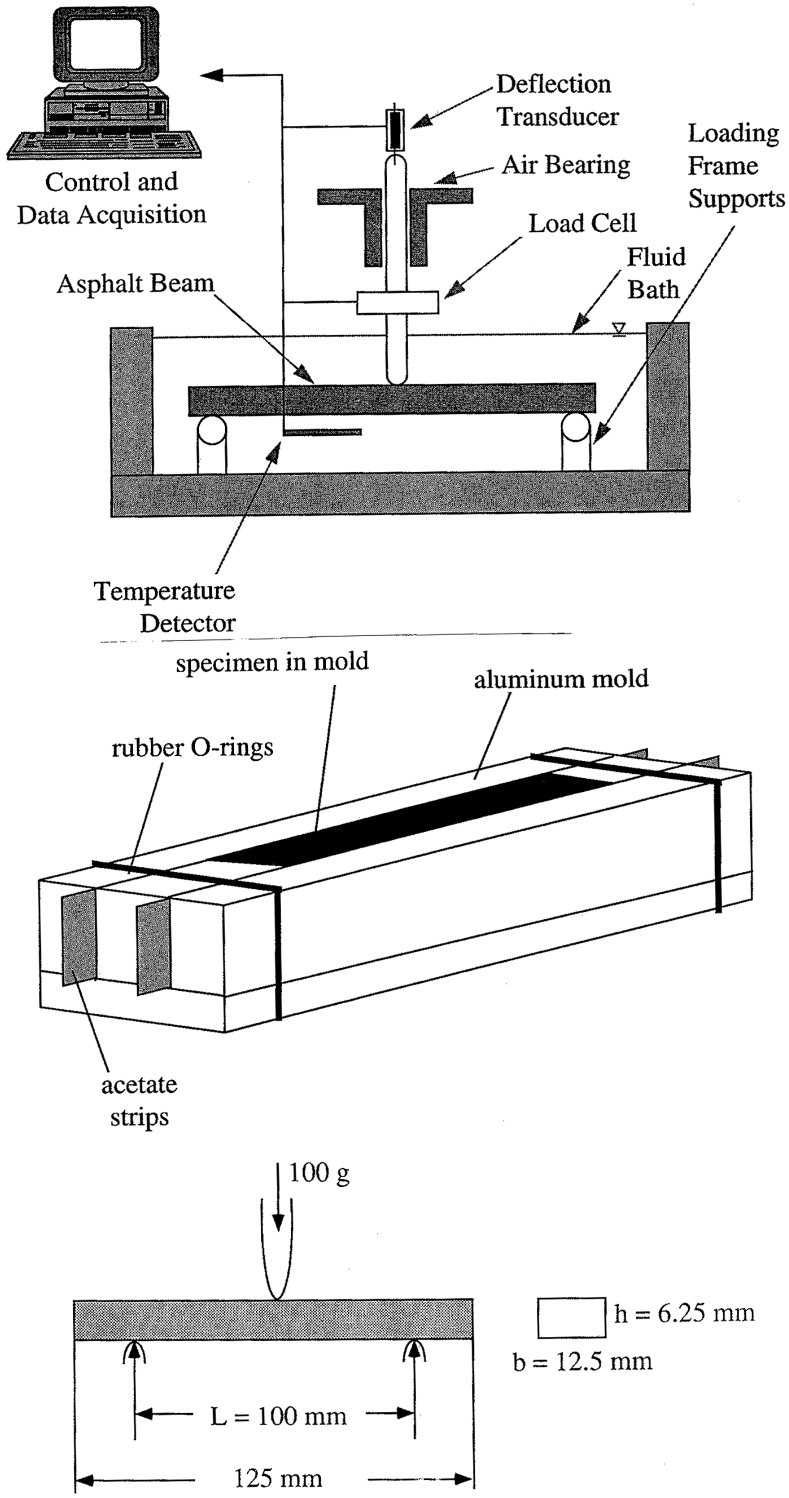


FIGURE 5. DIAGRAM OF BENDING BEAM RHEOMETER TESTING ARRANGEMENT SHOWING BEAM MOLD AND SIZE (Reprinted with permission from SHRP-A-410 (SHRP 1993-94o))

bending test. The beam is supported at two points 100 mm apart and the sample loaded by a 100-g static load. The load, sample deflection, and time of loading are monitored at a specified temperature throughout the test duration of 240 sec. At the completion of the test, the applied load and deflection yield the stiffness, S, of the sample with time (figure 6). A polynomial curve fit is employed to obtain a mathematical representation of the log-log plot of stiffness versus time for determination of the slope of the curve, m, at specific times of 8, 15, 30, 60, 120, and 240 sec (SHRP-A-369, SHRP-A-370) (SHRP 1993-94a, r).

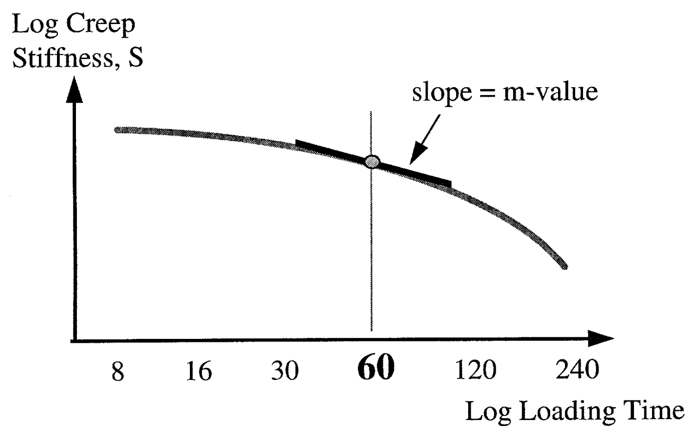


FIGURE 6. RELATIONSHIP OF CREEP STIFFNESS (S) AND SLOPE (m) TO BENDING BEAM RHEOMETER LOADING TIME (Reprinted with permission from SHRP-A-410 (SHRP 1993-94o))

The specification values for BBR are a maximum of 300 MPa stiffness and a minimum slope value of 0.3. However, if the binder stiffness is between 300 and 600 MPa with the slope value greater than 0.3, the direct tension test can be employed in lieu of the creep stiffness requirement.

DIRECT TENSION TEST (AASHTO TP3-93) (AASHTO 1996).

The direct tension test is designed to measure the ultimate strain at failure on a "dog-bone" type sample typically employed in tension experiments for plastic samples (figure 7). This test is only necessary if the stiffness, S, as measured by the BBR, is between 300 and 600 MPa and the slope, m, is above 0.3. The sample is stretched at a constant rate of 1 mm/min. The test temperature corresponds to that at which the BBR stiffness is between 300 and 600 MPa. The sample passes the test if the strain reaches 1 percent prior to failure of the sample (SHRP-A-369, SHRP-A-370) (SHRP 1993-94a, r).

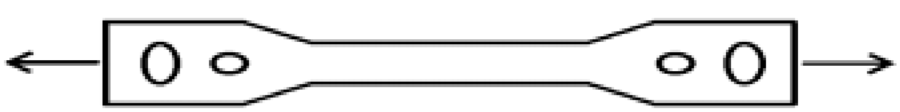


FIGURE 7. DIRECT TENSION SPECIMEN CONFIGURATION

SHRP AGGREGATE SELECTION AND TESTING.

Aggregate selection is based on numerous factors such as climate, moisture sensitivity, availability, cost, experience, etc. SHRP designates two types of properties for aggregates; consensus and agency source. Consensus properties are those that are deemed necessary for specification properties and have been arrived at by consensus within the aggregate community. The SHRP consensus properties are aggregate gradation, coarse and fine aggregate angularity, clay content, and thin or elongated particles. Agency source properties are specified by the state highway agency using the material (SHRP-A-407, SHRP-A-408) (SHRP 1993-94e, f).

AGGREGATE GRADATION.

The choice of aggregate gradations according to SHRP are not required specifications but are merely guidelines to steer the pavement engineer. The choice of gradation is made according to a 0.45 power particle size distribution chart shown in figure 8 and is based on expected traffic. The sieve size designations are listed in table 7. The nominal maximum sieve size refers to the sieve one size larger than the first sieve through which more than 10 percent of the material passes. The SHRP gradation control chart (figure 8) is designed to avoid the maximum density line which would result in inadequate voids in the mineral aggregate. The control points and restricted zone were arrived at by consensus after polling a panel of industry and state transportation officials. An acceptable gradation is one that lies within the control points and does not pass through the restricted zone.

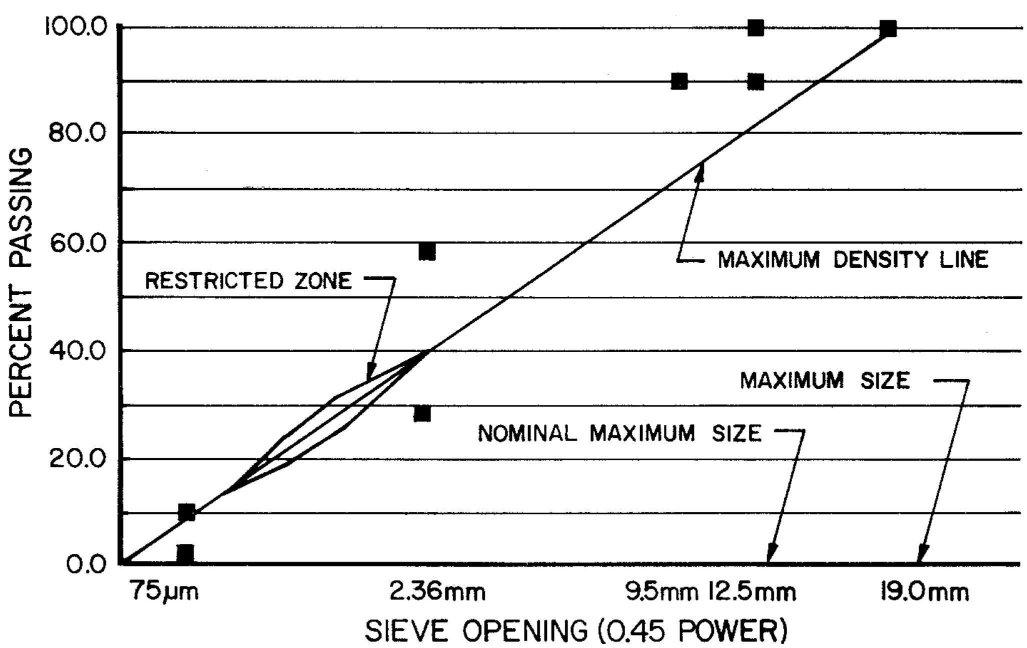


FIGURE 8. SUPERPAVE® GRADATION CONTROL POINTS AND RESTRICTED ZONE FOR A 12.5-mm NOMINAL MAXIMUM SIZE AGGREGATE GRADATION (Reprinted with permission from SHRP-A-407 (SHRP 1993-94e))

TABLE 7. SIEVE SIZES

Sieve Size and Designation	Appropriate English Equivalent
63.0 mm	2 1/2 in.
50.0 mm	2 in.
37.5 mm	1 1/2 in.
25.0 mm	1 in.
19.0 mm	3/4 in.
12.5 mm	2 in.
9.5 mm	3/8 in.
4.75 mm	No. 4
2.36 mm	No. 8
1.18 mm	No. 16
600 m	No. 30
300 m	No. 50
150 m	No. 100
75 m	No. 200

In addition, the gradation must meet all other SHRP aggregate consensus properties such as angularity and clay content including volumetric requirements such as voids filled with asphalt (VFA) and VMA for a given nominal aggregate size and traffic level. However, there are many known gradations that pass through the restricted zone and give perfectly acceptable performance. Past experience with local materials and historical performance should be strongly considered when selecting an aggregate gradation.

COARSE AGGREGATE ANGULARITY.

The angularity of the coarse aggregate is defined by the percentage of aggregate particles larger than 4.75-mm sieve size with at least one crushed face. The presence of crushed faces in the aggregate is directly related to the tendency of an asphalt-aggregate mix to resist permanent deformation. Crushed aggregate faces result in a larger amount of particle-particle contact and interlock and are able to resist applied forces better than rounded aggregates.

SHRP requirements for coarse aggregate angularity relate to the expected traffic levels as shown in table 8. In table 8, the first number designates the percentage of materials having at least one crushed face and the second number refers to that percentage having two crushed faces (SHRP-A-407, SHRP-A-410) (SHRP 1993-94e, o).

TABLE 8. COARSE AGGREGATE ANGULARITY REQUIREMENTS

Traffic Level (ESALs)	Surface Mixes (< 100 mm from surface), % one crushed face/% two crushed faces	Lower Mixes (>100 mm from surface), % one crushed face/% two crushed faces
$< 3 \times 10^5$	55/-	-/-
$< 10^6$	65/-	-/-
$< 3 \times 10^6$	75/-	-/-
$< 10^7$	85/80	65/-
$< 3 \times 10^7$	95/90	80/75
$< 10^8$	100/100	95/90
$> 10^8$	100/100[1]	100/100

FINE AGGREGATE ANGULARITY (AASHTO TP 33 (AASHTO 1995), ASTM C 1252 (ASTM 1996b)).

Fine aggregate is defined as that material passing the 2.36-mm sieve. Fine aggregate angularity is defined by the ASTM Method C 1252 "Uncompacted Void Content of Fine Aggregates" (ASTM 1996b). This test is intended to limit the amount of rounded fines because the more rounded aggregate particles have less void space between adjacent particles than angular aggregates (see table 9).

TABLE 9. FINE AGGREGATE ANGULARITY REQUIREMENTS

Traffic Level (ESALs)	Surface Mixes (< 100 mm from surface), % by Volume	Lower Mixes (>100 mm from surface), % by Volume
$< 3 \times 10^5$	-	-
$< 3 \times 10^6$	40	-
$< 3 \times 10^7$	45	40
3×10^7	45	45

AGGREGATE CLAY CONTENT (AASHTO T176) (AASHTO 1995).

Limiting the amount of clay content in the aggregate is advantageous for reducing the potential for stripping because of the water-absorptive and expansive characteristics of many clays. Clay content is measured by AASHTO T176 "Plastic Fines in Graded Aggregates and Soils by Use of the Sand Equivalency Test" (AASHTO 1995). This test indirectly measures the rate of particle settlement which is related to particle size (SHRP-A-407, SHRP-A-410) (SHRP 1993-94e, o). The criteria for different traffic levels are given in table 10.

TABLE 10. CLAY CONTENT CRITERIA

Traffic Level (ESALs)	Sand Equivalent Minimum %
$< 3 \times 10^6$	40
$< 3 \times 10^7$	45
3×10^7	50

FLAT OR ELONGATED AGGREGATE PARTICLES (ASTM D 4791).

Elongated aggregate particles are defined as those having a ratio of maximum to minimum dimension greater than 5. These particles have a tendency to break under applied load which contribute to aggregate segregation and breakdown during compaction. The percentage of these particles are limited to 10 percent by weight of the aggregate proportion as measured by ASTM D4791 "Flat or Elongated Particles in Coarse Aggregate." This test method requires manual measurements on a random sample of aggregate particles (SHRP-A-407, SHRP-A-410) (SHRP 1993-94e, o).

AGGREGATE TOUGHNESS (AASHTO T96) (AASHTO 1995).

Aggregate toughness is defined as the resistance to fracture under impact or applied load as measured by the Los Angeles Abrasion Test (ASTM C 131) (ASTM 1996a). Aggregate particles should have sufficient strength to prevent mechanical degradation during sieving, drying, and mixing (SHRP-A-407, SHRP-A-410) (SHRP 1993-94e, o). The criteria for the Los Angeles Abrasion Test for different traffic levels are given in table 11.

TABLE 11. SUGGESTED LIMITING VALUES OF LOS ANGELES ABRASION LIMITS

Traffic Level (ESALs)	LA Abrasion Loss (Wearing Course), %	LA Abrasion Loss (Wearing Course), %
$< 10^6$	50	50
$< 10^7$	45	50
$< 10^8$	40	50
10^8	35	50

AGGREGATE SOUNDNESS (AASHTO T104) (AASHTO 1995).

Aggregate soundness refers to the ability of the aggregate to withstand weathering cycles such as wetting and drying and freeze-thaw cycling. The method most often employed is AASHTO T104 "Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate."

DELETERIOUS MATERIALS (AASHTO T112) (AASHTO 1995).

Deleterious materials are particles of clay, coal, and organic material such as wood, leaves, etc., that may find their way into the aggregate. A suggested value of 2 percent maximum by weight of the aggregate is recommended by SHRP (SHRP-A-407, SHRP-A-410) (1993-94e, o).

SHRP LEVEL I MIX DESIGN.

Overviews of the SHRP Level I mix design procedure can be found in SHRP-A-407, SHRP-A-410, and SHRP-A-408 (SHRP 1993-94e, o, f).

AGGREGATE GRADATION SELECTION.

The SUPERPAVE Level I mix design system is based solely on the volumetric properties of an asphalt-aggregate combination (figure 9). The mix design engineer may opt to subject the specific asphalt-aggregate combination to the Net Absorption Test (AASHTO TP6-93) (AASHTO 1996) prior to mixing to determine the susceptibility of the materials to stripping. In addition, as part of the mix procedure, the compacted samples are subjected to moisture sensitivity testing (AASHTO T283 or TP34-93) (AASHTO 1996) to ensure stripping resistance. The method is different from the Marshall procedure employed in the past, utilizing multiple gyratory compaction cycles, *N*, rather than multiple hammer blows to compact the specimens.

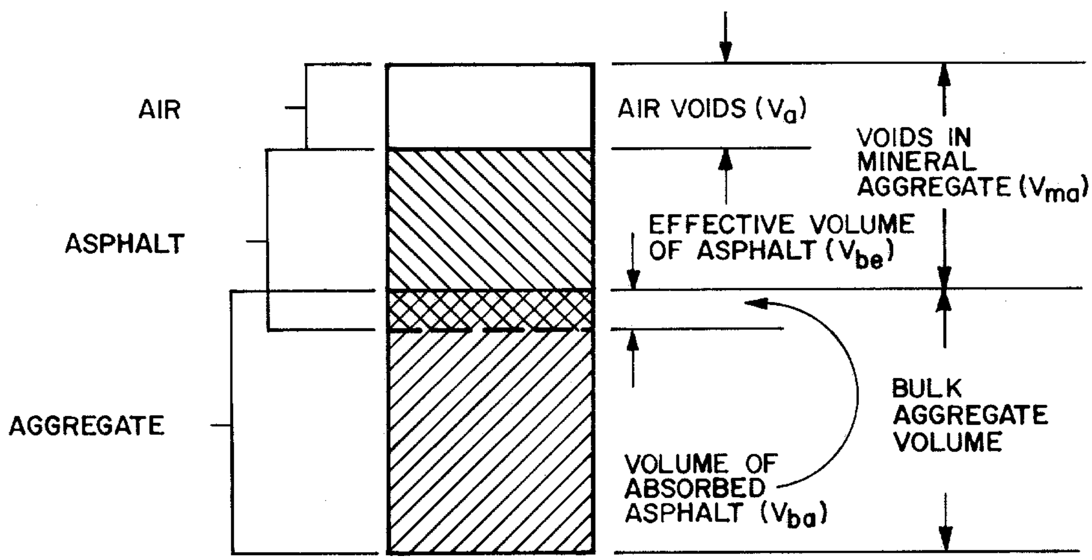


FIGURE 9. DEFINITIONS OF THE VOLUMETRIC PROPERTIES OF COMPACTED ASPHALT PAVING MIX (Reprinted with permission from SHRP-A-407 (SHRP 1993-94e))

The mix design process begins with a selection of aggregate gradations within the control points defined in figure 8. Initially, at least three trial blends are recommended with duplicate specimens for each. The initial design asphalt content (AC) is determined from the desired VMA for a 4 percent target V_a (air void content) as shown in figure 10, the VFA, the bulk specific gravity of the binder, and the bulk and apparent specific gravities of the aggregates (AASHTO T84, T85, and

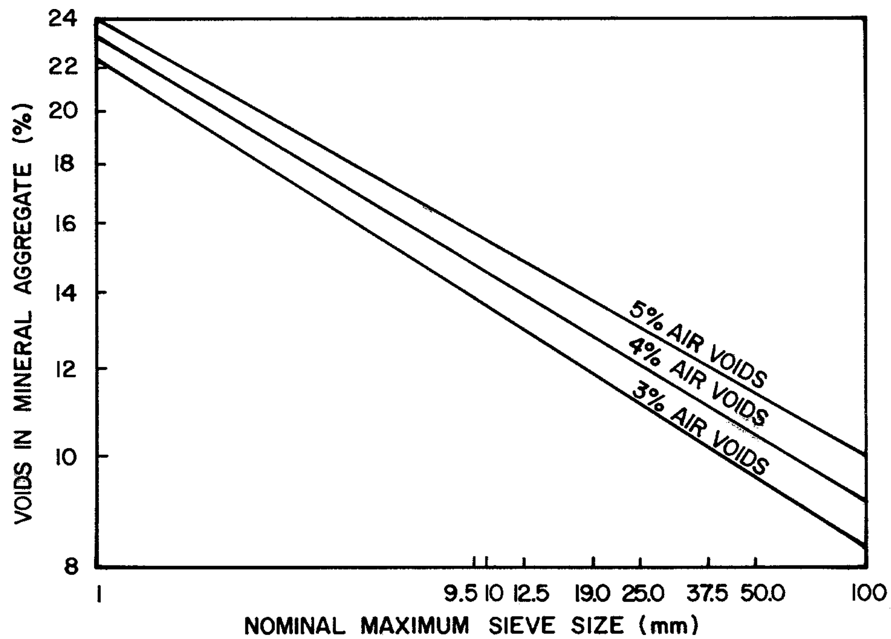


FIGURE 10. MINIMUM PERCENT VOIDS IN MINERAL AGGREGATE (VMA) FOR 3, 4, AND 5 PERCENT AIR VOIDS (Reprinted with permission from SHRP-A-407 (SHRP 1993-94e))

T100) (AASHTO 1995). Criteria for VFA are presented in table 12. The mixing process is conducted at an equiviscous temperature for different binders as described in AASHTO TP4-93 (AASHTO 1996), or at a temperature selected by the mix design engineer. After the mixing process, the loose mix is aged by a short-term process (AASHTO PP2-94) (AASHTO 1996) designed to simulate field aging of the mix during the precompaction phase.

TABLE 12. CRITERIA FOR VOIDS FILLED WITH ASPHALT

Traffic Level (ESALs)	Voids Filled with Asphalt (VFA), %
$< 3 \times 10^5$	70-80
$< 3 \times 10^6$	65-78
$< 10^8$	65-75
$> 10^8$	65-75

The samples are compacted at the initial design asphalt content using the SHRP gyratory compactor and method (AASHTO TP4-93) (AASHTO 1996). The design number of gyrations, N_{Design} , is determined based on the expected traffic levels and the 7-day mean maximum air temperature (MMAT) as shown in table 13. The samples are compacted to $N_{Maximum}$, the maximum number of gyrations for the specified traffic level. After compaction, the density is corrected by measurement of the bulk specific gravity of the compacted specimen. A typical densification curve is shown in figure 11.

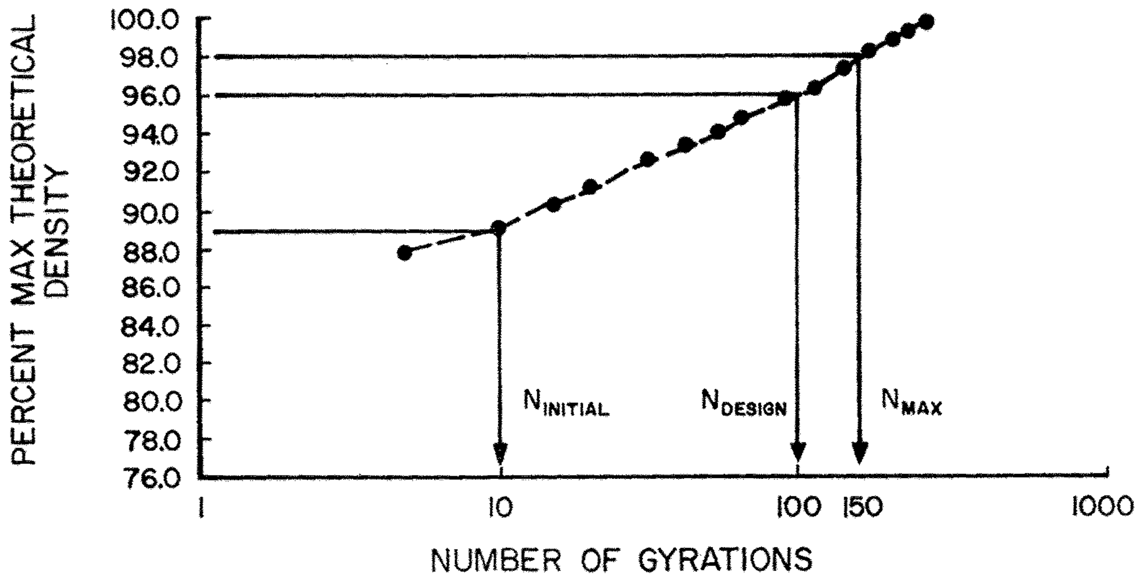


FIGURE 11. TYPICAL DENSIFICATION CURVE OBTAINED WITH SHRP GYRATORY COMPACTOR (Reprinted with permission from SHRP-A-410 (SHRP 1993-94o))

TABLE 13. NUMBER OF INITIAL ($N_{Initial}$), DESIGN (N_{Design}), AND MAXIMUM ($N_{Maximum}$) GYRATIONS REQUIRED FOR VARIOUS TRAFFIC LEVELS

Traffic (ESALs)	7-Day Mean Maximum Air Temperature											
	< 39			39-41			41-43			43-45		
	$N_{Initial}$	N_{Design}	$N_{Maximum}$	$N_{Initial}$	N_{Design}	$N_{Maximum}$	$N_{Initial}$	N_{Design}	$N_{Masimum}$	$N_{Initial}$	N_{Design}	$N_{Maximum}$
$< 3 \times 10^5$	7	8	104	7	74	14	7	8	121	7	82	127
$< 10^6$	7	76	117	7	83	129	7	88	138	8	93	146
$< 3 \times 10^6$	7	86	134	8	95	150	8	100	158	8	105	167
$< 10^7$	8	96	152	8	106	169	8	113	181	9	119	192
$< 3 \times 10^7$	8	109	174	9	121	195	9	128	208	9	135	220
$< 10^8$	9	126	204	9	139	228	9	146	240	10	153	253
10^8	9	143	235	10	158	262	10	165	275	10	172	288

The corrected specific gravity is used to obtain V_a at N_{Design}. The difference between the calculated air voids and the target air voids of $V_a = 4$ percent, ΔV_a, is used to obtain estimated values for asphalt content (P_b), VMA, VFA, G_{mm} at $N_{Initial}$, and $N_{Maximum}$ at $V_a = 4$ percent. This allows determination of whether the aggregate gradation will conform to the volumetric requirements (SHRP-A-407) (SHRP 1993-94d) at the estimated design asphalt content.

If the required volumetric properties are not met, the aggregate gradation must be changed. The most obvious choice is to reduce the fraction of aggregate below the 75-µm sieve size, increasing the VMA (SHRP-A-407) (SHRP 1993-94e).

OPTIMUM ASPHALT CONTENT DETERMINATION.

Once an aggregate gradation is selected that meets the volumetric requirements, the optimum asphalt content is determined by bracketing the estimated design asphalt content, P_b, at P_b - 0.5, P_b, P_b + 0.5, and P_b + 1.0. The samples are mixed, short-term aged, and compacted to $N_{Maximum}$. The volumetric properties are calculated and utilized to yield the plots shown in figure 12. The optimum asphalt content is obtained by graphic interpolation from the plot of V_a versus P_b at V_a = 4 percent. The remaining volumetric properties are checked at the design P_b to ensure compliance with the criteria. Samples are then compacted to V_a = 7 percent at the optimum asphalt content the moisture susceptibility of the mix is evaluated using AASHTO T283 or TP34-93 (AASHTO 1995, 1996). If the sample does not meet the required retained tensile strength criteria, the use of an antistrip agent or hydrated lime may be employed to bring the mix into compliance (SHRP-A-407) (SHRP 1993-94e).

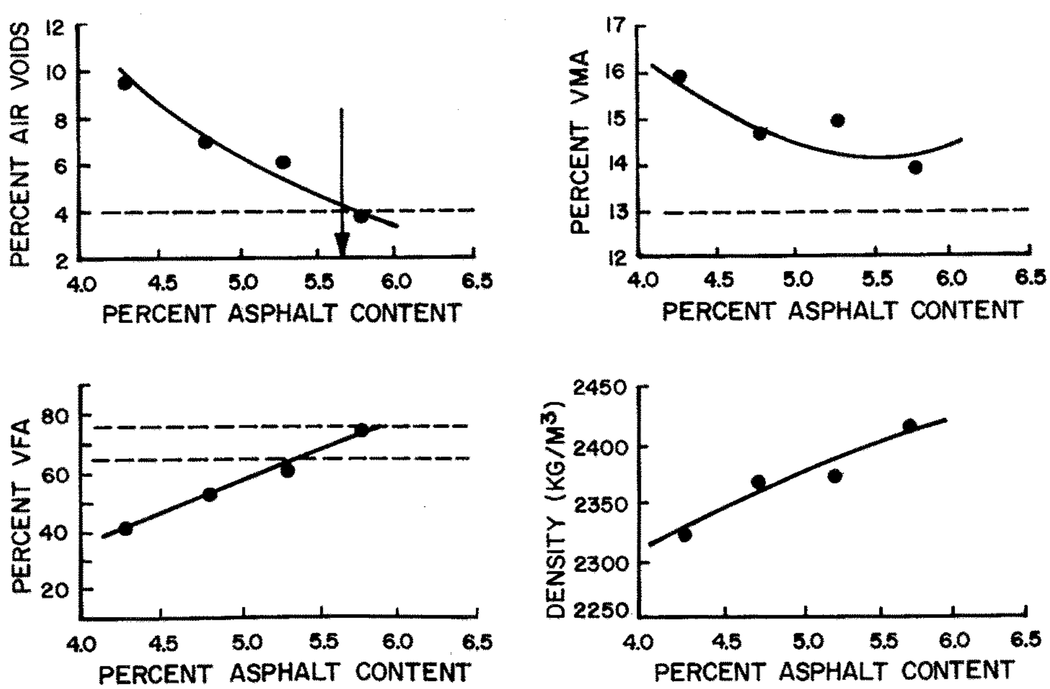


FIGURE 12. PLOTS OF PERCENT AIR VOIDS, PERCENT VMA, PERCENT VFA, AND DENSITY VERSUS PERCENT ASPHALT CONTENT (Reprinted with permission from SHRP-A-407 (SHRP 1993-94e))

SHRP ASPHALT MIXTURE TEST METHODS

As of March 1997, a decision was reached within FHWA to discontinue Level II and Level III (all performance prediction modeling). Implicit in that decision is that the use of test methods that provide input to the performance prediction models will also be discontinued. However, the test methods themselves are not without merit and may be used to provide comparisons between asphalt mixtures.

INTRODUCTION.

The only asphalt mixture characterization tests that apply to Level I mix design are the net absorption test, the retained tensile strength test, and the short-term aging practice. The SHRP gyratory compactor is used to prepare all the samples for tests on compacted mixtures. For Level II mixes, five additional tests are conducted to provide data for input into the performance prediction models. These tests are simple shear at constant height, simple shear at constant stress ratio, frequency sweep at constant height, indirect tensile strength, and indirect tensile creep. For Level III, two additional tests are added: characterization of the mix and uniaxial strain and hydrostatic state of stress. For Level II and Level III mix designs, the repeated shear at constant height is employed as a screening test to identify whether a mix is susceptible to tertiary creep, but the data is not used as input to performance prediction models.

NET ABSORPTION TEST (AASHTO TP6-93).

The net absorption test is a screening method used to determine the susceptibility of an asphalt-aggregate combination to stripping (SHRP-A-34l) (SHRP 1993-94g). The asphalt is dissolved in toluene and the absorptivity of the asphalt-toluene solution is measured by ultraviolet-visible (UV-VIS) spectroscopy. This solution is then allowed to come into contact with the aggregate surface for 6 hr, and the absorptivity is measured again to measure the initial adsorption of the asphalt onto the aggregate surface. A small amount of water is then introduced into the system and allowed to equilibrate for at least 8 hr. The absorptivity of the asphalt-toluene solution is again measured to determine the amount of desorption of asphalt from the aggregate surface. If more than 90 percent of the asphalt is retained on the surface, the combination is considered compatible and suitable for mixing. If the percent retained asphalt is between 70 and 90, the mix is questionable and may require an antistripping agent or hydrated lime in the mix to ensure adequate stripping performance. If less than 70 percent of the asphalt is retained, the mix is considered incompatible and should not be used (SHRP-A-407) (SHRP 1993-94e).

MOISTURE SENSITIVITY TESTING (AASHTO T283 OR TP34-93).

Two methods for determination of the moisture sensitivity of a compacted asphalt mix are deemed acceptable for SHRP mixes (SHRP-A-341) (SHRP 1993-94g). The first is the older and more widely accepted practice of retained tensile strength ratio (TSR) of a water-conditioned specimen to a dry sample. The second is a method developed under SHRP that utilizes the Environmental Conditioning System (ECS) for conditioning and testing the specimens for resilient modulus.

The retained tensile strength test is conducted in accordance with AASHTO T283-89 (AASHTO 1995). A compacted specimen is vacuum saturated, conditioned at -18 ± 3°C for 16 hr, placed in a water bath at 60 ± 1°C for 24 hr before determining the tensile strength of the sample using the device from AASHTO T245 or T167 (AASHTO 1995).

The ECS was developed under SHRP and is a complete closed system for measuring the resilient modulus of compacted specimens using dynamic loading, determining the air and water permeability of the specimen, vacuum saturation of the specimens, and temperature cycling. The ECS employs 100-mm (4-in.) -tall specimens rather than the 64-mm (2.5-in.) typical Marshall specimen.

The sample is placed within the ECS chamber, and the resilient modulus is determined on the dry specimen. A schematic of the testing apparatus is shown in figure 13. The applied load is in the form of a haversine wave with a pulse duration of 0.1 sec and rest of 0.9 sec and initial magnitude of 2,200 ± 25 N (494 lb). The dynamic load is adjusted to yield between 50 and 100 microstrains and no more than 250 loading cycles applied to determine the dry modulus. This usually requires approximately 4,000 N of force. The side of the sample is sealed with a bead of silicone around the circumference, and the permeability of the sample to air is determined. Linear variable differential transformers (LVDT) are mounted, and the specimen is vacuum saturated (at 50.8 cm of mercury for 30 min.). The specimen is then subjected to four conditioning cycles. The first three cycles are at 60°C for 6 hr in which the specimens are maintained at a vacuum level of 25.4 cm Hg and subjected to dynamic loading at 900 ± 25 N. At the end of each of the warm cycles, the temperature is reduced to 25°C, and the modulus is determined as previously described. The water permeability is also determined. Following the warm cycles, the temperature is reduced to -18 ± 0.5°C for 6 hr before warming back to 25°C to determine the final modulus. The resilient modulus after each conditioning cycle is averaged and the ECS modulus ratio determined by comparison to the dry modulus. The permeability ratio is also determined (SHRP-A-403) (SHRP 1993-94t).

SHORT-TERM AGING (AASHTO PP2-94) (AASHTO 1996).

This procedure simulates the short-term aging process that occurs in the precompaction phase (SHRP-A-383) (SHRP 1993-94d). The test method employs loose asphalt mixtures that are placed on a baking pan in a forced draft oven. Then 21 to 22 kg of uncompacted asphalt-aggregate mix is allowed to stand for 4 hr ± 5 min. at 135 ± 3°C. The material is stirred every 60 min. for consistent aging throughout the mix.

GYRATORY COMPACTOR AND METHOD (AASHTO TP4-93) (AASHTO 1996).

The gyratory compactor and method is employed to more closely simulate the compaction process that occurs in the field (SHRP-A-408) (SHRP 1993-94f). The SHRP gyratory compactor is available as a commercial device. The device produces a compacted asphalt concrete sample from loose mix. The compactive effort on the sample is 0.6 MPa (87.5 psi) with a 1.25° angle on the upper platen. The compaction is typically carried out at equiviscous temperatures for differing binder grades, but other temperatures for compaction can be selected by the mix design engineer.

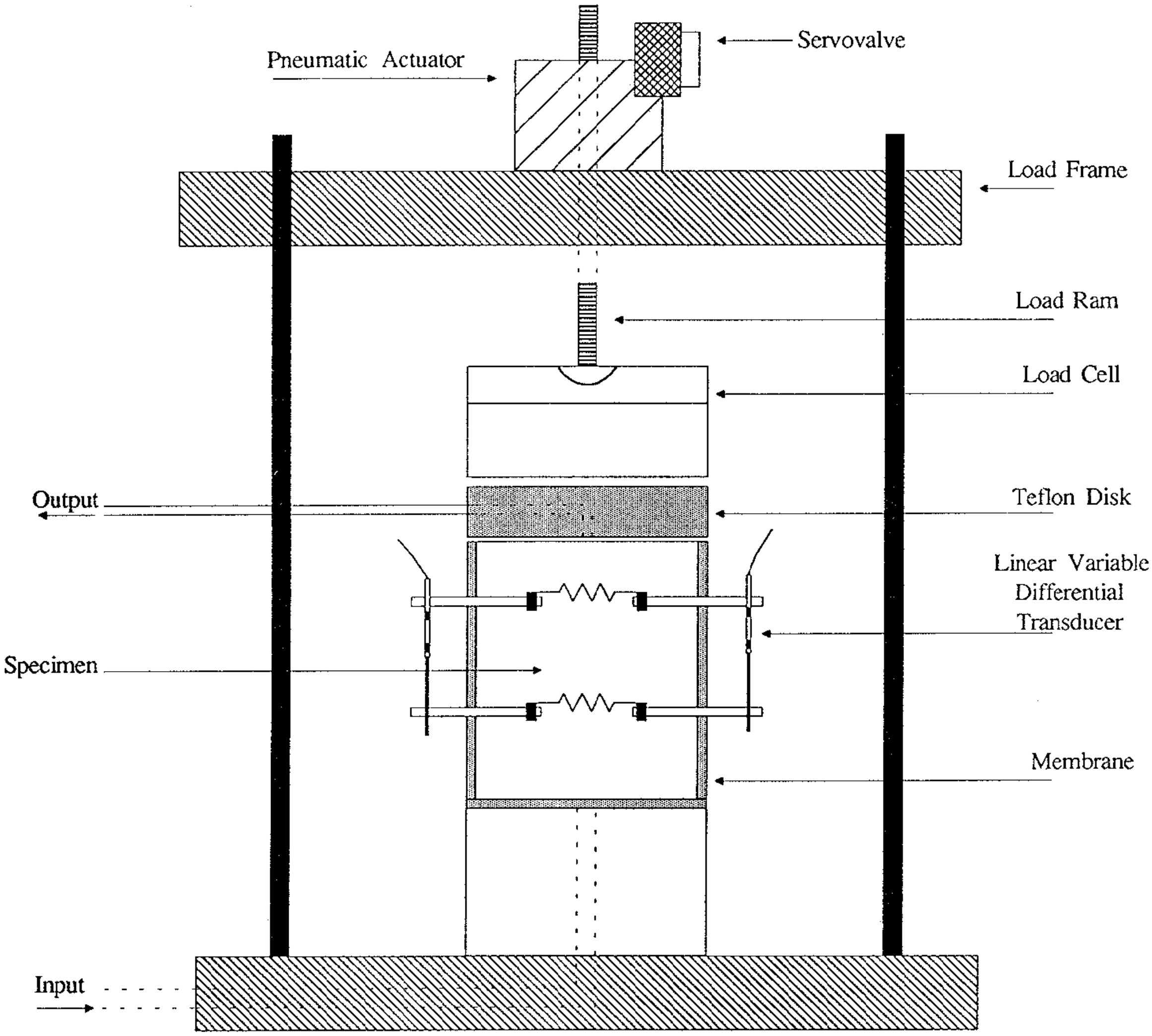


FIGURE 13. DIAGRAM OF THE LOAD FRAME INSIDE ENVIRONMENTAL CABINET OF THE ECS SYSTEM (Reprinted with permission from SHRP-A-403 (SHRP 1993-94t))

Increased compaction of the sample is accomplished by increasing the number of gyrations applied to the sample. A diagram of the apparatus is shown in figure 14.

LONG-TERM AGING (AASHTO PP2-94) (AASHTO 1996).

This test is not a required test and may be conducted on an optional basis. The method is intended to simulate 5 to 10 years of field aging and employs loose asphalt mixtures that have undergone short-term aging as described in SHRP 1025 (SHRP-A-383) (SHRP 1993-94d). The material is first compacted according to SHRP 1014 or 1015. The briquets are cooled to 60 ± 3 °C for approximately 2 hr before the sample is leveled by applying a 72 ± 30.05 kN/min load. The load is removed when the specimen ends are level or the applied load has reached 56 kN. The specimens are then cooled to room temperature for 16 hr.

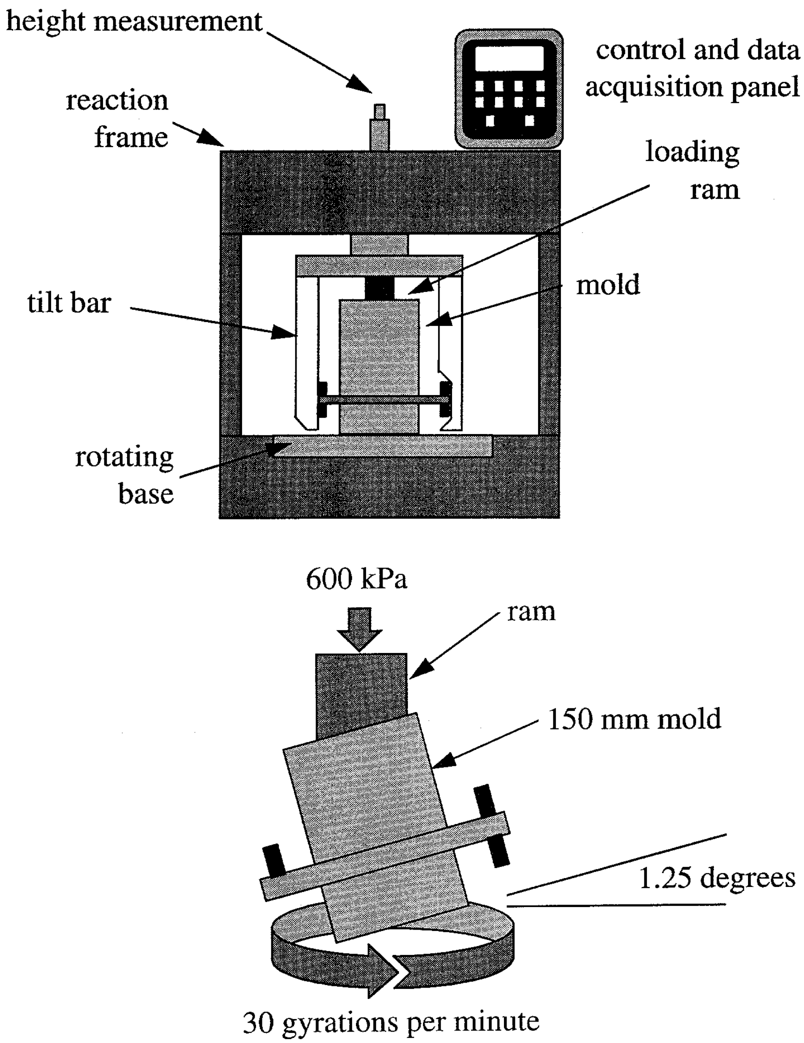


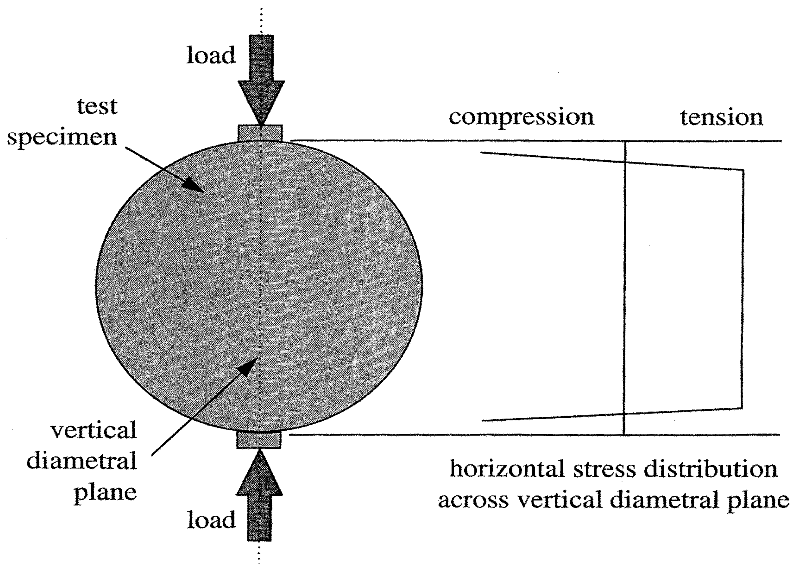
FIGURE 14. THE SHRP GYRATORY COMPACTOR; (a) SCHEMATIC, (b) PRINCIPLE OF OPERATION (Reprinted with permissiom from SHRP-A-410 (SHRP 1993-94o))

Core samples removed from freshly laid asphalt concrete can also be long-term aged. The compacted specimens are then placed in racks in a forced draft oven at 85 ± 3°C for 120 ± 0.5 hr. After removing the racks from the oven, the samples cannot be disturbed until cooled to room temperature.

INDIRECT TENSILE CREEP COMPLIANCE AND STRENGTH TEST (AASHTO TP9-94) (AASHTO 1996).

The indirect tensile creep compliance test is designed to measure the low temperature compliance of a compacted asphalt sample. The data is used with the bending beam rheometer data in the SUPERPAVE performance prediction models to predict the thermal cracking characteristics of the mix.

Specimens are tested at three temperatures below 0°C (usually 0°, -10°, and -20°C). Sample sizes up to 150 mm in diameter and 75 mm in height can be tested dependent on the nominal maximum aggregate size. A schematic of the testing arrangement and LVDT placement are shown in figure 15. Both vertical and horizontal strains are measured by mounting LVDTs to the faces of the test specimen. The samples are subjected to a static load placed on the diametral axis of the specimen for 1,000 sec to yield horizontal deformations within the linear viscoelastic range (0.00125 to 0.0125 mm for 100-mm specimens and 0.00125 to 0.0190 mm for 150-mm-diam specimens). If the deformations are outside these ranges, the test is interrupted and restarted at a lower applied load after at least 5 min to allow for recovery of the specimen. At the completion of the compliance test, the sample is loaded at a constant rate of 12.5 mm/min until the sample fails, yielding the ultimate tensile strength of the sample at that temperature.



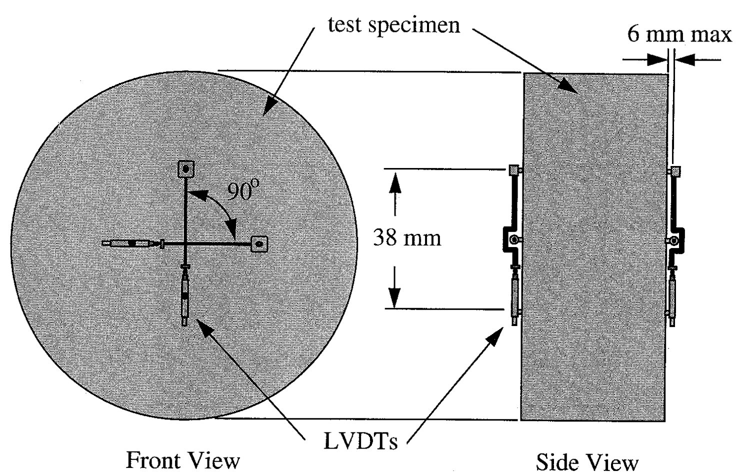


FIGURE 15. SCHEMATIC VIEW OF INDIRECT TENSILE TEST AND ARRANGEMENT OF LVDTs ON SPECIMEN FACES (Reprinted with permission from SHRP-A-410 (SHRP 1993-94o))

The individual creep curves from 0°, -10°, and -20°C are combined to generate a master creep compliance curve. The master creep compliance curve is then fit to a Prony series to yield a mathematical representation of the curve for easier analysis. An example of the individual creep curves, the shifted data, and the Prony series fit for the master compliance curve are shown in figure 16. The Prony series allows easy manipulation of the compliance curve into the relaxation modulus using Lorentzian transformations. The relaxation modulus can then be found at any temperature and time of loading between 0° and -20°C by interpolation and outside that temperature range by extrapolation.

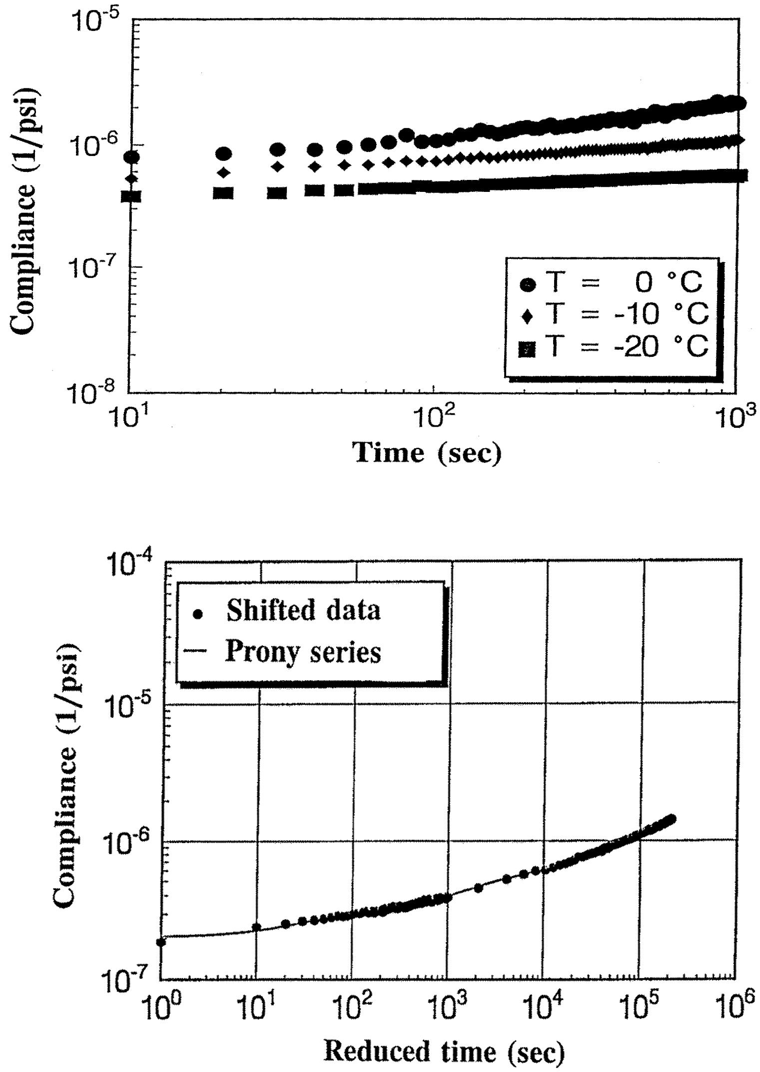


FIGURE 16. INDIVIDUAL CREEP COMPLIANCE CURVES AND SHIFTED DATA SHOWING PRONY SERIES FIT (Reprinted with permission from SHRP-A-357 (SHRP 1993-94q))

The indirect tensile strength test measures the ultimate fracture strength of an asphalt concrete specimen at a designated temperature for fatigue cracking analysis. A constant loading rate of 50 mm/min is applied until the sample fractures.

HYDROSTATIC STATE OF STRESS OR VOLUMETRIC TEST (AASHTO TP7-94) (AASHTO 1996).

A gyratory compacted specimen is sealed with a rubber membrane and placed in a confining pressure chamber with two vertical LVDTs (on the top and bottom of the specimen) and a radial LVDT fitted around the circumference of the sample. Preconditioning is achieved by application of a 70 kPa load for 1 sec and rapidly reduced to 7 kPa. The sample is then loaded from all sides with the same confining pressure. The pressure is applied at a rate of 70 kPa per sec until reaching 550, 690, or 830 kPa at 40°, 20°, and 4°C, respectively. The load is maintained constant for 10 sec and reduced at a rate of 25 kPa per sec until a load of 7 kPa is realized (figure 17). Axial and radial deformation is monitored (approximately 10 data points per sec) during the entire test. The change in volume of the sample throughout the test can be determined.

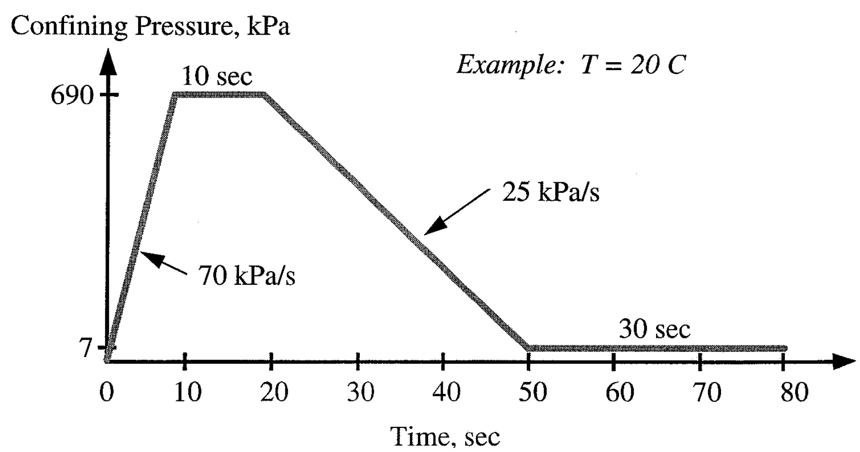


FIGURE 17. LOADING SCHEME OF VOLUMETRIC TEST (Reprinted with permission from SHRP-A-410 (SHRP 1993-94o))

UNIAXIAL STRAIN (AASHTO TP7-94) (AASHTO 1996).

The test setup is similar to that of the hydrostatic test, except that a 75-mm circular loading unit is placed between the load cell and the specimen to yield a more uniform stress distribution on the vertical face of the specimen. One radial LVDT is placed around the circumference and two LVDTs placed on the sides of the specimen. Preconditioning is achieved in the same fashion as the hydrostatic test. An axial load is then applied at a rate of 70 kPa per sec until the desired load of 345, 415, and 655 kPa at 40°, 20°, and 4°C, respectively, is realized. The axial load is applied for 10 sec and relieved at a rate of 23 kPa per sec to a residual load of 7 kPa. During this process, the confining pressure is adjusted by closed feedback control using the radial LVDT to track the change in the sample perimeter. Axial and radial deformations are recorded throughout the test and for another 30 sec after reducing the axial load to 7 kPa (figure 18). The uniaxial strain developed during the test is determined from the vertical strain divided by the specimen height. In addition, the axial stress is determined by P/A + confining stress. P is the applied load, and A is the cross-sectional area of the specimen.

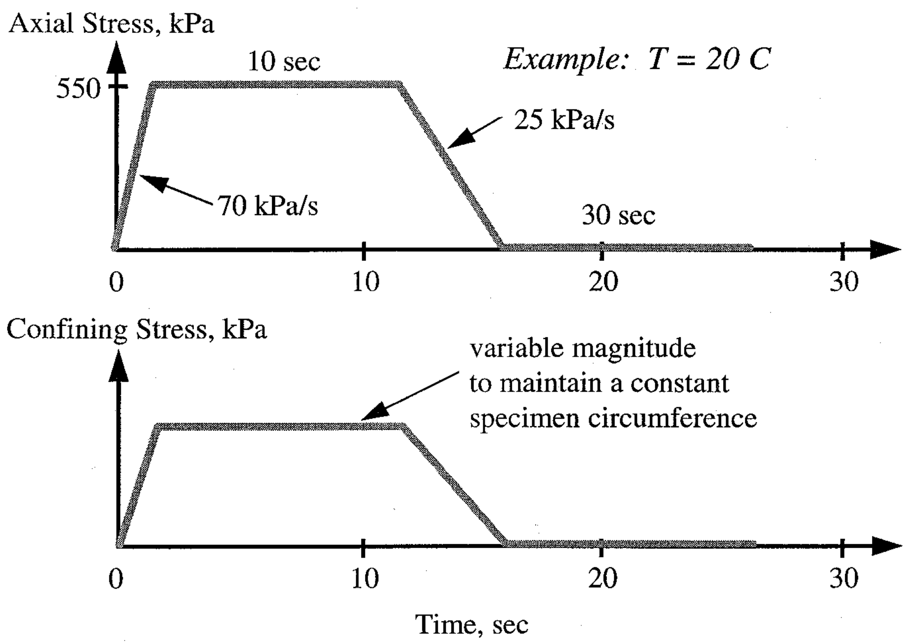


FIGURE 18. LOADING SCHEME IN UNIAXIAL STRAIN TEST (Reprinted with permission from SHRP-A-410 (SHRP 1993-94o))

REPEATED SHEAR AT CONSTANT STRESS RATIO (AASHTO TP7-94) (AASHTO 1996).

This test is employed as a screening test to evaluate whether the mix is susceptible to tertiary flow. Tertiary flow occurs when repeated loading further compacts the mixture to air void contents less than approximately 2 percent. In this region of air voids, the mix becomes unstable and, with further loading, enters a state of rapid plastic flow (figure 19).

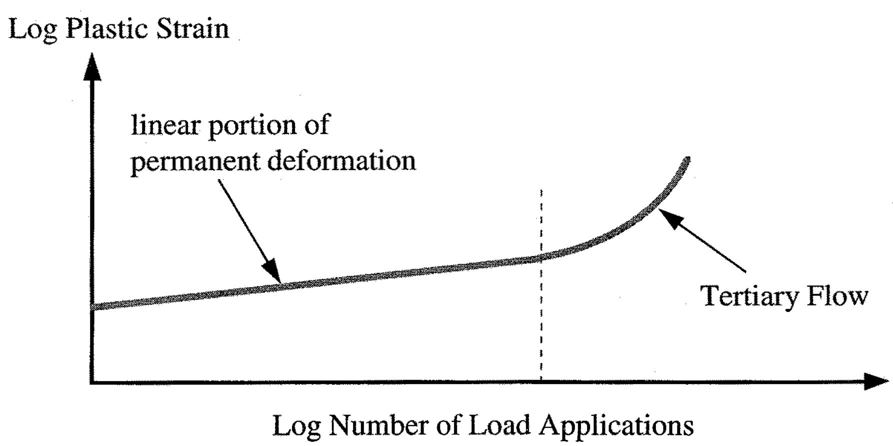


FIGURE 19. EXAMPLE OF TERTIARY FLOW (Reprinted with permission from SHRP-A-410 (SHRP 1993-94o))

This test is conducted in similar fashion to the repeated simple shear test at constant height. Both axial and shear strain are controlled by feedback from the respective load. The axial and shear stresses are haversine in shape and maintained at an axial/shear stress ratio between 1.2 and 1.5. The sample is preconditioned by application of synchronized axial and shear haversine waves of 0.1 sec in duration with 0.6 sec rest time. The applied stress during preconditioning should not exceed 7 kPa. The test is conducted by application of 5,000 cycles of the synchronized haversine waves or until the permanent strain level reaches 5 percent.

SIMPLE SHEAR AT CONSTANT HEIGHT (AASHTO TP7-94) (AASHTO 1996).

Both vertical and horizontal LVDTs are attached to the specimen. The test is stress controlled using a closed-loop feedback to generate the magnitude of the applied shear load. The test is conducted at constant height using feedback from the vertical LVDTs to control the height of the test specimen. Preconditioning is achieved by application of a 7 kPa shear stress for 100 cycles. The shear stress is then applied at a rate of 70 kPa/sec for 10 sec to achieve the desired stress of 35, 105, or 345 kPa at 40°, 20°, and 4°C, respectively. After application of the stress for 10 sec, the load is reduced to zero at 25 kPa/sec and the data collected for another 10 sec (figure 20). The data collection rate should be about 10 points/sec. The axial, P, and shear, V, loads are recorded along with the vertical, δ_v, and horizontal, δ_h, displacements of the specimen. The axial stress, σ_{11}, is determined from P/A and the shear stress, τ_{12}, from V/A. Shear strain, ε_{12}, is horizontal strain divided by specimen height.

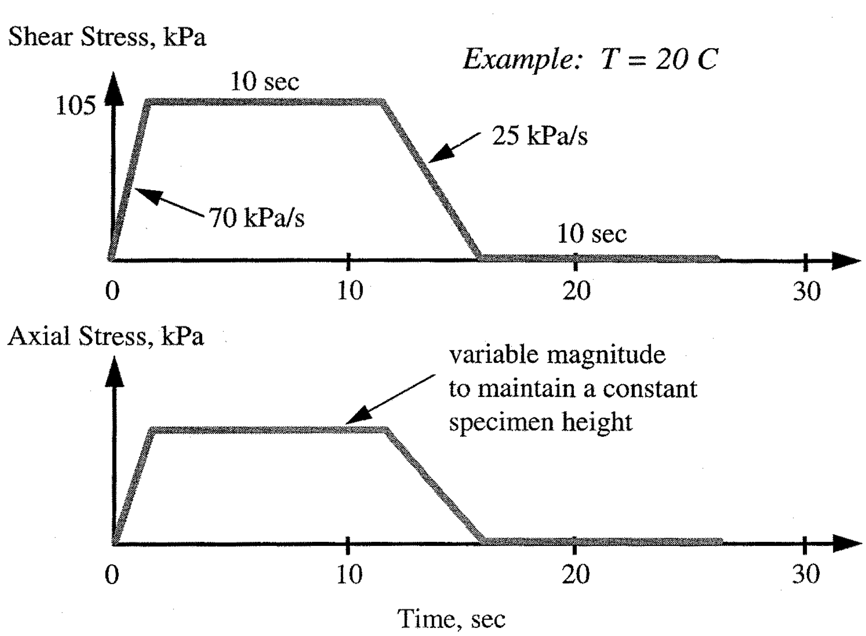


FIGURE 20. LOADING PROCEDURE IN SIMPLE SHEAR AT CONSTANT HEIGHT TEST (Reprinted with permission from SHRP-A-410 (SHRP 1993-94o))

REPEATED SHEAR AT CONSTANT HEIGHT (AASHTO TP7-94) (AASHTO 1996).

The repeated simple shear test at constant height is a repeated load test in which a sinusoidal cyclic shear is applied to a cylindrical test specimen for a given number of cycles or until a target strain is reached. This test is analogous to the simple shear at constant height, but is conducted using repetitive loads. Preconditioning of the specimen is the same. The load is applied as a 70 kPa haversine shear pulse of 0.1-sec duration followed a 0.6-sec rest period. The test is conducted to 5,000 cycles or until 5 percent shear strain is reached.

FREQUENCY SWEEP AT CONSTANT HEIGHT (AASHTO TP7-94) (AASHTO 1996).

As in the simple shear test, both vertical and horizontal LVDTs are attached to the specimen. Constant height of the specimen during the test is controlled by closed-loop feedback of the vertical LVDT. The sample is preconditioned by application of a sinusoidal horizontal shear strain of approximately 10^{-4} mm/mm at 10 Hz for 100 cycles. The maximum allowable strain during the test is limited to 10^{-4} mm/mm. The strain is applied at frequencies of 10, 5, 2, 1, 0.5, 0.2, 0.1, 0.05, 0.02, and 0.01 Hz in descending order at each temperature, (4°, 20°, and 40°C) starting with the lowest. The loading scheme is shown in figure 21. The axial load, P, and shear load, V, are recorded along with the vertical, δ_v, and horizontal, δ_h, displacement of the specimen. The axial stress, σ_{11}, is determined from P/A and the shear stress, τ_{12}, from V/A. Shear strain, ε_{12}, is horizontal strain divided by specimen height. Complex shear modulus is shear stress divided by shear strain, and the phase angle, ι, is measured in degrees.

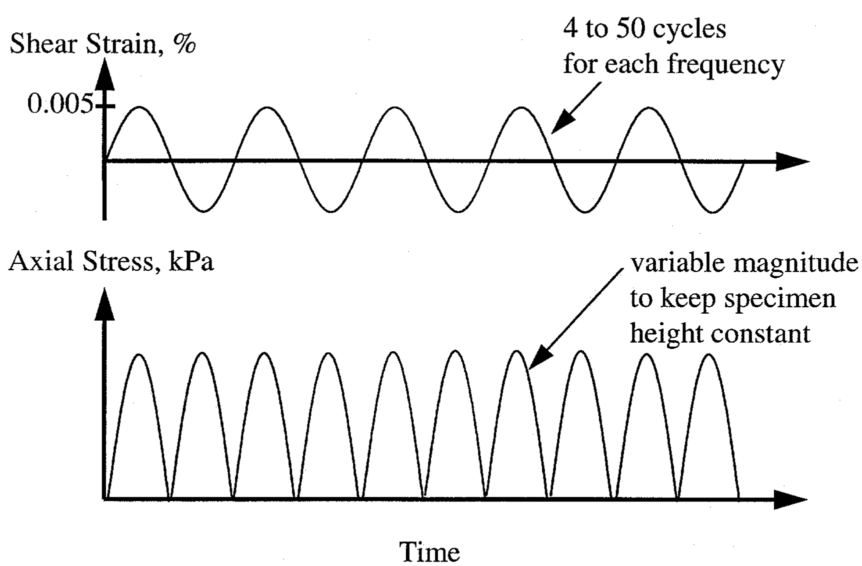


FIGURE 21. LOADING PROCEDURES IN FREQUENCY SWEEP TEST
(Reprinted with permission from SHRP-A-410 (SHRP 1993-94o))

RESULTS AND DISCUSSION

EXPERIMENTAL PLAN.

The test plan was designed to compare the current FAA and SHRP mix design procedures in three areas: effect of binder on mixture properties, effect of compaction techniques, and effect of aggregate gradations. Two asphalts will be selected that are typical for a cold and a hot environment, an AC-10 (PG58-34) and an AC-30 (PG64-22). Mix designs for a light-duty FAA and a heavy-duty FAA pavement with each binder will be conducted. The SHRP mixture design contains provisions for design of pavements based on both traffic and local temperatures, and this will be addressed in the test plan. A high-quality, 100-percent-crushed stone aggregate will be employed as the aggregate source. Two aggregate gradations will be compared. One gradation that strictly meets the FAA and SHRP aggregate gradation requirements will be employed. A second gradation that strictly meets the SHRP requirements, but does not meet FAA gradation specifications, will also be used.

The asphalt mixtures samples produced by each of the design compaction methods should not be directly compared to avoid a comparison of compaction techniques rather than the properties of field pavements. Studies of different methods of mixture compaction have shown that samples produced by the Marshall hammer, SGC, and kneading compactor generally do not produce samples representative to those in the field. Aggregate orientation and air void size and distribution are likely to very different from field cored samples (Sousa et al., 1990). These differences from field cored samples are manifested in measured physical properties and can have serious consequences for interpretation of laboratory data for performance prediction (Harvey and Monismith, 1994 and Harvey, Eriksen, Sousa, and Monismith, 1994). For the most reliable prediction of field performance based on laboratory specimens, use of rolling wheel compaction (Scholz, Allen, Terrel, and Hicks, 1994 and Sousa et al., 1990) has been shown to produce specimens with properties closest to actual field cored samples. This technique has been employed on several projects to provide performance prediction capabilities for shear and fatigue (Harvey, Deacon, Tsai, and Monismith, 1995 and Harvey, Vallerga, and Monismith, 1995).

The heavy-duty asphalt mixture samples (75 blow Marshall and SUPERPAVE® N_{Design}=143) were tested for permanent deformation, thermal, and fatigue properties. For permanent deformation characteristics, these mixtures will be examined using RSST-CH, a SHRP-developed test (SHRP Product 1017). Thermal characteristics will be evaluated using the thermal stress restrained specimen test (SHRP Product 1021). Fatigue properties will be analyzed using the beam method (SHRP Product 1019) developed by SHRP researchers at the University of California at Berkeley.

ASPHALT MIXTURE DESIGN.

Mixture designs were conducted according to FAA Advisory Circular 150/5370-10A Item P-401 for the Marshall design and AASHTO PP28-95 for the SHRP mixtures. The aggregate gradations employed are shown in figure 22 and tabulated in table 14.

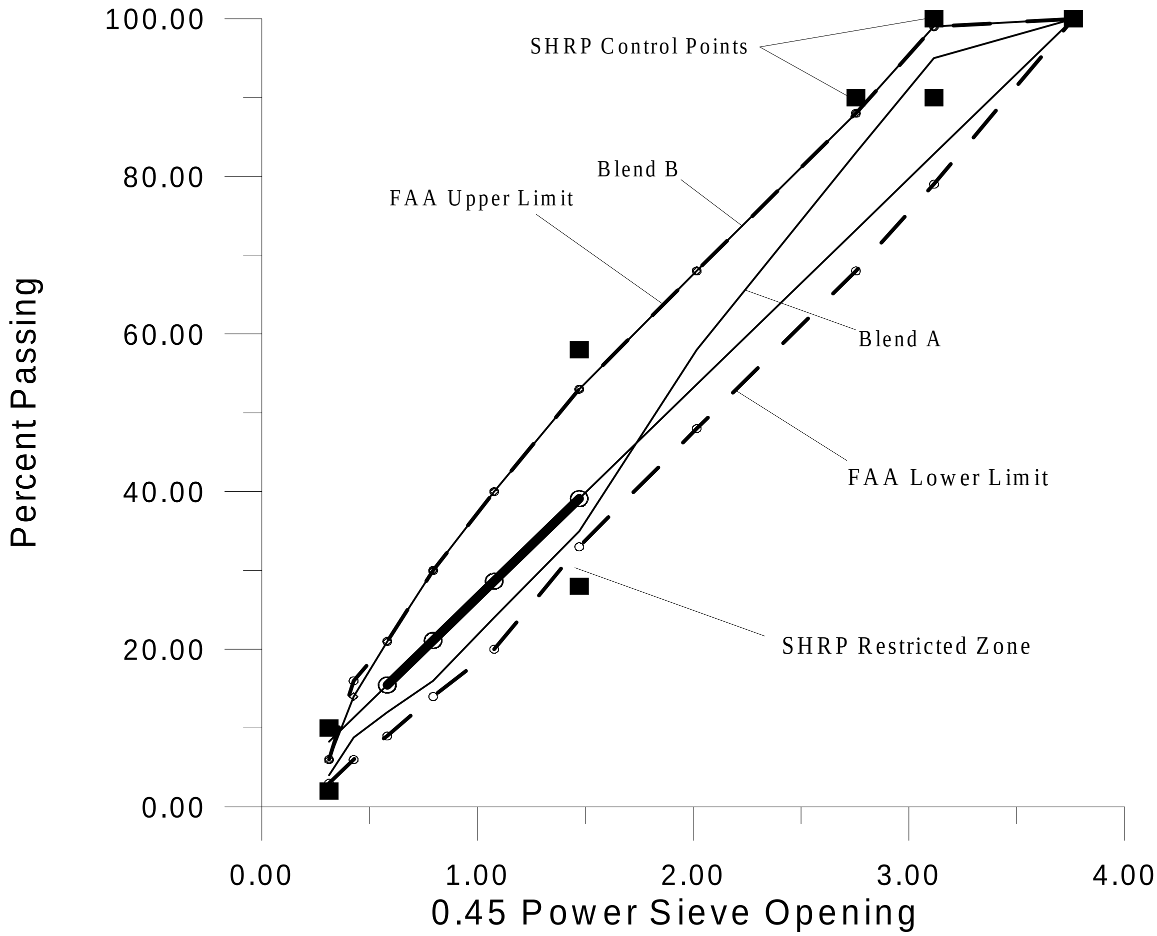


FIGURE 22. AGGREGATE BLENDS EMPLOYED IN THE MIXTURE DESIGNS FOR 19 mm (3/4 INCH) MAXIMUM SIZE AGGREGATE. Nominal maximum size is 12.5 mm (1/2 inch). The maximum density line, SHRP control points, SHRP restricted zone, and FAA gradation limits are shown. Blend A - SHRP, Blend B - FAA.

The aggregate was 100% crushed Alabama limestone. A SHRP PG58-34 (AC-10) and PG64-22 (AC-30) were obtained from Lion Oil in Eldorado, Arkansas. The mixture design matrix is given in table 15. The experimental design consisted of a light-duty SHRP mixture, a light-duty FAA mixture, a heavy duty SHRP mix, a heavy-duty FAA mix, and a hybrid design for both light and heavy-duty in which an FAA gradation was employed and compacted by the SHRP gyratory compactor. The purpose of the hybrid design was to evaluate the properties of an FAA gradation compacted according to the SHRP criteria. Three samples were compacted at each asphalt content. The volumetric properties were calculated according to the Asphalt Institute MS-2 for the FAA mixtures and AASHTO PP19-93 for the SHRP mixtures. The results of the mixture designs are given in table 16. The design charts are included in appendix E. The design parameters at $V_a = 4\%$ were obtained from the charts by linear interpolation.

TABLE 14. AGGREGATE BLENDS EMPLOYED FOR SHRP (BLEND A) AND FAA (BLEND B) MIXTURE DESIGNS

Sieve Size, mm	Blend A, % Passing	Blend B, % Passing
0.075	4	6
0.15	8.8	14
0.3	12	21
0.6	16	30
1.18	24	40
2.36	35	53
4.75	58	68
9.5	83	88
12.5	95	99
19	100	100

TABLE 15. EXPERIMENTAL MATRIX FOR MIXTURE DESIGNS

Mixture	Asphalt	Aggregate Blend	Compaction Effort
SAALD	A-PG 58-34	A	$N_{Design} = 68$
SBALD	B-PG 64-22	A	$N_{Design} = 68$
SABLD	A-PG 58-34	B	$N_{Design} = 68$
SBBLD	B-PG 64-22	B	$N_{Design} = 68$
MABLD	A-PG 58-34	B	50 Blows
MBBLD	B-PG 64-22	B	50 Blows
SAAHD	A-PG 58-34	A	$N_{Design} = 143$
SBAHD	B-PG 64-22	A	$N_{Design} = 143$
SABHD	A-PG 58-34	B	$N_{Design} = 143$
SBBHD	B-PG 64-22	B	$N_{Design} = 143$
MABHD	A-PG 58-34	B	75 Blow
MBBHD	B-PG 64-22	B	75 Blows

TABLE 16. MIXTURE DESIGN RESULTS AT 4% AIR VOID LEVEL

Mixture	Asphalt Content, %	VMA, %	VFA, %			
SHRP Mixtures				% G_{mm} at $N_{Initial}$	% G_{mm} at $N_{Maximum}$	Fines/Effective Asphalt Ratio
SAALD	4.9	15.5	75	86.5	97.5	0.9
SBALD	5.0	15.8	75	86.5	97.5	0.85
SABLD	4.8	15.2	75	89.0	97.0	1.3
SBBLD	5.0	15.1	73	89.0	97.0	1.35
SAAHD	4.2	14.0	72	86.0	97.6	1.05
SBAHD	4.1	14.1	72	86.0	97.7	1.1
SABHD	4.4	14.0	71	89	97.0	1.5
SBBHD	4.2	13.8	71	88	97.0	1.5
Marshall Mixtures				Stability, lbs	Flow, 0.01 inch	
MABLD	5.1	15.9	75	1620	9	
MBBLD	5.1	15.7	74	2050	9	
MABHD	4.6	14.8	72	2050	9	
MBBHD	4.4	14.6	71	2880	9	

The SHRP compaction effort for N_{Design} = 68 and N_{Design} = 143 is slightly greater than those of the Marshall 50 and 75 blow hammer, respectively, as evidenced by the differences in asphalt content for equivalent FAA blend B gradations. The FAA aggregate blend B fails the initial SHRP compaction criteria of G_{mm} > 89% at $N_{Initial}$. Assuming a linear relation of the number of gyratory revolutions and asphalt content, the equivalent compaction effort of the SHRP to the 50-blow Marshall occurs at N_{Design} = 49 and for 75-blow Marshall the equivalent effort is at N_{Design} = 117.

The most significant problem encountered in the heavy-duty SHRP mixture designs was meeting the VMA criteria for aggregate Blend A. Several trial blends were compared before a satisfactory value for VMA was obtained. Although the VMA criteria was strictly obtained, the field variability in VMA would certainly mean that this value would not be consistently reached under construction conditions. The recommendations in the SHRP procedure would prefer VMA values of 14.5-15.0 to insure that field variability would not allow values below 14.0. For aggregate blend B, the maximum density at $N_{Initial}$ = 9 of < 89% was not obtained during compaction of the PG58-34 asphalt. For blend B, the asphalt contents of the SHRP mixtures at 4% air voids are less than those of the Marshall 75-blow method indicating a higher level of compactive effort of the SHRP method at $N_{Design} = 143$.

ASPHALT MIXTURE ANALYSIS.

All of the statistical data reported here are calculated using the Student-t distribution for small samples sizes assuming the population standard deviation is unknown. The confidence limits are reported at the 95% level.

SAMPLE PREPARATION BY ROLLING WHEEL COMPACTION. Samples for performance-related testing were prepared by means of rolling wheel compaction to simulate field compaction conditions as closely as possible. The procedure was a variation of AASHTO PP3-94 and closely followed current methods in use at the University of California at Berkeley. A large square steel mold approximately 76 by 622 mm (3 by 24.5 inches) with a slight bevel towards the surface of the mold to facilitate sample removal was constructed. A smaller mold dividing the volume into three equal sizes approximately 203 by 76 by 610 mm (8 by 3 by 24 inches) was prepared. The surface of the mold was pretreated with a release agent and heated for at least one hour prior to sample placement. Approximately 21 kg (46.1 lbs) of asphalt-aggregate mixture at optimum asphalt content was placed in the mold at 140°C to achieve a target air void content of 4%. A small 600 kg steel wheel roller operating in static mode and using multiple passes was immediately employed to compact the material flush with the surface of the mold. The finished ingots were allowed to completely cool before removal from the mold. Samples for testing were either sawed or cored from the ingot. Air void contents were determined according to ASTM D 3203.

REPEATED SIMPLE SHEAR AT CONSTANT HEIGHT (RSST-CH). The RSST-CH was conducted at 40°C to be representative of a large portion of the United States climate. The results are tabulated in table 17. No statistical differences between any of the samples were measured.

TABLE 17. RESULTS OF REPEATED SIMPLE SHEAR TESTING AT CONSTANT HEIGHT

Sample	% Strain at 5000 reps
SAAHD	1.29 ± 0.77
SBAHD	1.61 ± 1.59
SABHD	1.08 ± 1.37
SBBHD	0.77 ± 0.60
MABHD	1.28 ± 0.86
MBBHD	1.07 ± 1.43

FLEXURAL BEAM FATIGUE TEST (FBFT). The FBFT was conducted at 20°C to be representative of a temperature where a majority of fatigue damage occurs. A strain level of 450 microstrains was chosen to allow the fatigue strength to be measured in a reasonable amount of experimental time. The results are compiled in table 18. No significant differences in fatigue cycles were measured between any of the mixtures. Mixtures prepared with the PG58-34 binder and aggregate blend A demonstrated significantly different initial flexural strengths at 20°C than those prepared with PG64-22. No significant differences were measured for other mixtures. No differences between aggregate gradations or mixture design procedures were measured.

TABLE 18. RESULTS OF FLEXURAL BEAM FATIGUE TEST

Sample	Strain cycles to 50% of Initial Flexural Strength	Initial Flexural Strength, kPa
SAAHD[c]	51,645 ± 16,581	3,680 ± 669
SBAHD[c]	28,988 ± 8,215	5,992 ± 697
SABHD[c]	51,343 ± 40,869	4,391 ± 1,439
SBBHD[c]	16,233 ± 11,540	6,000 ± 371
MABHD[b]	49,580 ± 21,756	3,645 ± 615
MBBHD[a]	27,100	5,519

[a] two samples tested
[b] three samples tested
[c] four samples tested

<u>THERMAL STRESS RESTRAINED SPECIMEN TEST (TSRST)</u>. The TSRST results are presented in table 19. There are no significant differences between the fracture temperatures or fracture strengths for any of the samples. A number of problems were encountered during the testing of the samples. It is unclear whether problems arose from sawing and milling of the samples to produce the "dog-bone" configuration, from the method used to compact the mixtures, or from sample handling. Samples of SHRP A and MB tested did not break during the test. Other specimens from those sample series did break but the data was invalid due to either breakage at the end cap, LVDT inconsistencies, or step motor problems. Of the four mixtures that did break during testing, only two of those (SHRP B) yielded statistical information. For SHRP A1, two of the samples broke at -18.7° and -18.2°C, respectively, while one of the specimens broke at -34.6°C and was not included in the data analysis. For mixture SHRP B1, only one sample yielded usable data, the other samples broke at the end cap or iced up during testing. For MB1, two samples broke at -34.8° and -34.6°C while a third sample did not break after cooling to -34.9°C.

TABLE 19. RESULTS OF THERMAL STRESS RESTRAINED SPECIMEN TEST

Sample	Temperature, °C	Strength, kPa
SAAHD[a,d]	-39.5	1,384
SBAHD[b]	-18.5	2,490
SABHD[c]	-37.1 ± 7.0	3,281 ± 668
SBBHD[a]	-27.3	2,573
MABHD[a,d]	-34.9	2,577
MBBHD[b]	-34.7	2,427

[a] single measurement
[b] two samples tested
[c] three samples tested
[d] sample did not break

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS.

1. SHRP Product Evaluations are described below.

The following SHRP Products are directly applicable to FAA pavements technology and require no modification before use. They are listed by category.

Asphalt

1002	Bending Beam Rheometer
1003	Pressure Aging Vessel
1004	Asphalt Extraction and Recovery
1005	Low-Temperature Direct Tension Test
1006	High-Temperature Viscosity Test
1007	Dynamic Shear Rheometer
1009	Binder Chromatography
1013	Net Adsorption Test
1015	Rolling Steel Wheel Compaction Method
1021	Thermal Stress Restrained Specimen Test
1022	Indirect Tensile Creep and Failure Test
1025	Short-Term Aging
1026	Modified Rice Correction Test

Concrete

2002	Aggregate Durability Test
2004	Mitigation of D-Cracking
2005	Handbook for Mix Design
2006	Guide to Thermal Effects
2007	Permeability Laboratory Test
2008	Fluorescent Microscopy Manual
2009	Screening Reactive Aggregates Test
2010	Manual for ASR Detection
2011	ASR Mitigation in Existing Concrete
2012	Flaw-Detection by Impact Echo Method
2013	Chemical Test for ASR Detection
2014	High-Performance Concrete Specifications
2015	Radar Method for Asphalt Decks
2017	ASR-Safe Mix Designs
2018	Modified Freeze and Thaw Test
2019	Soundness Test for Concrete
2020	Air Entrainment Specifications
2021	PCC Aggregate Specifications
2022	Guide to Strength/Maturity
2023	Flexural Strength Test
2024	Compressive Strength Test
2025	Interfacial Bond Test
2026	Permeability Test-Electrical Resistance
2027	Fresh Concrete Water Content Test
2028	Test for Consolidation
2029	Sealer Effectiveness Methods
2031	Permeability Test-Surface Air Flow
4001	Measuring Air Entrainment

Highway Operations

3005	Robotic Pothole Patching Vehicle
3022	Snowplow Cutting Edge
3026	Snowplow Scoop
3027	Snowplow Design Manual
3035	Epoxy-Core Test for Void Conditions

Pavement Engineering

4008	Software for Measuring Pavement Layer Thickness
5015	Dipstick Profile Software
5021	Guide to Field Sampling and Material Handling
5022	Examining Asphalt Pavement Cores
5023	Examining Asphalt Pavement Cores

5024	Fine Aggregate Particle Shape Test
5025	Laboratory Guide for Test Pavement Samples
5026	Visual Examination of Asphalt Stripping
5028	Proficiency Testing for Modulus
5029	Proficiency Tests for Concrete Cores
5030	Proficiency Tests for Moisture Content
5031	Modified Georgia Faultmeter
5032	LTPP Information Management Systems (IMS)

The following SHRP products are applicable with minor modifications to FAA pavements technology.

Asphalt

1001	Binder Specification
1014	Gyratory Compactor and Method
1017	Shear Test and Device
1019	Flexural Fatigue Life Test
1024	Environmental Conditioning System
1030	Long-term Aging

Concrete

2003	Concrete Removal Manual
2039	HWYCON—Concrete Expert System

Highway Operations

3003	Pavement Repair Materials Guidelines
3004	Robotic Crack-Filling Vehicle
3018	Radar for Pavement Subsurface Condition
3019	Seismic Pavement Analyzer Method
3033	Manual on Rating Preventive Maintenance
3034	Specifications for Preventive Maintenance

Pavement Engineering

5003	FWD Relative Calibration
5004	FWD Reference Calibration
5005	FWDREFCL Program for Calibration
5006	FWDCAL Program for Calibration
5007	FWDCHECK Program for Quality Assurance
5008	FWDSCAN Program for Quality Assurance
5009	Manual for FWD Testing
5016	Distress Identification Manual
5019	Resilient Modulus of Asphalt Pavement

5020	Resilient Modulus of Soils and Aggregates
5037	FWD Calibration Stations

The following SHRP products are applicable with major modifications to FAA pavements technology. These products cannot be utilized or applied to heavy-duty airfield pavements without a substantial effort to modify the product in some manner.

<u>Asphalt</u>

1011	Mix Specification
1012	Superpave Mix Design System

<u>Concrete</u>

None

<u>Highway Operations</u>

None

<u>Pavement Engineering</u>

4002	Capacitance Strip Weigh-in-Motion Sensor
5011	PROFCAL—Profile Quality Assurance
5012	PROFCHCK—Profile Quality Assurance
5013	PROFSCAN—Profile Quality Assurance
5014	Profile Measurement Manual

The following SHRP products are not applicable to FAA pavements.

<u>Asphalt</u>

1010	Refiner's Guide

<u>Concrete</u>

2001	Corrosion Rate Method
2016	Membrane Integrity Survey Method
2030	Chloride Content Test
2032	Bridge Condition Evaluation Manual
2033	Manual on Chloride Removal
2034	Cathodic Protection Manual
2035	Manual on Rapid Repair of Bridge Decks
2036	Field Guide on Bridge Rehab and Protection Options
2037	Manual for Selecting Bridge Rehab and Protection Options
2038	Computer Program for Bridge Rehab and Protection Options

2040	Guidelines for Cathodic Protection
4003	Monitoring Cathodic Protection
4009	Repairing Marine Structures

Highway Operations

3001	Snow Fence Guide
3008	Ultrasonic Intrusion Alarm
3009	Queue-Length Detector
3010	Infrared Intrusion Alarm
3011	Opposing Traffic Lane Divider
3012	Multidirectional Barricade-Sign
3013	Remotely Driven Vehicle
3014	Portable Crash Cushion
3015	Portable Rumble Strip
3016	Flashing Stop/Slow Paddle
3017	Portable All-Terrain Sign Stand
3020	Handbook on Deicer Test Methods
3021	Salt Spreader TMA
3023	Guide for Road Weather Information Systems
3024	Anti-Icing Operations Guide
3025	Snow Fence Engineering Design Manual
3030	Anti-Icing Equipment Evaluation
3031	Anti-Icing Application Rates
3032	Anti-Icing Chemical Evaluation
4006	Customized Weather Prediction System

Pavement Engineering

5001	LTPP Information Management Systems (IMS)
5034	Traffic Monitoring Data Reduction Software
5035	LTPP Traffic Monitoring Database
5040	IMS Microcomputer Version

2. The SHRP asphalt binder specifications may require some changes in PG selection criteria to reflect the lower durability of heavy-duty airfield pavements. The SHRP PG of asphalts as written is a significant advancement over current FAA asphalt binder selection criteria. However, the PG system must be used with caution when applied to polymer-modified asphalts (PMA).

3. The SHRP asphalt mix design system (Level I) will require some adjustments for application to the FAA. Some aggregate gradations meeting FAA specifications may not meet the SHRP gradation specifications or the VMA criteria. For the aggregate materials and gradations used in this study, the compaction level to achieve equivalent asphalt contents of the SHRP gyratory compactor and the 50-blow Marshall hammer occurs near $N_{Design} = 49$ and for the 75-blow at $N_{Design} = 117$.

4. The SHRP VMA criteria are difficult to meet at the highest compaction levels recommended by SHRP. The VMA criterion of 14.0% at N_{Design} = 143 for 12.5 nominal aggregate size was barely met and was achieved by lowering the amount of fines in the aggregate blend.

5. The FAA aggregate gradations employed in this study may not meet the SHRP compaction criteria of G_{mm} < 89% at $N_{Initial}$. Given the history of solid performance of FAA asphalt mixtures, this is of minor concern.

6. The SHRP thermal characterization asphalt mixture tests TSRST, SHRP 1021, and Indirect Tensile Creep and Failure Test, SHRP 1022) can be applied directly to FAA pavements as these technologies are not load related.

7. The SHRP mixture design procedure has been demonstrated to produce heavy-duty asphalt mixtures having properties similar to those produced by FAA design procedures, and vice-versa, as measured by SHRP performance-related mixture tests. No significant difference between SHRP and FAA mixtures were measured in any of the performance-related testing. The data set for the thermal stress restrained specimen test was incomplete due to a number of problems encountered in the testing.

8. The SHRP repeated simple shear test at constant height and flexural beam fatigue testing procedures have application to the FAA for identifying asphalt mixes that may experience rutting and fatigue problems. These tests are not designed for aircraft loads or multiple-wheel gear configurations, but can be used to provide comparative information on the performance-related properties of airfield mixtures.

9. The SHRP asphalt performance predictions models are no longer being recommended for use. Numerous technical problems surfaced during validation of the models. Thus, Level II and Level III mixture designs are no longer available.

10. The SHRP products regarding anti-icing chemicals have been rated as not applicable. Many of these technologies for highways utilize corrosive salts and are unacceptable for use on airfields. However, there are aspects of this work that may be of some use for airfield personnel involved in deicing technology.

RECOMMENDATIONS.

1. The use of SHRP products rated as directly applicable can be used as is for FAA pavements technology. Products rated as applicable with minor modifications can be used, but will require some judgement on the part of the user as to the type and extent of changes necessary. Products rated as applicable with major modifications should not be used for FAA pavements.

2. The SHRP asphalt binder specifications should be adopted for use in FAA pavements. Although rated as applicable with minor modifications, the specification, as written, represents a considerable advancement in binder selection technology over current methods of viscosity and/or penetration grading. Until further data are available, choosing a

conservative approach to binder selection using SHRP PG binder specifications is prudent. A minimum of the upper limit specified for *G*/sin δ* in a highway pavement may not provide sufficient stiffness for permanent deformation resistance on heavy-duty airfields due to the higher loads. Airfield pavements generally contain less binder than a typical highway pavement and are more susceptible to durability problems (primarily aging and thermal cracking). More rigorous durability criteria for airfield mixtures are probably warranted. However, changes to the specification values are not absolutely necessary because use of different PG binder would accomplish the same goal. For instance, if a PG 64-22 binder is recommended for highway pavement, use of a PG 70-28 should provide increased protection against rutting, aging, and thermal cracking without changing the values of the specification parameters. The use of SHRP PG with polymer-modified asphalts continues to be a complex issue. Generally, The SHRP PG system is applicable to polymer-modified asphalt binders, however, some binders display complex rheological behavior that invalidate the SHRP grading system. In any case, for polymer-modified asphalt binders, the low temperature grade must be based on the 1% failure strain criteria from the direct tension test and not on BBR parameters alone.

3. The SHRP asphalt mixture protocols as currently written (March 1997) should not be adopted by the FAA at this time. However, these procedures have been shown to produce heavy-duty asphalt mixtures with properties similar to those produced by FAA design procedures. Current aggregate gradations specified in FAA AC 150/5370-10A Item P-401 may not meet minimum compaction, VMA, or Fines/Effective Asphalt ratio. The SHRP compaction efforts are based on numerous levels of highway traffic in ESALs that are not directly applicable to airfield design. For the materials and gradations used in this work, SHRP compaction efforts that yield equivalent asphalt contents with the 50- and 75-blow Marshall hammer design were found to be N_{Design} = 49 and N_{Design} =117, respectively. Currently, there are no provisions for measurement of mixture physical properties (similar to Marshall Stability and Flow) after a SHRP volumetric design, although this is being addressed in further research funded by FHWA. This could be overcome through the use of RSST-CH, FBFT, and TSRST. The use of SHRP mixture design technology to generate heavy-duty asphalt mixtures for the FAA is certainly feasible, but will require changes to volumetric specifications to adapt to current FAA mixture gradations.

4. It is highly recommended that the FAA explore the possibility of improved durability of airfield mixtures using PMA. Numerous studies of highway pavements have demonstrated the ability of PMA to improve the rutting resistance of asphalt mixtures. However, little data is available on the durability properties (i.e. thermal cracking resistance, age embrittlement, fatigue, and water damage) of polymer-modified heavy-duty airfield mixtures. Given that environmental damage to airfield pavements is by far the primary factor determining pavement condition, substantial savings could be realized through lower life cycle costs by improving the durability and service life.

REFERENCES

American Association of State Highway and Transportation Officials (AASHTO). 1995. *Standard Specifications for Transportation Materials and Methods of Sampling and Test* , 17th ed.

American Association of State Highway and Transportation Officials (AASHTO) June 1996 Edition Provisional Standards.

Advisory Circular 150/5370-10A, "Standards for Specifying Construction of Airports," U.S. Department of Transportation, Federal Aviation Administration, 1994.

Ahlrich, R.C., "Influence of Aggregate Gradation and Particle Shape/Texture on Permanent Deformation of Hot Mix Asphalt Pavements," Technical Report GL-96-1, US Army Corps of Engineers Waterways Experiment Station, 1996.

American Society for Testing Materials (ASTM). 1996. *Annual book of ASTM Standards*. ASTM D 3381-92, Philadelphia, PA.

a. ASTM C131, "Standard Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine."

b. ASTM C 1252, "Standard Test Methods for Uncompacted Void Content of Fine Aggregate (As Influenced by Particle Shape, Surface Texture, and Grading)."

c. ASTM D 3381, "Standard Specification for Viscosity-Graded Asphalt Cement for Use in Pavement Construction."

Brown, E.R. and Foo, K.Y., "Comparison of Unconfined and Confined Creep Tests for Hot Mix Asphalt," ASCE Journal for Materials in Civil Engineering 6 (2), 1994.

Deacon, J.A., S. Coplantz, A.A. Tayebali, and C.L. Monismith, "Temperature Considerations in Asphalt-Aggregate Mixture Analysis and Design," TRR 1454, 97 (1994).

Deacon, J.A., Leahy, R.B., and Monismith, C.L., "Mix Testing and Analysis Systems Resulting From SHRP Contract A-003A," Transportation Congress, American Society of Civil Engineers, Volume 1, 691, 1995.

EBA Engineering Consultants Ltd., "SHRP PG Binder and SUPERPAVE® Level I Mix Design Investigation, Laboratory Testing, and Analysis: PART I SHRP PG Binder Specification for Airports," Final Report, Public Works and Government Services Canada Report no. 104-97-21155.01, March 1997.

Harvey, J. and Monismith, C.L., "Effects of Laboratory Asphalt Concrete Specimen Preparation Variables on Fatigue and Permanent Deformation Test Results Using Strategic Highway Research Program A-003A Proposed Testing Equipment," TR 1417, 38, 1994.

Harvey, J., Eriksen, K., Sousa, J. and Monismith, C.L., "Effects of Laboratory Specimen Preparation on Aggregate-Asphalt Structure, Air-Void Content Measurement, and Repetitive Simple Shear Test Results," TRR 1454, 113, 1994.

Harvey, J., Lee, T., Sousa, J., Pak, J., and Monismith, C.L., "Evaluation of Fatigue and Permanent Deformation Properties of Several Asphalt-Aggregate Field Mixes Using Strategic Highway Research Program A-003A Equipment," TRR 1454, 123, 1994.

Harvey, J., Deacon, J.A., Tsai, B., and Monismith, C.L., "Fatigue Performance of Asphalt Concrete Mixes and its Relationship to Asphalt Concrete Pavement Performance in California," California Department of Transportation, Report No. RTA-65W485-2, October, 1995.

Harvey, J., Vallerga, B.A., and Monismith, C.L., "Mix Design Methodology for a Warrantied Pavement: Case Study," TRR 1492, 184, 1995.

Harvey, J.T., Deacon, J.A., Tayebali, A.A., Leahy, R.B., and Monismith, C.L., "A Reliability-Based Mix Design and Analysis System for Mitigating Fatigue Distress," Eighth International Conference on Asphalt Pavements, Seattle, Washington, August, 1997.

Harvey, J. and Tsai, B., "Long-Term Oven Aging Effects on Fatigue and Initial Stiffness of Asphalt Concrete," Transportation Research Board Preprint 970332, 76th Annual Meeting, Washington, DC, January 12-16, 1997.

Mallick, R.B., Ahlrich, R.C., and Brown, E.R., "Potential of Dynamic Creep to Predict Rutting," American Society of Testing and Materials STP 1265, Philadelphia, PA, 1994.

Matthews, J.M, Monismith, C.L., and Craus, J., "Investigation of Laboratory Fatigue Testing Procedures for Asphalt Aggregate Testing," J. Trans. Eng. 119, 634, 1993.

Scholz, T.V., Allen, W.L., Terrel, R.L., and Hicks, R.G., "Preparation of Asphalt Concrete Test Specimens Using Rolling Wheel Compaction," TRR 1417, 150, 1994.

Strategic Highway Research Program (SHRP). 1993-94. National Research Council, Washington, DC.

a. Anderson, D. A., Bahia, H., Christensen, D. W., Dongre, R., Sharma, M. G., and Antle, C. E. 1994. "Binder Characterization and Evaluation—Volume 3: Physical Characterization," SHRP-A-369.

b. Austin Research Engineers, Inc., and SWK Pavement Engineering, 1994. "Stage I Validation of the Relationship Between Asphalt Properties and Asphalt-Aggregate Mix Performance," SHRP-A-398. University of California at Berkeley, Oregon State University, Berkely, CA.

c. Bell, C. A., Weider, A., and Fellin, M., "Laboratory Aging of Asphalt Aggregate Mixtures: Field Validation," SHRP-A-390, Strategic Highway Research Program, National Research Council, Washington, DC, 1990.

d. Bell, C. A., and Sosnovske, D., 1994. "Selection of Laboratory Aging of Asphalt-Aggregate Mixtures," SHRP-A-383.

e. Cominsky, R. J., Huber, G. A., Kennedy, T. W., and Anderson, M., 1994. "The SUPERPAVE® Mix Design Manual for New Construction and Overlays," SHRP-A-407.

f. Cominsky, R., Leahy, R. B., and Harrigan, E. T., 1994. "Level One Mix Design: Materials Selection, Compaction, and Conditioning," SHRP-A-408.

g. Curtis, C. W., Ensley, K., and Epps, J., 1993. "Fundamental Properties of Asphalt-Aggregate Interactions Including Adhesion and Absorption," SHRP-A-341.

h. Harrigan, E. T., Leahy, R. B., and Youtcheff, J. S., 1994. "Superpave Manual of Specifications, Test Methods and Practices," SHRP-A-379.

i. Institute of Transportation Studies, 1994. "Permanent Deformation Response of Asphalt-Aggregate Response," SHRP-A-415. University of California at Berkeley.

j. Institute of Transportation Studies, 1994. "Accelerated Performance-Related Tests for Asphalt-Aggregate Mixes and Their Use in Mix Design and Analysis Systems," SHRP-A-417. University of California at Berkeley.

k. Institute for Transportation Studies, 1994. "Fatigue Response of Asphalt-Aggregate Mixes," SHRP-A-404. University of California at Berkeley.

l. Jung, D. H., and Vinson, T. S., 1993. "Low-Temperature Cracking: Binder Validation," SHRP-A-399.

m. Jung, D. H., and Vinson, T. S., 1993. "Low Temperature Cracking: Test Selection," SHRP-A-400.

n. Kanerva, H. K., Vinson, T. S., and Zeng, H., 1993. "Low Temperature Cracking: Field Validation of the Thermal Stress Restrained Specimen Test," SHRP-A-401.

o. Kennedy, T. W., Huber, G. A., and Harrigan, W. T., 1994. "Superior Performing Asphalt Pavements (SUPERPAVE®): The Product of the SHRP Asphalt Research Program," SHRP-A-410.

p. Leahy, R. B., Harrigan, E. T., and von Quintus, H. 1994. "Validation of Relationships Between Specification Properties and Performance," SHRP-A-409.

q. Lytton, R. L., Uzan, J., Fernando, E. G., Roque, R., Hiltunen, D., and Stoffels, S. 1993. “Development and Validation of Performance Prediction Models and Specifications for Asphalt Binders and Paving Mixes,” SHRP-A-357.

r. Petersen, J. C., Robertson, R. E., Branthaver, J. F., Harnsbarger, P. M., Duvall, J. J., and Kim, S. S., 1994. “Binder Characterization and Evaluation—Volume 4: Test Methods,” SHRP-A-370.

s. Sousa, J.B., Craus, J., and Monismith, C.L., 1991. “Summary Report on Permanent Deformation in Asphalt Concrete,” SHRP-A/IR-91-104.

t. Terrel, R. L., and Al-Swailmi, S., 1994. “Water sensitivity of asphalt-aggregate mixes: Test selection,” SHRP-A-403.

u. Vinson, T., Janoo, V., and Haas, R., 1990. “Summary Report on Low Temperature and Thermal Fatigue Cracking,” SHRP-A-306 or SHRP-A/IR-90-001.

Sousa, J.B., Harvey, J., Painter, L., Deacon, J.A., and Monismith, C.L., “Evaluation of Laboratory Procedures for Compacting Asphalt-Aggregate Mixtures,” TM-UCB-A-003A-90-5, Strategic Highway Research Program, National Research Council, Washington, DC, 1990.

Tangella, R., Craus, J., Deacon, J.A., and Monismith, C.L.,”Summary Report of Fatigue Response of Asphalt Mixtures,” TM-UCB-A-003A-89-3M, Institute of Transportation Studies, University of California, Berkeley, 1990.

Vinson, T., Zubeck, H., and Zeng, H., “Field Validation of the Thermal Stress Restrained Specimen Test—Six Case Histories,” Preprint #960888, Transportation Research Board, 1996.

Vinson, T. and Zubeck, H., “Prediction of Low Temperature Cracking of Asphalt Concrete Mixtures With the Thermal Stress Restrained Specimen Test,” Preprint #960881, Transportation Research Board, 1996.

APPENDIX A—STRATEGIC HIGHWAY RESEARCH PROGRAM ASPHALT PRODUCT REVIEWS

SHRP PRODUCT FACT SHEET

PRODUCT NUMBER: 1001

PRODUCT TITLE: Binder Specification

REPORT NUMBER(S) AND TITLE(S):

SHRP-A-379: SUPERPAVE™ Manual of Specifications, Test Methods and Practices

SHRP-A-367: Binder Characterization and Evaluation—Volume 1

SHRP-A-368: Binder Characterization and Evaluation—Volume 2

SHRP-A-369: Binder Characterization and Evaluation—Volume 3

SHRP-A-370: Binder Characterization and Evaluation—Volume 4

SHRP-A-384: Aging: Binder Validation

SHRP-A-630: Advanced High-Performance Gel Permeation Chromatography Methodology

SHRP-A-631: Review of Relationships Between Modified Asphalt Properties and Pavement Performance

SHRP-A-645: SHRP Materials Reference Library: Asphalt Cements: A Concise Data Compilation

SHRP-A/UIR-91-503: HP-GPC and Asphalt Characterization and Literature Review

SHRP-A/UIR-91-509: SHRP Materials Reference Library Aggregates: Chemical, Mineralogical, and Sorption Analyses

SHRP-A/UIR-91-510: Chemical Properties of Asphalts and Their Relationships to Pavement Performance

SHRP-A/UIR-91-525: Validation in the SHRP Asphalt Research Program (October 1991)

SHRP-A-612: A Differential Scanning Calorimetry Study of Asphalt Binders

SHRP-A-623: Review of State and Industry Reports on Asphalt Properties and Relationship to Pavement Performance

SHRP-A-626: Bibliographies for Physical Properties of Asphalt Cements

(Sheet 1 of 4)

SHRP-A-646: The SHRP Materials Reference Library

SHRP-A-649: Fluorometric Characterization of Asphalts

SHRP CATEGORY: Asphalt

APPLICABILITY RATING: Applicable with Minor Modifications

OBJECTIVE: To provide a specification for the selection of asphalt binder that minimizes permanent deformation, fatigue, and thermal cracking potential of an asphalt mix. Selection criteria for highway pavements include geographic area, traffic density, and rate of loading.

DESCRIPTION: The binder is graded according to a range of temperatures through which the material has been demonstrated by field validation to perform at an acceptable level for highway pavements. For example, a PG 64-22 asphalt refers to a binder that is acceptable from a maximum pavement temperature of 64°C to a minimum of -22°C.

In designing a mix for an asphalt paving job using the SHRP specifications, the first step is to determine the design temperature range for a particular geographic location. This is accomplished using the weather database which contains the temperatures and related information for determining the maximum 7-day pavement temperature and the minimum pavement temperature from air temperatures stored in the climatic database. The weather database is available in the SUPERPAVE™ software and in a more user-friendly format in the SHRPBIND program available from the FHWA. The pavement temperatures are given in 6-°C increments. This results from a typical standard deviation of 2°C, approximately the mean pavement temperature. For example, if the mean maximum pavement temperature is 58°C, there is a 69 percent probability the pavement temperature will not exceed 59°C during the year (one half the standard deviation above the mean). At 64°C (three standard deviations above the mean), there is a greater than 99.9 percent probability that the temperature will not exceed 64°C. Therefore, if the maximum 7-day temperature for a given location has a mean of 58°C, by selection of a binder that is graded for 64°C, there is a greater than 99.9 percent probability that this selection would be adequate. A similar scheme can be performed for the minimum pavement temperature.

$$T_{\min} = 0.0859 T_{air} + 1.7°C$$

In March, 1997, a modification to the low pavement design temperature was made. Pavement temperatures are generally slightly warmer than the air surrounding the pavement, and this is reflected in the new design equation. Formerly, the yearly 1-day minimum air temperature for a given locale was used as the low pavement temperature, but this has been proven to be inaccurate. The new procedure uses the lowest air temperature to estimate the low pavement temperature.

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A performance grade (PG) of PG 64-22 will be used to illustrate the use of binder specifications. The asphalt must meet a minimum flash point of 230°C to ensure that the material will not be hazardous during mixing; a maximum rotational viscosity of 3 Pa·sec at 135°C ensures pumpability; and, using a dynamic shear rheometer, a minimum of 1.00 kPa for $G^*/\sin\delta$ at 10 rad/sec and 64°C to eliminate susceptibility to tenderness before Rolling Thin-Film Oven Test (RTFOT) aging. The asphalt is subjected to the RTFOT and must have a minimum of 2.20 kPa for $G^*/\sin\delta$ at 10 rad/sec and 64°C to ensure a minimum level of permanent deformation resistance immediately after placement.

Accelerated aging is conducted on the RTFO-conditioned binder by subjecting the material to the Pressure Aging Vessel (PAV) test (100EC for a PG64 asphalt). After aging, the maximum value allowed for $G^* \sin\delta$ at 25EC (for a PG64-22) is 5,000 kPa. This limit prevents binders that have excessive age hardening properties from contributing to fatigue cracking in a 5- to 10-year period.

The low-temperature properties are determined on the aged material using the bending beam rheometer (BBR) and the direct tension device (DT). For the BBR, the maximum stiffness allowed at -18°C (for a PG64-22) is 300 MPa with a minimum slope of 0.3. These specifications disallow binders with excessive stiffness and poor flow characteristics at low temperatures. The DT is not a required test but can be performed if the stiffness of the binder in the BBR test is between 300 and 600 MPa but the slope is above 0.3. Some modified binders may exhibit higher stiffness than 300 MPa but slopes of less than 0.3. A PG64-22 binder must display a minimum of 1 percent failure strain at -18°C.

CRITICAL EVALUATION:

This specification, without modification, would represent an improvement over the current method of binder selection in use by the FAA.

The binder specification is an important step for selection of materials with specific laboratory-measured properties based on field performance of highway pavements. Asphalt concrete mixtures for airfields often contain a slightly lower asphalt content than a typical highway mixture to obtain the stiffness properties necessary for heavier aircraft loads. Depending upon aggregate gradation, this can result in a thinner film of asphalt coating on the aggregate, affecting stress development during thermal cycling and durability properties. The current method of binder selection in use by the FAA contains no criteria for evaluation of binders of embrittlement caused by aging nor thermal cracking at low temperatures.

In addition, asphalt producers will soon begin to offer multiple SHRP asphalt grades and gradually phase out the viscosity/penetration grading system.

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APPLICABILITY ISSUES: The binder specifications should be applicable for the selection of binder for airfield asphalt mixtures. However, differences in airfield loads, thermal cracking potential, and aging characteristics for airfield mixtures versus highway mixtures should be addressed to determine if more rigid selection criteria for airfield binders are necessary. Rather than changing the specification values, the use of more conservative binder performance grades than suggested for a highway pavement in a given locale will accomplish the same goal.

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	1002
PRODUCT TITLE:	Bending Beam Rheometer
REPORT NUMBER(S) AND TITLE(S):	SHRP-A-367: Binder Characterization and Evaluation - Volume 1 SHRP-A-368: Binder Characterization and Evaluation - Volume 2 SHRP-A-369: Binder Characterization and Evaluation - Volume 3 SHRP-A-370: Binder Characterization and Evaluation - Volume 4 SHRP-A-626: Bibliographies for Physical Properties of Asphalt Cements
SHRP CATEGORY:	Asphalt
APPLICABILITY RATING:	Directly Applicable
OBJECTIVE:	To provide a test method for the evaluation of the creep stiffness and creep rate properties of asphalt cements at low temperatures.
DESCRIPTION:	A three-point bending test is conducted on a beam of PAV-aged asphalt cement with dimensions 102 mm by 6.4 mm by 12.75 mm immersed in a constant-temperature fluid bath. The test temperatures range from 0 to -36°C in 6-°C increments. The applied load (100 g) and the deflection of the beam are measured for a period of 240 sec before removing the load. A curve of log stiffness with log time is fit to a polynomial equation using least-squares regression. The measured and the calculated values for stiffness at 8, 15, 30, 60, 120, and 240 sec are compared. The regression and correlation coefficients of the fitted curve are also given in the printout. The values used for the SHRP specification are the slope m and stiffness calculated from the regression curve at 60 sec.
CRITICAL EVALUATION:	A significant finding of the initial SHRP research with validation of the premise that viscoelastic properties of binders control the thermal cracking properties of unmodified asphalt mixtures. This test method measures the low-temperature creep properties of the asphalt cement which have been related to the degree of thermal cracking experienced in highway pavement test

(Sheet 1 of 2)

sections. Often airfield pavements contain significantly less binder than a typical highway pavement to obtain a stiffer mix necessary for handling large aircraft loads, resulting in mixes that may be more susceptible to thermal cracking. Correlations between stiffness and thermal fracture properties of polymer-modified asphalts have not been validated. Thus, caution should be applied when using BBR results of modified asphalts as a predictor of thermal cracking propensity.

APPLICABILITY ISSUES:

Heavy-duty airfield pavements often contain less binder compared to a highway pavement and often result in less durable pavements due to thinner asphalt films on aggregate particles. The specifications of 300 MPa stiffness and an *m*-value of 0.3 for the PAV-aged binder may not be sufficient for mitigation of thermal cracking in an airfield mix. However, this may be addressed by choosing a different PG binder for an airfield pavement compared to a highway pavement rather than changing the BBR specification values.

(Sheet 2 of 2)

SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	1003
PRODUCT TITLE:	Pressure Aging of Binders
REPORT NUMBER(S) AND TITLE(S):	SHRP-A-384: Aging: Binder Validation SHRP-A-305: Summary Report on the Aging of Asphalt-Aggregate Systems SHRP-A-367: Binder Characterization and Evaluation - Volume 1 SHRP-A-368: Binder Characterization and Evaluation - Volume 2 SHRP-A-369: Binder Characterization and Evaluation - Volume 3 SHRP-A-370: Binder Characterization and Evaluation - Volume 4 SHRP-A-626: Bibliographies for Physical Properties of Asphalt Cements
SHRP CATEGORY:	Asphalt
APPLICABILITY RATING:	Directly Applicable
OBJECTIVE:	To provide a test method for accelerated oxidative aging of asphalt binders that simulates the in-service asphalt binder condition after several years of field service.
DESCRIPTION:	Increased pressure and temperature are used to accelerate the oxidative aging process in the binder that occurs naturally with time in compacted asphalt mixtures. A stainless-steel vessel capable of withstanding up to 2.068 Mpa internal pressure of compressed air at temperatures up to 110°C is employed to accelerate the aging process. Up to 10 thin-film oven pans containing a 6.2-mm film of asphalt binder (approximately 50 g) are placed in the pressure vessel. The vessel is allowed to equilibrate to the test temperature, and the pressure is rapidly advanced to 2.068 MPa. The pressure is maintained in the vessel at 2.068 MPa for 20 hr before slow release.
CRITICAL EVALUATION:	The test has been shown to simulate between 5 and 10 years of highway pavement service depending on the geographic location. Pavements in hot desert climates age faster than other climates.

(Sheet 1 of 2)

APPLICABILITY
ISSUES:

Aging in heavy-duty airfield pavements is often accelerated compared to highway pavements due to a thinner film of asphalt coating the aggregates. Thus, more stringent aging requirements may be necessary for binders used on airfield pavements.

(Sheet 2 of 2)

SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	1004
PRODUCT TITLE:	Asphalt Extraction and Recovery
REPORT NUMBER(S) AND TITLE(S):	SHRP-A-368: Binder Characterization and Evaluation - Volume 2
SHRP CATEGORY:	Asphalt
APPLICABILITY RATING:	Directly Applicable
OBJECTIVE:	To provide a method for the quantitative extraction of asphalt from an asphalt-aggregate mixture without changing the properties of the extracted asphalt.
DESCRIPTION:	The asphalt binder is extracted from an asphalt concrete sample using a mixture of toluene and ethanol. The method is designed to yield quantitative extraction of the asphalt binder from the asphalt concrete. This extraction method is not to be used for analysis of sieve properties of the aggregate. The asphalt concrete sample is warmed at 110°C if necessary to break up the sample before extraction. The procedure is designed to yield approximately 50 to 60 g of asphalt binder from a sample of asphalt cement depending on the asphalt content. A special extraction vessel is employed for holding the sample during the extraction process. The sample is repeatedly washed with extraction solvent. The filtrate is transferred to a vacuum evaporator where the solvent is removed, preventing overheating of the extract during solvent removal. Nitrogen gas is employed in the latter stages of the extraction to drive off any remaining solvent and to prevent thermal degradation of the extract.
CRITICAL EVALUATION:	The method can be employed directly for the extraction of asphalt binder from airfield asphalt concrete samples without modification. This extraction method is not to be used for analysis of sieve properties of the aggregate due to the tendency of aggregate to be fractured during the extraction process.
APPLICABILITY ISSUES:	None

(Sheet 1 of 1)

SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	1005
PRODUCT TITLE:	Low-Temperature Direct Tension Test
REPORT NUMBER(S) AND TITLE(S):	SHRP-A-367: Binder Characterization and Evaluation - Volume 1 SHRP-A-369: Binder Characterization and Evaluation - Volume 3 SHRP-A-370: Binder Characterization and Evaluation - Volume 4 SHRP-A-626: Bibliographies for Physical Properties of Asphalt Cements SHRP-A-641: Direct Tension Test Experiments
SHRP CATEGORY:	Asphalt
APPLICABILITY RATING:	Directly Applicable
OBJECTIVE:	To provide a test method for determining the susceptibility of asphalt binders to low-temperature cracking.
DESCRIPTION:	This test method applies tension directly to an asphalt binder specimen to determine the failure stress and strain of an asphalt binder sample in the range from -40 to 25°C. "A dog-bone" type of test sample is prepared and mounted in specially designed sample holders. The specimen is elongated at a rate of 1 mm/min and the stress and strain are measured until failure. The specific test temperatures are determined from the binder specification. The test is conducted on PAV-aged binders and the required minimum failure strain is 1 percent. Generally, the direct tension test is not employed but is performed for modified binders that exhibit stiffness values above the SHRP specification limit of 300 MPa and *m* values less than 0.3.
CRITICAL EVALUATION:	The method can be employed directly for the examination of both neat and polymer-modified asphalt binders for determining their thermal fracture properties at low temperatures. This test has been validated to identify unmodified binders that exhibit thermal cracking problems in highway pavements. Airfield pavements are often more susceptible to thermal cracking than highway pavements.

(Sheet 1 of 2)

APPLICABILITY ISSUES: The specific values of the criteria may need to be addressed for airfield pavements. Lower binder contents often result in less durable pavements due to thinner asphalt films on aggregate particles. The specifications of 1 percent strain at 1 mm/min strain rate, the PAV-aged binder may not be sufficient for mitigation of thermal cracking in an airfield mix. However, this may be addressed by choosing a different PG binder for an airfield pavement compared to a highway pavement rather than changing the direct tension specification values.

(Sheet 2 of 2)

SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	1006
PRODUCT TITLE:	High-Temperature Viscosity Test
REPORT NUMBER(S) AND TITLE(S):	SHRP-A-369: Binder Characterization and Evaluation - Volume 3 SHRP-A-626: Bibliographies for Physical Properties of Asphalt Cements
SHRP CATEGORY:	Asphalt
APPLICABILITY RATING:	Directly Applicable
OBJECTIVE:	To provide a test method for determining the high-temperature viscosity properties of an asphalt binder.
DESCRIPTION:	This test method requires a commercially available test device (such as a Brookfield viscometer) for determining the viscosity of an asphalt binder at 135°C. This test has been introduced because of the problems associated with determination of the viscosity of modified binders by conventional capillary methods. Shear thinning of polymer-modified binders and inconsistencies in measurements on crumb-rubber modified binders using capillary techniques are overcome using a rotational viscometer. For specification purposes, a maximum viscosity of 3 Pa/sec is allowed. This ensures that the pumping requirements of the asphalt binder at the mixing plant are adequate.
CRITICAL EVALUATION:	The method can be employed directly for the examination of asphalt binders for determining their flow properties at high temperatures. It can be applied to both neat and polymer-modified asphalts.
APPLICABILITY ISSUES:	None

(Sheet 1 of 1)

SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	1007
PRODUCT TITLE:	Dynamic Shear Rheometer
REPORT NUMBER(S) AND TITLE(S):	SHRP-A-369: Binder Characterization and Evaluation - Volume 3 SHRP-A-626: Bibliographies for Physical Properties of Asphalt Cements
SHRP CATEGORY:	Asphalt
APPLICABILITY RATING:	Directly Applicable
OBJECTIVE:	To provide a test method for determining the viscoelastic (elastic and viscous) components of the binder stiffness as a function of temperature and frequency of the applied load.
DESCRIPTION:	This test method determines the complex modulus characteristics of an asphalt binder to identify binders that may contribute to rutting and/or exhibit extreme age hardening that contributes to fatigue. The method requires precise temperature control (± 0.1°C) at an applied frequency of 10 rad/sec (approximately 1.59 Hz). The asphalt binder sample is placed between two parallel plates and a sinusoidal load applied to one plate. The response of the sample is measured as a torque. The time lag (or phase angle δ) between the peak of the applied load and the peak response of the sample is also measured. This allows the elastic (G') and viscous (G") stiffness components of the complex shear modulus to be resolved. These properties have been related to the rutting and fatigue properties of asphalt binders. The specification tests are conducted at temperatures ranging from 46 to 82°C in increments of 6°C. The specifications for this test are determined with three samples: unaged (virgin) , RTFO-conditioned (Rolling Thin Film Oven), and PAV-aged (Pressure Aging Vessel) binder specimens. The rationale of sampling the unaged and RTFO-conditioned material is to reject any binders that may show tenderness or rutting tendencies. In this case, a minimum specified value for $G^*/\sin\delta$ of 1.0 kPa for the unaged or tank binders is required and 2.2 kPa for the RTFO-conditioned material. For the PAV-aged material, a maximum value for $G^*\sin\delta$ of 5.0 MPa is required.

(Sheet 1 of 2)

CRITICAL EVALUATION:

The method can be employed directly in the examination of asphalt binders for determining their complex modulus over a wide range of temperatures and frequencies. The correlations between G*/sin δ and rut depth were poor in the SHRP validation tests, indicating that the aggregate structure is the primary load-bearing component. However, it is generally accepted that low modulus characteristics of the binder will contribute to permanent deformation if aggregate characteristics or compaction are poor. Although fatigue cracking of asphalt concretes in airfield pavements is generally not a major problem, the upper limit of G*sin δ helps to reject binders that may exhibit severe embrittlement with age. SHRP validation testing revealed a good correlation between G*sin δ and fatigue life.

APPLICABILITY ISSUES:

Heavy-duty airfield pavements often contain less binder compared to a highway pavement and often result in less durable pavements due to thinner asphalt films on aggregate particles. The specification values for the DSR properties of asphalt binders may not be sufficient to reduce rutting and fatigue due to the much higher loads experienced by airfield pavements. However, this may be addressed by choosing a different PG binder for an airfield pavement compared to a highway pavement rather than changing the DSR specification values.

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	1009
PRODUCT TITLE:	Binder Chromatography
REPORT NUMBER(S) AND TITLE(S):	SHRP-A-301: Asphalt - A Strategic Plan - 1990
	SHRP-A-313: Binder Characterization and Evaluation - Volume 2
	SHRP-A-335: Binder Characterization and Evaluation by Nuclear Magnetic Resonance Spectroscopy
	SHRP-A-368: Binder Characterization and Evaluation - Volume 2
	SHRP-A/UIR-91-503: HP-GPC and Asphalt Characterization and Literature Review
	SHRP-A/UIR-91-510: Chemical Properties of Asphalts and Their Relationships to Pavement Performance
	SHRP-A-663: Size Exclusion Chromatography and Ion Exchange Chromatography
	SHRP-A-630: Advanced High-Performance Gel Permeation Chromatography
SHRP CATEGORY:	Asphalt
APPLICABILITY RATING:	Directly Applicable
OBJECTIVE:	To provide a method for the determination of the gel permeation and ion-exchange chromatographic profiles of an asphalt binder.
DESCRIPTION:	Methods for the determination of both the gel permeation and ion-exchange chromatographic characteristics of asphalt binders are presented. The methods describe the selection of appropriate columns, solvents, and test conditions for conducting the tests. These steps are necessary to ensure the accuracy and precision of the testing procedures when conducted at different laboratories.
	Gel Permeation Chromatography (GPC) is a method developed for determining the hydrodynamic size of molecular species dissolved in a solvent. The technique has been widely employed in polymer science for determining molecular weights of polymers. The technique as applied to asphalts cannot yield molecular weights of asphalt species but provides information on the molecular size of

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asphalt components that can be related to some aspects of performance such as permanent deformation. A standard test method employing the same column types and sample preparation must be employed between laboratories to ensure consistent results.

Ion-Exchange Chromatography (IEC) separates molecular species based on their affinity for various functional groups immobilized on a solvent swollen polymer matrix. If a basic column is employed, acidic components that interact with the immobilized basic groups are retained on the column. If an acidic column is employed, the basic components are retained. If both acidic and basic groups are present on the column, then only those molecular species that are neutral in polarity and not interacting with the column can pass through the matrix. This provides a method for separating asphalt components based on their polarity.

Differences in asphalt chemistry based on crude source can be evaluated as well as the changes occurring in the asphalt binder caused by oxidative aging.

CRITICAL EVALUATION: This test method can be employed for the analysis of asphalt binders employed in airfield paving applications but is not a part of the SHRP binder specification. These techniques are employed almost exclusively for research purposes.

APPLICABILITY ISSUES: None

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	1010
PRODUCT TITLE:	Refiner's Guide
REPORT NUMBER(S) AND TITLE(S):	SHRP-A-686: Guideline for Asphalt Refiners and Suppliers
SHRP CATEGORY:	Asphalt
APPLICABILITY RATING:	Not Applicable
OBJECTIVE:	To provide guidelines and descriptions of the SHRP specifications and the impact on asphalt refiners and suppliers.
DESCRIPTION:	Descriptions of the SHRP specifications for binders and the SUPERPAVE™ mix design system are provided for refiners and suppliers of asphalts. Methods for grading the binders are discussed and means of estimating the performance grade of the binder from conventional asphalt tests are discussed.
CRITICAL EVALUATION:	This product is intended for asphalt producers to provide guidelines for the SHRP PG grading system and has no direct application to FAA pavements technology.
APPLICABILITY ISSUES:	None

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	1011
PRODUCT TITLE:	Mixture Specification
REPORT NUMBER(S) AND TITLE(S):	SHRP-A-404: Fatigue Response of Asphalt-Aggregate Mixes, 1994 SHRP-A-407: The SUPERPAVE™ Mix Design Manual for New Construction and Overlays, Strategic Highway Research Program, National Research Council, Washington, D.C. 1994. SHRP-A-408: Level One Mix Design: Materials Selection, Compaction, and Conditioning, 1994 SHRP-A-410: Superior Performing Asphalt Pavements (SUPERPAVE™): The Product of the SHRP Asphalt Research Program, 1994 SHRP-A-415: Permanent Deformation Response of Asphalt Aggregate mixes, 1994 SHRP-A-357: Development and Validation of Performance Prediction Models and Specifications for Asphalt Binders and Paving Mixes, 1993
SHRP CATEGORY:	Asphalt
APPLICABILITY RATING:	Applicable with Major Modifications
OBJECTIVE:	To provide specifications for asphalt mixes designed by the SHRP SUPERPAVE™ system.
DESCRIPTION:	The mixture specification is designed to address three pavement distress modes: rutting, fatigue, and thermal cracking. This product is intended to be much like the asphalt binder specification in which the design of the mix would depend on pavement temperatures, moisture susceptibility, traffic, and aging characteristics of the mix. The specification originally contained three levels of mixture characterization dependent on traffic level: Level I, Level II, and Level III. However, this has been recently revised to one level; volumetric mix design only. The mix is compacted by the SHRP gyratory machine to meet strict volumetric criteria. Binder and aggregate selection are controlled. The binder selection is based on the PG grading and aggregate selection is based on aggregate properties, including gradation. The mixture specifications control the volumetric properties and moisture susceptibility of

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The mix. The mixture is designed to a target of 4 percent air voids that is controlled primarily by the voids in the mineral aggregate, VMA. The VMA specifications are based on the largest nominal aggregate size in the mix. Acceptable ranges for the voids filled with asphalt (VFA) are selected based on traffic volume. The mixture is compacted by gyratory compaction at a constant pressure, and the number of compaction cycles is defined by traffic volume. The moisture susceptibility of the mix is determined to meet the acceptable criteria. The volumetric properties of the mix are also measured after compaction to determine percent asphalt, VMA, VFA, and air voids. These values must be within the ranges of specification values; if not, a different aggregate gradation must be used.

CRITICAL EVALUATION:	The major portion of the SHRP mixture design specification cannot be employed for the design of FAA pavements. As of March 1997, the use of the performance prediction schemes has been terminated, and along with that, Level II and Level III mixture designs. Currently, only Level I of the SHRP mix design is available, and this technology is being evaluated in the testing phase of this project to determine the applicability to FAA pavements.
APPLICABILITY ISSUES:	The applicability of SHRP Level I mix design to FAA applications is being addressed in the testing phase of this project.

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	1012
PRODUCT TITLE:	SUPERPAVE™ Mix Design System
REPORT NUMBER(S) AND TITLE(S):	SHRP-A-407: The SUPERPAVE™ Mix Design Manual for New Construction and Overlays, Strategic Highway Research Program, National Research Council, Washington, D.C. 1994. SHRP-A-408: Level One Mix Design: Materials Selection, Compaction, and Conditioning, 1994 SHRP-A-410: Superior Performing Asphalt Pavements (SUPERPAVE™): The Product of the SHRP Asphalt Research Program, 1994 SHRP-A-357: Development and Validation of Performance Prediction Models and Specifications for Asphalt Binders and Paving Mixes, 1993
SHRP CATEGORY:	Asphalt
APPLICABILITY RATING:	Applicable with Major Modifications
OBJECTIVE:	To provide a complete system for the selection of materials, compaction, characterization, and performance predictions for asphalt concrete systems in a convenient software package.
DESCRIPTION:	The SHRP SUPERPAVE™ mix design system is intended to guide the pavement engineer in the selection of proper materials for an asphalt pavement in a particular geographic location and traffic intensity. The system employs a large weather database that determines the average 7-day mean maximum pavement temperature and the average minimum pavement temperature per year for a given location anywhere in the United States. These temperatures are used to select a binder grade for that given area. An aggregate gradation chart is also used to ensure that a proper aggregate structure is selected for the expected traffic level. The traffic level is used to determine the level at which the materials will be designed; only volumetric design for lower traffic levels and both volumetric design and performance predictions for higher traffic levels. The materials are mixed and the volumetric and moisture susceptibility properties determined. The properties must meet the required specifications for retained tensile strength, air voids, voids in the mineral aggregate, and voids filled with asphalt. This is all that is required for a volumetric mix design.

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The system is to be implemented in a software package that takes the input data from a test and performs many of the calculations for the pavement designer. In addition, the software is to contain the performance models employed for prediction of each of the distress modes.

CRITICAL EVALUATION:

The SHRP SUPERPAVE™ system is currently not recommended for use by the FAA. The system is cumbersome to use, and the mixture calculations are more easily implemented on a spreadsheet than by using the software. In addition, the software does not contain performance prediction capabilities. The Level I volumetric mix design is being evaluated for FAA application in the testing phase of this project.

APPLICABILITY ISSUES:

The SUPERPAVE™ mixture design system (Level I volumetric mix design only) should not be used to design heavy-duty FAA airfield pavements until the technology has been evaluated. This is being addressed in the testing phase of this project.

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	1013
PRODUCT TITLE:	Net Adsorption Test
REPORT NUMBER(S) AND TITLE(S):	SHRP-A-641: Fundamental Properties of Asphalt-Aggregate Interactions Including Adhesion and Absorption SHRP-A/UIR-90-009: Adsorption of Asphalt into Porous Aggregate SHRP-A/UIR-90-016: A Literature Review of Liquid Antistripping Agents, Mineral Additives, and Tests for Measuring Stripping SHRP-A/UIR-91-508: Factors Influencing Mix Setting Characteristics and Tests to Predict Mix Setting Characteristics SHRP-A/UIR-90-507: The Effect of Physical and Chemical Characteristics of the Aggregate on Bonding
SHRP CATEGORY:	Asphalt
APPLICABILITY RATING:	Directly Applicable
OBJECTIVE:	To provide a test method for the evaluation of the water stripping potential of an asphalt-aggregate combination.
DESCRIPTION:	The test method is applicable to unmodified asphalt binders only. The binder is dissolved in toluene and is allowed to interact with the aggregate surface without the presence of water. The amount of asphalt adsorbed onto the surface of the aggregate is monitored by ultraviolet-visible (UV-VIS) spectroscopy. Water is then introduced into the system, and the amount of asphalt desorbed from the surface is determined. The degree to which the asphalt is desorbed from the aggregate is a measure of the potential of the mix to exhibit stripping problems.
CRITICAL EVALUATION:	The test is employed as a screening device for rejecting potential asphalt-aggregate combinations that display insufficient adhesion of asphalt to aggregate in the presence of water.
APPLICABILITY ISSUES:	None

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	1014
PRODUCT TITLE:	Gyratory Compactor and Method
REPORT NUMBER(S) AND TITLE(S):	SHRP-A/UWP-91-523: Evaluation of Laboratory Procedures for Compacting Asphalt-Aggregate Mixtures SHRP-A-408: Level I Mix Design: Materials Selection, Compaction, and Conditioning, 1994
SHRP CATEGORY:	Asphalt
APPLICABILITY RATING:	Applicable with Minor Modifications
OBJECTIVE:	To provide a method for the compaction of laboratory asphalt-aggregate mixture samples that simulates field compaction.
DESCRIPTION:	A gyratory compaction device is employed to compact asphalt-aggregate mixtures in the laboratory. The device is constructed to simulate the kneading action of roller compaction in the field. Samples 100 mm or 150 mm in diameter may be prepared from laboratory-mixed samples, plant mix, or short-term and long-term oven-aged mixtures. The mold is designed for a 1.25°C angle of gyration, and the compaction frequency is 30 rpm. The ram pressure for compaction is 600 kPa. The samples are compacted to a predetermined number of gyrations that are dependent on the traffic density (number of ESALs).
CRITICAL EVALUATION:	The gyratory compaction method more closely simulates the kneading action of field compaction than the Marshall hammer. The SHRP gyratory compaction method utilizes a head pressure of only 600 kPa but can compact asphalt mixtures to the densities necessary for airfield mixtures.
APPLICABILITY ISSUES:	The device is capable of producing heavy-duty asphalt mixtures with densities similar to that produced by the Marshall hammer. This device is likely to become the dominant tool for compaction of asphalt mixtures in the future and should be investigated as a compaction tool for adoption by the FAA.

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	1015
PRODUCT TITLE:	Rolling Steel-Wheel Compaction Method
REPORT NUMBER(S) AND TITLE(S):	SHRP-A/UWP-91-523: Evaluation of Laboratory Procedures for Compacting Asphalt-Aggregate Mixtures
SHRP CATEGORY:	Asphalt
APPLICABILITY RATING:	Directly Applicable
OBJECTIVE:	To provide a method for the compaction of laboratory asphalt-aggregate mixture samples that simulates field compaction.
DESCRIPTION:	The rolling steel wheel compaction method was developed as a possible SHRP method due to the similarity to field compaction by steel rollers. A slab of asphalt-aggregate mixture is prepared by compaction in a 22.86-cm-deep mold in three 7.62-cm lifts. After compaction, core and beam samples are cut for testing. The procedure was compared to both gyratory and kneading compaction and the gyratory method was chosen as the most satisfactory method of compaction in the laboratory.
CRITICAL EVALUATION:	Although this method of compaction simulates the actual process of rolling compaction in the field, it has not been adopted as the preferred method of compacting mixtures in the laboratory. The method is cumbersome and requires coring and sawing of the compacted slab to obtain samples for analysis. This method is preferred for compaction of laboratory mixtures to be used for research, evaluation, and performance prediction purposes because of its similarity to actual pavement compaction.
APPLICABILITY ISSUES:	None

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER: 1017

PRODUCT TITLE: Shear Test and Device

REPORT NUMBER(S) AND TITLE(S):

SHRP-A-318: Summary Report on Permanent Deformation in Asphalt

SHRP-A-388: Stiffness of Asphalt-Aggregate Mixtures

SHRP-A-379: The SUPERPAVE™ Mix Design System: Manual of Specifications, Test Methods, and Practices

SHRP-A-410: Superior Performing Asphalt Pavements (SUPERPAVE™): The Product of the SHRP Asphalt Research Program

SHRP CATEGORY: Asphalt

APPLICABILITY RATING: Applicable with Minor Modifications

OBJECTIVE: To provide a single device for conducting several of the SHRP mixture tests (hydrostatic testing, uniaxial testing, frequency sweep, simple shear, and repeated shear).

DESCRIPTION: The shear test device is commercially available and is a comprehensive testing device capable of a number of different testing modes. The device is capable of performing the following tests: hydrostatic testing, uniaxial testing, frequency sweep, simple shear, and repetitive shear. Each test will be described below; further details are available in the above reports.

The device is capable of applying both vertical and horizontal loads to a test specimen. The test specimens are obtained from gyratory compaction (150 mm diam and 50 to 60 mm in height). The device can apply static loads, ramp loads, or frequency-dependent repeated loads. Load control is obtained using closed-loop feedback. LVDTs can be placed on the specimens for monitoring strains during the testing. Both horizontal and vertical strains can be measured. Confining pressures can also be applied to test specimens.

Hydrostatic (Volumetric) Testing

A gyratory compacted specimen is sealed with a rubber membrane and placed in a confining pressure chamber with two vertical LVDTs (on the top and bottom of the specimen) and a radial LVDT fitted around the circumference of the sample. The sample is allowed time

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to reach thermal equilibrium. Preconditioning is achieved by application of a 70-kPa load for 1 sec and rapidly reduced to 7 kPa. The sample is then loaded from all sides with the same confining pressure. The pressure is applied at a rate of 70 kPa/sec until reaching 550, 690, or 830 kPa at 40, 20, and 4°C, respectively. The load is maintained constant for 10 sec and reduced at a rate of 23 kPa/sec until a load of 7 kPa is realized. Axial and radial deformation is monitored (approximately 10 data points per second) during the entire test. The uniaxial strain is determined from the vertical strain divided by the specimen height.

Uniaxial Strain Test

The test setup is similar to that of the hydrostatic test, except that a 75-mm circular loading unit is placed between the load cell and the specimen to yield a more uniform stress distribution on the vertical face of the specimen. One radial LVDT is placed around the circumference, and two LVDTs are placed on the ends of the specimen. Preconditioning is achieved in the same way as the hydrostatic test. An axial load is then applied at a rate of 70 kPa/sec until the desired load of 345, 415, and 655 kPa at 40, 20, and 4°C, respectively, is realized. The axial load is applied for 10 sec and relieved at a rate of 23 kPa/sec to a residual load of 7 kPa. During this process, the confining pressure is adjusted by closed feedback control using the radial LVDT to track the change in the sample perimeter. Axial and radial deformations are recorded throughout the test and an additional 30 sec after reducing the axial load to 7 kPa. The uniaxial strain developed during the test is determined from the vertical strain divided by the specimen height. In addition, the axial stress is determined by P/A + confining stress. P is the applied load and A is the cross-sectional area of the specimen.

Frequency Sweep at Constant Height

Both vertical and horizontal LVDTs are attached to the specimen. Constant height of the specimen during the test is controlled by closed-loop feedback of the vertical LVDT. The sample is preconditioned by application of a sinusoidal horizontal shear strain of approximately 10^{-4} mm/mm at 10 Hz for 100 cycles. The maximum allowable strain during the test is limited to 10^{-4} mm/mm. The shear strain is applied at frequencies of 10, 5, 2, 1, 0.5, 0.2, 0.1, 0.05, 0.02, and 0.01 Hz in descending order at each temperature, (4, 20, and 40°C) starting with the lowest. The axial load P and shear load V are recorded along with the vertical, δ_v, and horizontal, δ_h, displacement of the specimen. The axial stress, σ_{11}, is determined from P/A and the shear stress, τ_{12}, from V/A. Shear strain, ϵ_{12}, is horizontal

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strain divided by specimen height. Complex shear modulus is shear stress divided by shear strain, and the phase angle is measured in degrees.

Simple Shear at Constant Height

As in the frequency sweep tests, both vertical and horizontal LVDTs are attached to the specimen. The test is stress controlled using a closed-loop feedback to generate the magnitude of the applied shear load. The test is conducted at constant height using feedback from the vertical LVDTs to control the height of the test specimen. Preconditioning is achieved by application of a 7 kPa shear stress for 100 cycles. The shear stress is then applied at a rate of 70 kPa/sec for 10 sec to achieve the desired stress of 35, 105, or 350 kPa at 40, 20, and 4°C, respectively. After application of the stress for 10 sec, the load is reduced to zero at a rate of 21 kPa/sec and the data collected for another 30 sec. Data collection rate should be about 10 points/sec. The axial, P, and shear, V, loads are recorded along with the vertical, δ_v, and horizontal, δ_h, displacements of the specimen. The axial stress, σ_{11}, is determined from P/A, and the shear stress, τ_{12}, from V/A. Shear strain, ϵ_{12}, is horizontal strain divided by specimen height.

Repeated Shear at Constant Stress Ratio

This test is conducted similarly to the simple shear test at constant height. Both axial and shear stress are controlled by feedback from the respective loads. The synchronized axial and shear loads are haversine in shape. The sample is preconditioned by application of 100 cycles of synchronized axial and shear haversine stress waves of 0.1 sec in duration with 0.6-sec rest period. The applied shear stress during preconditioning should not exceed 7 kPa. The test is conducted by application of 5,000 cycles of the synchronized haversine waves or until permanent accumulated strain reaches 5 percent at a constant axial to shear stress ratio of 1.2 to 1.5. The magnitude of the applied stresses is determined using the SUPERPAVE™ software.

CRITICAL EVALUATION:

The shear test device performs several critical measures of the shear stability and load response of asphalt concrete specimens. The device can be employed to measure properties of airfield mixes but may require some modifications to the test methods for aircraft loads.

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APPLICABILITY ISSUES:

As of March 1997, use of the shear device to generate input data for the performance models has been discontinued. The SHRP performance models and their required tests are being reevaluated. The magnitude of the loads employed for the hydrostatic, uniaxial, and simple shear tests by the shear test device may not be adequate for the types of loadings experienced in airfield applications. However, the test methods can be altered since the device is capable of generating higher loads. One of the test methods, the repeated simple shear test at constant height, is being employed in the testing phase of this project to determine its applicability to assess the relative shear properties of different mixtures.

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	1019
PRODUCT TITLE:	Flexural Fatigue Life Test
REPORT NUMBER(S) AND TITLE(S):	SHRP-A-404: Fatigue Response of Asphalt-Aggregate Mixes SHRP-A-312: Summary Report on Fatigue Response of Asphalt Mixtures, 1990 SHRP-A-379: SUPERPAVE™ Manual of Specifications, Test Methods and Practices, 1994
SHRP CATEGORY:	Asphalt
APPLICABILITY RATING:	Applicable with Minor Modifications
OBJECTIVE:	To provide a test method for the evaluation of the fatigue properties of an asphalt-aggregate mixture.
DESCRIPTION:	The test method employs asphalt concrete beams prepared by kneading or rolling steel-wheel compaction. The beam is subjected to four-point bending by repeated sinusoidal strains of between 100 and 300 microstrains applied at a frequency between 5 and 10 Hz. The initial stiffness is measured after 50 load cycles. The strain level should be such that after 10,000 load cycles, the specimen stiffness has been reduced by at least 50 percent.
CRITICAL EVALUATION:	This test can be employed on airfield mixtures but may require some adjustment in strain levels and load cycles to simulate a lower number of passes of heavy aircraft.
APPLICABILITY ISSUES:	Fatigue damage in asphalt pavements occurs from repetitive strains and has both a material and structural design origin. Fatigue is usually not observed on many airfields because of lower amounts of traffic on most airfields compared to a highway pavement. The structural design of airfield pavements also contributes to fatigue damage resistance. However, the asphalt mixture design of heavy-duty airfield pavements results in very stiff materials and is susceptible to fatigue damage. This test is being employed in the testing phase of this project to determine its applicability to assess the relative fatigue properties of different mixtures.

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	1021
PRODUCT TITLE:	Thermal Stress Restrained Specimen Test
REPORT NUMBER(S) AND TITLE(S):	SHRP-A-357: Development and Validation of Performance Prediction Models and Specifications for Asphalt Binders and Paving Mixes, 1993 SHRP-A-398: Stage I Validation of the Relationship Between Asphalt Properties and Asphalt-Aggregate Mix Performance, 1994
SHRP CATEGORY:	Asphalt
APPLICABILITY RATING:	Directly Applicable
OBJECTIVE:	To provide a test method for the direct measurement of low-temperature fracture strength and temperature.
DESCRIPTION:	The thermal stress restrained specimen test (TSRST) method employs an asphalt concrete beam (50 by 50 by 260 mm) glued at both ends to a special platen and enclosed in an environmental chamber at 5°C for at least 6 hr before testing. A small initial stress is applied to the sample which is then cooled at a rate of 10 ± 1°C/hr. As the sample cools, stress begins to build up, and the feedback for the displacement maintains the specimen at a constant length. The sample is cooled until fracture occurs. The device monitors the stress during the test, allowing the determination of the fracture strength and the temperature at which fracture occurred.
CRITICAL EVALUATION:	This test can be employed on airfield mixtures directly without modification and is a direct measure of the fracture temperature of the mix. Low-fracture strengths and high-fracture temperatures signify a mix more susceptible to thermal cracking. The test can be performed on laboratory or field samples. However, the test requires careful sample preparation, gluing of the sample in the test devices, and the test itself is very slow.
APPLICABILITY ISSUES:	This test has direct application to airfield mixtures since it is not load related but requires specialized equipment, sample preparation, and is very slow. However, it provides direct measurements of thermal properties that have strong correlation with field observations of thermal cracking.

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	1022
PRODUCT TITLE:	Indirect Tensile Creep and Failure Test
REPORT NUMBER(S) AND TITLE(S):	SHRP-A-357: Development and Validation of Performance Prediction Models and Specifications for Asphalt Binders and Paving Mixes, 1993 SHRP-A-398: Stage I Validation of the Relationship Between Asphalt Properties and Asphalt-Aggregate Mix Performance, 1994 SHRP-A-379: SUPERPAVE™ Manual of Specifications, Test Methods and Practices, 1994
SHRP CATEGORY:	Asphalt
APPLICABILITY RATING:	Directly Applicable
OBJECTIVE:	To provide a test method for the measurement of low-temperature creep compliance and strength of asphalt concretes.
DESCRIPTION:	The indirect tensile creep compliance test is designed to measure the low-temperature compliance of a compacted asphalt sample. The results are used with the bending beam rheometer data in the SUPERPAVE™ performance prediction models to predict the thermal cracking characteristics of the mix. Specimens are tested at three temperatures 0, -10, and -20°C. Sample sizes up to 150 mm in diameter and 75 mm in height can be tested dependent on the nominal maximum aggregate size. A schematic of the testing arrangement and LVDT placement is shown in figure 15 in the text. Both vertical and horizontal strains are measured by mounting LVDTs to the faces of the test specimen. The samples are subjected to a static load for 1,000 sec and then placed on the diametral axis of the specimen. The magnitude of the applied load is adjusted to yield a horizontal deformation within the linear viscoelastic range (0.00125 to 0.0125 mm for 100-mm specimens and 0.00125 to 0.0190 mm for 150-mm diam specimens). If the deformations are outside these ranges, the test is stopped and restarted at a lower applied load after unloading for at least 5 min to allow for recovery of the specimen. At the completion of the compliance test, the sample is loaded at a constant rate of 12.5 mm/min until the sample fails, yielding the ultimate tensile strength of the sample at that temperature.

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The individual creep curves from 0, -10, and -20°C are combined to generate a master creep compliance curve. The master creep compliance curve is then fit to a Prony series to yield a mathematical representation of the curve for easier analysis. An example of the individual creep curves, the shifted data, and Prony series fit to the master compliance curve are shown in figure 16 in the text. The Prony series allows easy manipulation of the compliance curve into the relaxation modulus using Lorentzian transformations. The relaxation modulus can then be found at any temperature and time of loading between 0 and -20°C by interpolation and outside that temperature range by extrapolation.

The indirect tensile strength test also measures the ultimate fracture strength of an asphalt concrete specimen at a designated temperature for fatigue cracking analysis (generally -10°C). A constant loading rate of 50 mm/min is applied until the sample fractures.

CRITICAL EVALUATION:

This test can be employed on airfield mixtures directly without modification and provides a measure of the low-temperature creep properties of the mix. It can be performed on laboratory samples or field samples. The data can be used in the thermal cracking portion of the performance prediction models to yield the linear feet of transverse cracks per year in a 500-ft section of pavement. The indirect tensile test shows correlations with the TSRST, is easier to run, requires less specialized equipment, and can be performed on typical Marshall-type laboratory specimens as well as field cores.

APPLICABILITY ISSUES:

This test has direct application to airfield mixtures since it is not load related and can be employed to assess the relative differences in low-temperature behavior between asphalt mixes and provide input to thermal cracking models. As of March 1997, the use of the performance prediction schemes was terminated; thus, Level II and Level III mixture designs are no longer available. This test was part of Level II and Level II testing and was designed to provide fundamental material characterization to provide input data for performance prediction models. Although it can be used to observe relative differences between asphalt mixture, interpretation of the test results is not straightforward.

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	1024
PRODUCT TITLE:	Environmental Conditioning System
REPORT NUMBER(S) AND TITLE(S):	SHRP A-403: Water Sensitivity of Asphalt-Aggregate Mixes: Test Selection, 1994 SHRP-A-379: SUPERPAVE™ Manual of Specifications, Test Methods and Practices, 1994 SHRP-A-396: Field Validation of the Environmental Conditioning System, 1994
SHRP CATEGORY:	Asphalt
APPLICABILITY RATING:	Applicable with Minor Modifications
OBJECTIVE:	To provide a test method for the measurement of water permeability and susceptibility to stripping of an asphalt concrete mixture.
DESCRIPTION:	The Environmental Conditioning System (ECS) was developed under SHRP and is a complete closed system for measuring the resilient modulus of compacted specimens using dynamic loading and determining the air and water permeability of the specimens, vacuum saturation of the specimens, and temperature cycling. The ECS employs 100-mm tall specimens. The sample is placed within the ECS chamber and the resilient modulus determined on the dry specimen. A schematic of the testing apparatus is shown in figure 13 in the text. The applied load is in the form of a haversine wave with a pulse duration of 0.1 sec and rest of 0.9 sec and initial magnitude of 2,200 ± 25 N. The dynamic load is adjusted to yield between 50 and 100 microstrains and no more than 250 loading cycles applied to determine the dry modulus. This usually requires approximately 4,000 N of force. The side of the sample is sealed with a bead of silicone around the circumference, and the permeability of the sample to air is determined. To begin wet testing, the specimen is vacuum saturated (at 50.8 cm of mercury for 30 min). The specimen is then subjected to four conditioning cycles. The first three cycles are at 60°C for 6 hr in which the specimens are maintained at a vacuum level of 25.4 cm. Hg and subjected to dynamic loading at 900 ± 25 N. At the end of each of the warm cycles, the temperature is reduced to 25°C and the modulus determined as previously described. Following the warm cycles, the temperature is reduced to -18 ± 0.5°C for 6 hr before warming backup to 25°C to determine the

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final modulus. The resilient modulus after each conditioning cycle is averaged, and the ECS modulus ratio determined by comparison to the dry modulus. The permeability is also determined after each conditioning sample.

CRITICAL EVALUATION:

The magnitude of the applied loads for determination of the retained tensile strength may need to be adjusted for some airfield mixtures. The test is somewhat cumbersome to run since it requires specialized equipment, and the sample must be 100 mm tall and must be sealed around the circumference to measure permeability. However, this test generates information on the moisture characteristics of the mix available from no other test. The simpler retained tensile strength test may be run in lieu of the ECS test for determining the moisture susceptibility of an asphalt-aggregate combination for the SUPERPAVE® mix design system.

APPLICABILITY ISSUES:

This test can be employed on airfield mixtures but may require some adjustment in the magnitude of the applied loads for determination of the retained resilient modulus.

(Sheet 2 of 2)

SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	1025
PRODUCT TITLE:	Short-Term Aging
REPORT NUMBER(S) AND TITLE(S):	SHRP-A-383: Selection of Laboratory Aging of Asphalt-Aggregate Mixtures SHRP-A-305: Summary Report on the Aging of Asphalt-Aggregate Systems
SHRP CATEGORY:	Asphalt
APPLICABILITY RATING:	Directly Applicable
OBJECTIVE:	To provide a test method for the simulation of the short-term aging characteristics at asphalt mixtures before compaction.
DESCRIPTION:	The test method employs loose asphalt mixtures that are placed on a baking pan in a forced draft oven. Uncompacted asphalt-aggregate mix (21 to 22 kg) is allowed to stand for 4 hr ± 5 min at 135 ± 3°C. The material is stirred every 60 min for consistent aging throughout the mix.
CRITICAL EVALUATION:	This method can be employed as a method for simulating the short-term aging properties that occur in uncompacted mixtures. This test requires no modification for application to airfield mixes since the aging that occurs in the storage, mixing, and transport is not substantially different from a highway mix.
APPLICABILITY ISSUES:	None

(Sheet 1 of 1)

SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	1026
PRODUCT TITLE:	Modified Rice Correction Test
REPORT NUMBER(S) AND TITLE(S):	SHRP-A-641: Fundamental Properties of Asphalt-Aggregate Interactions Including Adhesion and Absorption
SHRP CATEGORY:	Asphalt
APPLICABILITY RATING:	Directly Applicable
OBJECTIVE:	To provide an improved test method for the determination of the theoretical maximum specific gravity and density of asphalt mixtures.
DESCRIPTION:	This method is a modification of the Rice specific gravity test method. Loose asphalt mix is weighed and placed in a tared vessel and submerged under a sufficient amount of water at 25°C. A vacuum is applied for 15 min and slowly released. The volume of the sample is determined by either immersing the sample into a water bath and weighing or by filling the vacuum container with water and weighing in air. From the mass and volume of the mixture, the specific gravity and density at 25°C is determined.
CRITICAL EVALUATION:	This method can be employed for the determination of the specific gravity and density of asphalt-aggregate mixtures. It is used in Marshall and SUPERPAVE® mix design procedures.
APPLICABILITY ISSUES:	None

(Sheet 1 of 1)

SHRP PRODUCT FACT SHEET

PRODUCT NUMBER: 1030

PRODUCT TITLE: Long-Term Aging

REPORT NUMBER(S) AND TITLE(S): SHRP-A-383: Selection of Laboratory Aging of Asphalt-Aggregate Mixtures

SHRP-A-305: Summary Report on the Aging of Asphalt-Aggregate Systems

SHRP CATEGORY: Asphalt

APPLICABILITY RATING: Applicable with Minor Modification

OBJECTIVE: To provide a test method for the simulation of the long-term aging (7 to 10 years) characteristics of asphalt mixtures after compaction.

DESCRIPTION: The method is intended to simulate 7 to 10 years of field aging and employs loose asphalt mixtures that have undergone short-term aging as described in SHRP 1025. The material is first compacted according to SHRP 1014 or 1015. The asphalt specimens are cooled to 60 ± 3°C for approximately 2 hr before the sample is leveled by applying a 72 ± 30.05 kN/min load. The load is removed when the specimen ends are level or the applied load has reached 56 kN. The specimens are then cooled to room temperature for 16 hr. Core samples removed from freshly laid asphalt concrete can also be long-term aged. The compacted specimens are then placed in racks in a forced draft oven at 85 ± 3°C for 120 ± 0.5 hr. After removing the racks from the oven, the samples cannot be disturbed until cooled to room temperature. The method is intended to simulate 7 to 10 years of field aging.

CRITICAL EVALUATION: This method can be employed as a method for simulating the long-term aging properties that occur in asphalt mixtures. The procedure is conducted on compacted samples according to the job mix formula. As such, the major consideration in application of the test method to airfield mixtures is that of the time of aging and the temperature used. However, this procedure at least provides some method for aging of the asphalt mixtures that can be employed to evaluate the aged properties of the mix where no test existed before. The test can also be conducted on core samples from freshly laid asphalt concrete.

APPLICABILITY ISSUES: The time and temperature of the aging procedure may need adjustment for airfield applications.

(Sheet 1 of 1)

APPENDIX B—STRATEGIC HIGHWAY RESEARCH PROGRAM CONCRETE PRODUCT REVIEWS

SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	2001
PRODUCT TITLE:	Corrosion Rate Method
REPORT NUMBER(S) AND TITLE(S):	SHRP-S-324: Condition Evaluation of Concrete Bridges Relative to Reinforcement Corrosion, Volume 2: Method for Measuring the Corrosion Rate of Reinforcing Steel
SHRP CATEGORY:	Concrete and Structures
APPLICABILITY RATING:	Not Applicable
OBJECTIVE:	To ascertain the parameters that are prominent in determining the rate of corrosion of reinforcing steel in concrete bridges.
DESCRIPTION:	A detailed examination of the parameters that most influence the rate of corrosion of reinforcing steel in bridge decks has been conducted. The parameters are ranked in terms of their impact on the corrosion rate of the steel reinforcing materials.
CRITICAL EVALUATION:	None
APPLICABILITY ISSUES:	Corrosion of reinforcing steel is generally not a problem on airfields due to the relatively small volumes of steel used, thick slabs that provide a large depth of concrete cover, and a lack of deicing chemicals containing corrosive salts.

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	2002
PRODUCT TITLE:	Aggregate Durability Test
REPORT NUMBER(S) AND TITLE(S):	SHRP-C-391: Resistance of Concrete to Freezing and Thawing SHRP-C/UFR-92-617: Freeze-Thaw Resistance in Concrete - An Annotated Bibliography
SHRP CATEGORY:	Concrete and Structures
APPLICABILITY RATING:	Directly Applicable
OBJECTIVE:	To determine the parameters that most affect the freeze-thaw fracture of concrete and design, a test to measure the susceptibility of the concrete to freeze-thaw damage.
DESCRIPTION:	A new procedure for measuring the susceptibility of a concrete mix to freeze-thaw damage based on a hydraulic test of the aggregate is described. Field experiments relating to laboratory results are presented. A modified version of the standard test for determination of concrete durability is described along with a procedure for determination of the fundamental transverse frequency. A predried aggregate sample is pressurized under water to force the fluid into the pore structure. As the fluid enters closed pores, air is trapped under pressure. When the pressure is rapidly released, the air expands. The amount of fracturing is determined to yield a hydraulic fracture index (HFI). The HFI is an estimate of the number of pressurization cycles necessary to fracture 10 percent of the aggregate. Aggregates that displayed high HFI values (between 80 and 100) were less susceptible to D-cracking than those aggregates with HFI values of less than 60.
CRITICAL EVALUATION:	This method should be useful for determining whether a particular aggregate employed in a concrete mix design will be susceptible to D-cracking.
APPLICABILITY ISSUES:	None

(Sheet 1 of 1)

SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	2003
PRODUCT TITLE:	Concrete Removal Manual
REPORT NUMBER(S) AND TITLE(S):	SHRP-S-336: Techniques for Concrete Removal and Bar Cleaning on Bridge Rehabilitation Projects
SHRP CATEGORY:	Concrete and Structures
APPLICABILITY RATING:	Applicable with Minor Modifications
OBJECTIVE:	To evaluate current methods of concrete removal in damaged areas on bridge decks.
DESCRIPTION:	Three methods are evaluated for the removal of damaged concrete from bridge decks: pneumatic breakers, milling, and hydrodemolition. Issues such as cost, production, and quality are evaluated.
CRITICAL EVALUATION:	This product provides guidance for selection of the proper technique based on the job aspects and costs.
APPLICABILITY ISSUES:	Concrete removal on airfields is generally accomplished using slab lifting, where possible. However, in many cases, pneumatic breakers or hydrodemolition can be employed on airfields for removing shattered slabs. Milling of concrete is not normally used for repair of slabs on airfields. Bar cleaning methods also have potential application to airfield concrete repair for cleaning of exposed dowel bars prior to covering with concrete.

(Sheet 1 of 1)

SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	2004
PRODUCT TITLE:	Mitigation of D-cracking
REPORT NUMBER(S) AND TITLE(S):	SHRP-C-391: Resistance of Concrete to Freezing and Thawing SHRP-C/UFR-92-617: Freeze-Thaw Resistance in Concrete - An Annotated Bibliography
SHRP CATEGORY:	Concrete and Structures
APPLICABILITY RATING:	Directly Applicable
OBJECTIVE:	To determine various strategies for mitigation of D-cracks in existing pavements.
DESCRIPTION:	D-cracking in concrete pavements is the result of water-saturated aggregate causing fracture of the aggregate. For new pavements, the susceptibility for an aggregate towards D-cracking can be determined using the hydraulic fracture test outlined in SHRP product 2002. However, the avoidance of further D-cracking in an existing pavement must rely on excluding water from penetrating the concrete structure or preventing freezing. Water intrusion can be prevented by a surface sealer, an asphalt overlay, and maintenance of expansion joints to prevent water intrusion. In climates that do not have many days of freezing temperatures, an asphalt overlay can often prevent the temperature of the underlying concrete from reaching the freezing point.
CRITICAL EVALUATION:	Various strategies for preventing further D-cracking in existing pavements are discussed. The results of testing indicate that sealers and overlays can be effective for reducing D-cracking but the best solution is a full depth patch of the damaged pavement.
APPLICABILITY ISSUES:	None

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	2005
PRODUCT TITLE:	Handbook for Mix Design
REPORT NUMBER(S) AND TITLE(S):	SHRP-C-334: A Guide for Determining the Optimal Gradation of Concrete Aggregates SHRP-C-339: Concrete Microstructure: Recommended Revisions to Test Methods SHRP-C-340: Concrete Microstructure SHRP-C-624: Concrete Components Packing Handbook SHRP-C-629: Cement Paste Aggregate Interface Microstructure
SHRP CATEGORY:	Concrete and Structures
APPLICABILITY RATING:	Directly Applicable
OBJECTIVE:	To provide guidance for improved proportioning of concrete mixtures. The guidelines are primarily related to optimizing the relative proportions of different aggregates in an aggregate blend. Optimization in this sense refers to achieving a dense-graded blend.
DESCRIPTION:	The guidelines are intended to be used as supplemental information for standard mixture proportioning procedures. They are not intended to serve as an alternative procedure. Report C-334 includes numerous packing tables, which consist of output from computer simulations of aggregate packing densities. Input for the tables requires an average diameter and a packing density for each aggregate in a blend. As output, the tables provide the optimal volume percent of each aggregate component. In order to facilitate the optimization of aggregate packing, several American Society for Testing and Materials (ASTM) and American Concrete Institute (ACI) standards were evaluated as part of Report C-339. General recommendations are offered for incorporating packing models into aggregate specifications. Report C-340 serves as a literature review for fresh concrete rheology and hardened concrete durability. The effects of particle packing on rheology are discussed. Also, considerations for mixture design with mineral and chemical admixtures are discussed.

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CRITICAL EVALUATION:	The particle-packing guide is limited to combining four types of aggregates: one sand and three types of coarse aggregate. The packing tables are based on theoretical packing of spherical particles. The packing tables consider only dense packing by continuous grading. They do not consider dense packing by gap grading. Reports C-339 and C-340 cover mixture design concepts briefly and in general terms. Aggregate packing density affects both the rheology of fresh concrete and the quality of hardened concrete. These issues are of interest to airfield pavement engineers. The guide may also be used for producing dense-graded aggregate blends for asphalt concrete. Packing tables for sands include average particle sizes up to 4.6 mm. Packing tables for coarse aggregates include average particle sizes up to 29.7 mm.
APPLICABILITY ISSUES:	None

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	2006
PRODUCT TITLE:	Guide to Thermal Effects
REPORT NUMBER(S) AND TITLE(S):	SHRP-C-321: Guide to Thermal Effects SHRP-C-339: Concrete Microstructure: Recommended Revisions to Test Methods SHRP-C-340: Concrete Microstructure
SHRP CATEGORY:	Concrete and Structures
APPLICABILITY RATING:	Directly Applicable
OBJECTIVE:	To provide a quick method for determining whether a concrete slab has potential for problems related to thermal effects. These problems occur at early ages and include freezing, high internal temperatures, and large temperature differences within slabs.
DESCRIPTION:	Temperature-related concrete problems are predicted with the help of user-friendly data tables, which are included in Report C-321. The tables were generated from computer simulations of heat flow and strength development. The tables require the following as input: type of cementitious material, content of cementitious material, concrete temperature at time of placement, air temperature, and thickness of the pavement. Based on knowledge gained during the development of temperature-effects models, revisions for ASTM specifications related to concrete maturity are provided in Report C-339. Report C-340 provides a literature review for concrete maturity models.
CRITICAL EVALUATION:	The development of both heat and strength in concrete are modeled as functions of maturity. The concept of maturity is based on the assumption that the rate of hydration of a given cementitious material can be approximated as a function of its degree of hydration and its temperature. Thermal conduction between concrete and its environment is assessed by Fourier's Law. Thermal convection is assessed by an empirical equation. Thermal cracking due to temperature differences within a concrete slab are assumed to occur when this difference

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exceeds 20°C. Freezing is assumed to cause damage if it occurs before the concrete has attained a compressive strength of 3.44 MPa. High temperatures during curing are assumed to cause damage if they exceed 60°C.

In order to keep the reports reasonable in size, the range of possible input parameters had to be limited. Cementitious materials may include a Type I, Type II, or Type III cement. Pozzolanic materials may include a Class F fly ash. The content of cementitious material may range from 525 to 750 lb/yd^3 (311.5 to 445.0 kg/m^3). Many aspects of concrete mixture design, such as water-cement ratio and air content are held constant. Slab thickness may range from 20.32 to 50.80 cm. Air temperature may be between -17.6 to 37.4°C. Wind velocity is assumed to be 17.702817 kph. Several characteristics concerning the base course and construction sequence are assumed.

The theoretical ideas used in developing these temperature-effects tools could be applied to a broader range of circumstances.

APPLICABILITY ISSUES: None

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	2007
PRODUCT TITLE:	Permeability Laboratory Test
REPORT NUMBER(S) AND TITLE(S):	SHRP-C-340: Concrete Microstructure SHRP-C-627: Development of Transient Permeability Theory and Apparatus for Measurements of Cementitious Materials SHRP-C-628: Concrete Microstructure Porosity and Permeability
SHRP CATEGORY:	Concrete and Structures
APPLICABILITY RATING:	Directly Applicable
OBJECTIVE:	To determine the critical parameters affecting permeability of concretes and determine a method of testing that provides a consistent, universal test for many different types of concretes.
DESCRIPTION:	Theoretical analyses of concrete microstructure have been used to develop a model for relating porosity to permeability. An apparatus for determining permeability was designed and constructed. A sample of concrete acting as a permeable membrane is placed between two pressurized reservoirs. A sudden pressure drop on one side provides the driving force for liquid flow through the sample. The change in pressure versus time is related to the porosity of the sample. The technique is capable of rapid accurate measurements of permeabilities ranging from microdarcy to nanodarcy.
CRITICAL EVALUATION:	This method provides a rapid and direct method for the accurate determination of porosity in a concrete sample.
APPLICABILITY ISSUES:	None

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	2008
PRODUCT TITLE:	Fluorescent Microscopy Manual
REPORT NUMBER(S) AND TITLE(S):	SHRP-C-339: Concrete Microstructure: Recommended Revisions to Test Methods SHRP-C-340: Concrete Microstructure
SHRP CATEGORY:	Concrete and Structures
APPLICABILITY RATING:	Directly Applicable
OBJECTIVE:	To provide procedures for using optical microscopy as a tool for diagnosing concrete performance problems.
DESCRIPTION:	Two forensic techniques involving fluorescent microscopy (transmitted light and reflected light) are suggested as potential tools for petrographic examinations; however, testing techniques and data interpretation need refinement. Potential future modifications to ASTM petrography standards are introduced in Report C-339. Report C-340 discusses concrete microstructure in terms of interfacial zones between mortar and aggregates. Some experimental work is reviewed, including both fluorescent microscopy of thin sections and scanning electron microscopy. The review of analytical studies includes computer model simulations of particle packing at an interface. Report C-340 also discusses the mathematical modeling of pore-size distributions in hardened cement paste. These models would be useful due to the relationships between pore structure and both permeability and fracture mechanics.
CRITICAL EVALUATION:	These studies offer state-of-the-art information and serve as progress statements for ongoing research at Pennsylvania State University. Concrete microscopy, as it affects petrography, is important for forensic studies of airfields. Modeling pore structures is important for understanding and predicting concrete durability. Experimental and analytical procedures introduced along these lines require further development.
APPLICABILITY ISSUES:	None

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	2009
PRODUCT TITLE:	Screening Reactive Aggregates Test
REPORT NUMBER(S) AND TITLE(S):	SHRP-C-342: Alkali-Silica Reactivity: An Overview of Research SHRP-C-343: Eliminating or Minimizing Alkali-Silica Reactivity
SHRP CATEGORY:	Concrete and Structures
APPLICABILITY RATING:	Directly Applicable
OBJECTIVE:	To develop a rapid test for evaluating the potential for aggregates to participate in ASR.
DESCRIPTION:	Report C-342 is a literature review composed of three primary topics concerning alkali-silica reactivity: (1) mechanisms of damage to concrete, (2) factors affecting the severity of damage, and (3) gaps in our knowledge. The identification of reactive aggregates is addressed in the "gaps in our knowledge" section. Problems with current test procedures are discussed, including their inability to identify slowly reacting aggregates. Report C-343 discusses a new, rapid laboratory test for evaluating aggregates potential for ASR. The test can be performed in only 14 days and does not require any expensive laboratory equipment. Mortar bars are cast, cured for 2 days, and are then immersed in sodium hydroxide solution. During the immersion period, the lengths of the bars are measured periodically.
CRITICAL EVALUATION:	The new test procedure identifies slowly reacting aggregates and can be used to determine the effects mineral admixtures. Due to the test's dependence on diffusion, specimens are limited to mortar bars of small cross sections. Therefore, common concrete mixtures cannot be tested. A more scientific method for determining aggregate ASR potential of an aggregate is needed. At the present time, aggregate potential for ASR is typically appraised by its historical data.
APPLICABILITY ISSUES:	None

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	2010
PRODUCT TITLE:	Manual for ASR Detection
REPORT NUMBER(S) AND TITLE(S):	SHRP-C/FR-91-101: Handbook for the Identification of Alkali-Silica Reactivity in Highway Structures
SHRP CATEGORY:	Concrete and Structures
APPLICABILITY RATING:	Directly Applicable
OBJECTIVE:	To provide a handbook for the rapid and simple identification of alkali-silica reactions (ASR) in concrete.
DESCRIPTION:	The handbook provides photographs of ASR-associated distresses in concrete and simple analysis procedures for the positive identification of ASR reactions in concrete. A simple analysis method that employs uranyl acetate and an ultraviolet lamp to obtain a positive identification of ASR in concrete is presented. A solution of uranyl acetate is applied to the surface of the concrete and illuminated with the UV lamp. A positive reaction for ASR yields bright yellow and green areas under UV illumination.
CRITICAL EVALUATION:	A concise and brief manual for visual identification of ASR-associated pavement distresses using photographs is presented. A simple analysis method employing uranyl acetate and an ultraviolet lamp to obtain a positive identification of ASR in concrete is detailed. However, disposal of waste solutions of uranyl acetate and the possibility of other problems besides ASR that may yield a positive test response are not addressed.
APPLICABILITY ISSUES:	None

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	2011
PRODUCT TITLE:	ASR Mitigation in Existing Concrete
REPORT NUMBER(S) AND TITLE(S):	SHRP-C-342: Alkali-Silica Reactivity: An Overview of Research SHRP-C-343: Eliminating or Minimizing Alkali-Silica Reactivity
SHRP CATEGORY:	Concrete and Structures
APPLICABILITY RATING:	Directly Applicable
OBJECTIVE:	To develop methods for mitigating alkali-silica reactions once damage is observed in hardened concrete.
DESCRIPTION:	Report C-342 is a literature review composed of three primary topics concerning alkali-silica reactivity: (1) mechanisms of damage to concrete, (2) factors affecting the severity of damage, and (3) gaps in our knowledge. In terms of mitigating damage caused by expansive ASR, mechanical restraint and the use of chemical agents are discussed. Lithium solutions appear to be effective at minimizing or preventing expansions due to ASR. However, a method for introducing the solution into concrete must be developed. Where it is practical, triaxial restraint or drying can prevent expansion due to ASR. Sealing cracks with high molecular weight methacrylate can stiffen the ASR-affected structure and can minimize the access for moisture.
CRITICAL EVALUATION:	The use of chemical agents to reduce or alter the course of ASR in concrete is in its experimental stage. Most studies to date have been performed in the laboratory. The details by which the chemicals operate remain obscure. The chemical methods of mitigating damage and most of the mechanical methods are difficult to apply in field situations. Although crack sealing is the easiest mitigation technique to apply, its effect is temporary.
APPLICABILITY ISSUES:	None

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	2012
PRODUCT TITLE:	Flaw Detection by the Impact-Echo Method
REPORT NUMBER(S) AND TITLE(S):	No report could be located for this product
SHRP CATEGORY:	Concrete and Structures
APPLICABILITY RATING:	Directly Applicable
OBJECTIVE:	To provide a method for the rapid detection of concrete flaws such as cracks, voids, and possible delamination from underlying layers.
DESCRIPTION:	Flaw detection is accomplished using the technique of impact echo, in which the characteristics of a pulse wave reveal the presence of voids, cracks, and other flaws in the concrete structure. The device can also measure the thickness of concrete pavements. The device consists of a portable notebook computer, a small hand-held device with a manual impact generator to create a pulse wave, and associated transducers for detection of the pulse wave at some distance from the pulse-wave generator. The system is small and very portable.
CRITICAL EVALUATION:	This system can be used to locate defects such as voids in concrete and would be very useful for precise determination of concrete pavement thickness.
APPLICABILITY ISSUES:	None

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	2013
PRODUCT TITLE:	Chemical Test for ASR Detection
REPORT NUMBER(S) AND TITLE(S):	SHRP-C/FR-91-101: Handbook for the Identification of Alkali-Silica Reactivity in Highway Structures
SHRP CATEGORY:	Concrete and Structures
APPLICABILITY RATING:	Directly Applicable
OBJECTIVE:	To provide a simple, rapid field test for the positive identification of ASR in concrete.
DESCRIPTION:	A simple analysis method that employs uranyl acetate and an ultraviolet lamp to obtain a positive identification of ASR in concrete is presented. A solution of uranyl acetate is applied to the surface of the concrete and illuminated with the UV lamp. A positive reaction for ASR yields bright yellow and green areas under UV illumination.
CRITICAL EVALUATION:	The method is presented with very little detail about the chemistry of the reaction of ASR gel with uranyl acetate; therefore, it is difficult to determine if the ASR gel is the material in the concrete that may yield a positive response to the uranyl acetate. Disposal of waste solutions of uranyl acetate and the possibility of other problems besides ASR that may yield a positive test response are not addressed.
APPLICABILITY ISSUES:	None

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	2014
PRODUCT TITLE:	High-Performance Concrete Specifications
REPORT NUMBER(S) AND TITLE(S):	SHRP-C-307: High-Performance Concretes: An Annotated Bibliography SHRP-C-317: High-Performance Concretes: A State-of-the-Art Report SHRP-C-361: Summary Report: Mechanical Behavior of High-Performance Concretes, Volume 1 SHRP-C-362: Production of High-Performance Concrete: Mechanical Behavior of High-Performance Concretes, Volume 2 SHRP-C-363: Very Early-Strength Concrete: Mechanical Behavior of High-Performance Concretes, Volume 3 SHRP-C-364: High Early-Strength Concrete: Mechanical Behavior of High-Performance Concretes, Volume 4 SHRP-C-365: Very High-Strength Concrete: Mechanical Behavior of High-Performance Concretes, Volume 5 SHRP-C-366: High Early-Strength Fiber-Reinforced Concrete: Mechanical Behavior of High-Performance Concretes, Volume 6
SHRP CATEGORY:	Concrete and Structures
APPLICABILITY RATING:	Directly Applicable
OBJECTIVE:	To develop needed information on the mechanical behavior of high-performance concrete (HPC). HPC is defined as concrete with rapid early-strength development and greatly enhanced durability against freezing and thawing. These concretes are divided into four categories: very early-strength concrete, high early-strength concrete, very high-strength concrete, and high early-strength fiber-reinforced concrete.
DESCRIPTION:	This product is not a specification. It is a collection of information and related experiments that could be used in writing specifications for the use of HPC. The information could also be used for modifying current specifications that inadvertently exclude the use of HPC.

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SHRP Report C-361 includes, a "Guide to Field Production and Use of High-Performance Concrete for Highway Applications" as its appendix. The guide discusses the selection of materials and concrete proportions and offers direction for the production and placement of HPC. It makes particular reference to any changes from normal procedures required of the concrete supplier, the contractor, or the project engineer.

The mechanical behavior of each category of HPC, as determined by laboratory testing, is reported separately. These results could be used to develop reasonable requirements in an HPC specification. Some of the test procedures adhered to current standards: ASTM C 157, Shrinkage Test; ASTM C 666, Freezing-Thawing Test; and ASTM C 1202, Rapid Chloride Permeability Test. Some of the test procedures were adaptations from current standards: ASTM C 39, Compression Test and ASTM C 78, Flexural and Split Tension Tests. Some of the test procedures were developed during the SHRP study: an AC impedance test and an interfacial bond strength test. Proposed specifications for the new SHRP tests can be found as appendices C and D in SHRP Report C-361.

CRITICAL EVALUATION:

This study resulted in a thorough literature survey, followed by extensive laboratory evaluations. Certain laboratory batching and mixing methods were also confirmed in large-scale field production facilities. Although pavement concrete does not need excessive strength, it does need to be durable. Very early-strength concrete would be useful for rapid repairs in critical high traffic areas that cannot be closed for long periods of time.

APPLICABILITY ISSUES:

None

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	2015
PRODUCT TITLE:	Radar Method for Asphalt Decks
REPORT NUMBER(S) AND TITLE(S):	SHRP-S-325: Condition Evaluation of Concrete Bridges Relative to Reinforcement Corrosion, Volume 3: Method for Evaluating the Condition of Asphalt Covered Decks
SHRP CATEGORY:	Concrete and Structures
APPLICABILITY RATING:	Directly Applicable
OBJECTIVE:	To provide a nondestructive means of determining the condition of asphalt-overlaid bridge decks.
DESCRIPTION:	The method relies on the use of ground penetrating radar to identify delamination of the asphalt layer from the bridge deck.
CRITICAL EVALUATION:	This technology could be employed to determine if delamination of asphalt overlays from underlying concrete is occurring.
APPLICABILITY ISSUES:	None

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	2016
PRODUCT TITLE:	Membrane Integrity Survey Method
REPORT NUMBER(S) AND TITLE(S):	SHRP-S-326: Condition Evaluation of Concrete Bridges Relative to Reinforcement Corrosion, Volume 4: Deck Membrane Effectiveness and a Method for Evaluating Membrane Integrity
SHRP CATEGORY:	Concrete and Structures
APPLICABILITY RATING:	Not Applicable
OBJECTIVE:	To determine the effectiveness of barrier membranes in bridge decks and develop a method for this determination.
DESCRIPTION:	A nondestructive method for determining the effectiveness of bridge deck membranes was developed by applying an ultrasonic pulse and measuring the velocity of the pulse through the deck surface.
CRITICAL EVALUATION:	None
APPLICABILITY ISSUES:	This technology is applicable only to bridge decks.

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER: 2017

PRODUCT TITLE: ASR-Safe Mix Designs

REPORT NUMBER(S) AND TITLE(S): SHRP-C-342: Alkali-Silica Reactivity: An Overview of Research

SHRP-C-343: Eliminating or Minimizing Alkali-Silica Reactivity

SHRP CATEGORY: Concrete and Structures

APPLICABILITY RATING: Directly Applicable

OBJECTIVE: To provide information that will enable engineers to minimize their risks of alkali-silica reactions in hardened concrete.

DESCRIPTION: Report C-342 is a literature review that is composed of three primary topics concerning alkali-silica reactivity: (1) mechanisms of damage to concrete, (2) factors affecting the severity of damage, and (3) gaps in our knowledge.

Report C-343 provides information on the development and implementation of a new, rapid test for evaluating aggregates for their potential for ASR. This mortar test, along with the knowledge gained from the literature review, could be used for ensuring ASR-safe concrete.

CRITICAL EVALUATION: The product is actually two SHRP reports from which helpful information can be extracted. The literature review presents both scientific principles and engineering experience that would be informative to designers who wish to avoid ASR in their concrete.

APPLICABILITY ISSUES: None

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	2018
PRODUCT TITLE:	Modified Freeze and Thaw Test
REPORT NUMBER(S) AND TITLE(S):	SHRP-C-391: Resistance of Concrete to Freezing and Thawing
SHRP CATEGORY:	Concrete and Structures
APPLICABILITY RATING:	Directly Applicable
OBJECTIVE:	To evaluate the parameters that have the greatest bearing on the resistance of concrete to freezing and thawing and determine if current test methods are adequate.
DESCRIPTION:	A comprehensive study of the parameters that most affect the freeze-thaw behavior of concrete was conducted leading to a modification of the current standard freeze-thaw test (AASHTO T 161 or ASTM C 666). The modification of the test is described in AASHTO TP17. The former test allowed the samples to dry after freezing by sublimation of water from the specimen due to the dry air present in the freezers. The current test keeps the specimens wrapped in moist towels to prevent sublimation. In addition, the current test does not allow the samples to be confined in a sample holder that may cause damage to the specimen due to confinement pressure within the sample holder upon freezing.
CRITICAL EVALUATION:	This test should be directly applicable to FAA concrete pavements in that this technology employs the latest data on freeze-thaw damage to concrete in an updated version of a standard test.
APPLICABILITY ISSUES:	None

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	2019
PRODUCT TITLE:	Soundness Test for Concrete
REPORT NUMBER(S) AND TITLE(S):	SHRP-C-391: Resistance of Concrete to Freezing and Thawing SHRP-C/UFR-92-617: Freeze-Thaw Resistance in Concrete - An Annotated Bibliography
SHRP CATEGORY:	Concrete and Structures
APPLICABILITY RATING:	Directly Applicable
OBJECTIVE:	To evaluate the condition of a concrete specimen using impact-frequency techniques.
DESCRIPTION:	The fundamental transverse frequency employed in the calculation of the durability factor (DF) is measured using an impact-frequency test. The test involves the use of an instrumented hammer to generate a vibratory wave throughout the specimen. The frequency response is measured by an accelerometer and is more than an order of magnitude more sensitive than previous methods. Model development of frost resistance using this technique was not accomplished due to a lack of sufficient data.
CRITICAL EVALUATION:	The use of the technique for determination of the durability factor should provide more accurate data than previous techniques due to the increased sensitivity. However, a lack of sufficient data to verify models for freeze-thaw resistance of concrete specimens was not accomplished.
APPLICABILITY ISSUES:	None

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	2020
PRODUCT TITLE:	Air Entrainment Specifications
REPORT NUMBER(S) AND TITLE(S):	SHRP-C-391: Resistance of Concrete to Freezing and Thawing SHRP-C/UFR-92-617: Freeze-Thaw Resistance in Concrete - An Annotated Bibliography SHRP-C/UFR-91-519: Quantitative and Rapid Measurement of the Air-Void System in Fresh Concrete
SHRP CATEGORY:	Concrete and Structures
APPLICABILITY RATING:	Directly Applicable
OBJECTIVE:	To provide a set of specifications that can be used to ensure that concrete is resistant to freeze-thaw damage.
DESCRIPTION:	The product title is somewhat misleading in that a set of specifications for the incorporation of air voids in concrete is not presented. However, the SHRP-C-391 report provides tabular data on the measured air voids and durability of concrete specimens. This data should be employed only as a guide for engineers in selection of concrete mixes with properties similar to tested samples.
CRITICAL EVALUATION:	A set of specifications for the incorporation of air voids into concrete to reduce freeze-thaw damage is not presented. Instead, a tabular summary of testing data for various specimens with differing air voids is presented.
APPLICABILITY ISSUES:	None

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER: 2021

PRODUCT TITLE: PCC Aggregate Specifications

REPORT NUMBER(S) AND TITLE(S):

SHRP-C-391: Resistance of Concrete to Freezing and Thawing

SHRP-C/UFR-92-617: Freeze-Thaw Resistance in Concrete - An Annotated Bibliography

SHRP CATEGORY: Concrete and Structures

APPLICABILITY RATING: Directly Applicable

OBJECTIVE: To provide a set of specifications that can be used to ensure that concrete is resistant to freeze-thaw damage.

DESCRIPTION: The SHRP aggregate durability test can be used to determine the susceptibility of concrete aggregates to freeze-thaw damage. Susceptibility to damage is quantified with an hydraulic fracture index (HFI). Aggregates with HFI values between 80 and 100 demonstrated less susceptibility to D-cracking than aggregates with HFI values less than 60.

CRITICAL EVALUATION: This product does not provide a set of specifications for the selection of aggregates that meet certain durability requirements, only general guidelines are presented.

APPLICABILITY ISSUES: None

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	2022
PRODUCT TITLE:	Guide to Strength/Maturity
REPORT NUMBER(S) AND TITLE(S):	SHRP-C-376: Field Manual for Maturity and Pullout Testing on Highway Structures
SHRP CATEGORY:	Concrete and Structures
APPLICABILITY RATING:	Directly Applicable
OBJECTIVE:	To provide a guide on the use of rapid field methods for the determination of early-age strengths for fresh concrete.
DESCRIPTION:	This guide describes the use of pullout testing to estimate the compressive strength of concrete mixes. A specially shaped steel insert placed in the fresh concrete upon laydown is pulled out, and the strength of that process is correlated with the compressive strength of the concrete. This test can be useful in determining when to remove concrete forms. Maturity testing is accomplished by measuring the temperature of the concrete which is related to the degree of hydration of the cement and ultimately to the strength.
CRITICAL EVALUATION:	These tests are easily conducted and provide important measures of concrete properties soon after placing the concrete. The equipment is inexpensive, the tests are easy to conduct, and the results correlate well with the strength properties of the concrete.
APPLICABILITY ISSUES:	None

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	2023
PRODUCT TITLE:	Flexural Strength Test
REPORT NUMBER(S) AND TITLE(S):	SHRP-C-362: Mechanical Behavior of High-Performance Concretes: Volume 2, Production of High-Performance Concrete SHRP-C-361: Mechanical Behavior of High-Performance Concretes: Volume 1, Summary Report SHRP-C-363: Mechanical Behavior of High-Performance Concretes: Volume 3, Very Early-Strength Concrete SHRP-C-364: Mechanical Behavior of High-Performance Concretes: Volume 4, High Early-Strength Concrete SHRP-C-365: Mechanical Behavior of High-Performance Concretes: Volume 5, Very High-Strength Concrete SHRP-C-366: Mechanical Behavior of High-Performance Concretes: Volume 6, High Early-Strength Fiber Reinforced Concrete SHRP-C-307: High-Performance Concretes: An Annotated Bibliography SHRP-C-317: High-Performance Concretes: A State-of-the-Art Report
SHRP CATEGORY:	Concrete and Structures
APPLICABILITY RATING:	Directly Applicable
OBJECTIVE:	To examine current concrete testing technology and determine if test methods can be improved or modified.
DESCRIPTION:	A modification to the current ASTM C 78 method of flexural testing of concrete beams is suggested. The modification involves the use of reinforcement at the center of gravity to eliminate sudden failure of the specimen and the possibility of equipment damage. In addition, flexural strain data are measured along with the applied load.
CRITICAL EVALUATION:	This test method suggests an improvement to the current ASTM method for evaluating the flexural strength of a concrete specimen and should be directly applicable to FAA pavements. The method employs the same testing

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apparatus as the ASTM C 78 method with slight modifications to the equipment.

APPLICABILITY ISSUES: None

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	2024
PRODUCT TITLE:	Compressive Strength Test
REPORT NUMBER(S) AND TITLE(S):	SHRP-C-364: Mechanical Behavior of High-Performance Concretes: Volume 4, High Early-Strength Concrete SHRP-C-361: Mechanical Behavior of High-Performance Concretes: Volume 1, Summary Report SHRP-C-362: Mechanical Behavior of High-Performance Concretes: Volume 2, Production of High-Performance Concrete SHRP-C-363: Mechanical Behavior of High-Performance Concretes: Volume 3, Very Early-Strength Concrete SHRP-C-365: Mechanical Behavior of High-Performance Concretes: Volume 5, Very High-Strength Concrete SHRP-C-366: Mechanical Behavior of High-Performance Concretes: Volume 6, High Early-Strength Fiber Reinforced Concrete SHRP-C-307: High-Performance Concretes: An Annotated Bibliography SHRP-C-317: High-Performance Concretes: A State-of-the-Art Report
SHRP CATEGORY:	Concrete and Structures
APPLICABILITY RATING:	Directly Applicable
OBJECTIVE:	To examine current concrete testing technology and determine if test methods can be improved or modified.
DESCRIPTION:	A modification to the current ASTM C 39 method of compressive testing of concrete specimens is suggested for accommodating high-performance concretes. The modification involves the use of steel caps and neoprene pads to replace the sulfur caps. Hardened sulfur cannot attain the strengths of high-performance concretes and therefore cannot serve as an effective capping agent. Steels caps and neoprene pads can be used for high-strength concrete. They are also quick and easy to use.

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CRITICAL EVALUATION: This test method suggests an improvement to the current ASTM method for evaluating the compressive strength of a concrete specimen and should be directly applicable to FAA pavements.

APPLICABILITY ISSUES: None

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	2025
PRODUCT TITLE:	Interfacial Bond Test
REPORT NUMBER(S) AND TITLE(S):	SHRP-C-307: High-Performance Concretes: An Annotated Bibliography SHRP-C-317: High-Performance Concretes: A State-of-the-Art Report SHRP-C-361: Mechanical Behavior of High-Performance Concretes: Volume 1, Summary Report SHRP-C-364: Mechanical Behavior of High-Performance Concretes: Volume 4, High Early-Strength Concrete
SHRP CATEGORY:	Concrete and Structures
APPLICABILITY RATING:	Directly Applicable
OBJECTIVE:	To examine current concrete bond testing technology and determine if test methods can be improved or modified.
DESCRIPTION:	This is a new test method for determining the interfacial strength of two concrete sections. It is intended to provide information on the strength of a bond formed when old concrete is overlaid with fresh concrete. The test is performed by casting an inverted L-shaped specimen against an upright L-shaped specimen. The two parts are then pulled apart under tension, subjecting the bonded area to direct shear.
CRITICAL EVALUATION:	This test method provides a means for determining if a concrete overlay will form a proper bond to the concrete layer below and should be of use to the FAA when concrete overlays are considered.
APPLICABILITY ISSUES:	None

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	2026
PRODUCT TITLE:	Permeability Test - Electrical Resistance
REPORT NUMBER(S) AND TITLE(S):	SHRP-C-361: Mechanical Behavior of High-Performance Concretes: Volume 1, Summary Report SHRP-C-364: Mechanical Behavior of High-Performance Concretes: Volume 4, High Early-Strength Concrete
SHRP CATEGORY:	Concrete and Structures
APPLICABILITY RATING:	Directly Applicable
OBJECTIVE:	To determine the critical parameters affecting permeability of concretes and determine a method of testing that provides a consistent, universal test for many different types of concretes.
DESCRIPTION:	An apparatus for determining permeability using AC impedance through salt solutions was designed and constructed. The resistivity of chloride solutions in saturated concrete provides a measure of the permeability of the concrete to chloride penetration. This is especially useful for determining the corrosion potential of reinforcing steel in different concretes.
CRITICAL EVALUATION:	The method can be used for measuring the permeability of bridge decks to intrusion by salts since the method employs conductivity of salt solutions to measure the permeability of the concrete. However, results from the this test method can also provide information concerning the water permeability of the concrete, which is important for durability considerations.
APPLICABILITY ISSUES:	Relationships between chloride ion permeability and water permeability are dependent on concrete chemistry. Therefore, results from this test should be used only to make general observations concerning water permeability as it relates to durability.

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	2027
PRODUCT TITLE:	Fresh-Concrete Water Content Test
REPORT NUMBER(S) AND TITLE(S):	SHRP-C-373: Optimization of Highway Concrete Technology
SHRP CATEGORY:	Concrete and Structures
APPLICABILITY RATING:	Directly Applicable
OBJECTIVE:	To provide a rapid, efficient test method for the determination of the amount of water in fresh concrete.
DESCRIPTION:	A test method for rapid determination of the amount of water in fresh concrete is described. A sample of concrete is weighed, placed in a microwave oven for 15 min and the residue weighed to determine the weight loss.
CRITICAL EVALUATION:	This is a rapid, efficient technique for determining the water content of fresh concrete. Due to the 15-min test time, this method could be used for quality assurance procedures, but not for quality control.
APPLICABILITY ISSUES:	None

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	2028
PRODUCT TITLE:	Test for Consolidation
REPORT NUMBER(S) AND TITLE(S):	SHRP-C-373: Optimization of Highway Concrete Technology
SHRP CATEGORY:	Concrete and Structures
APPLICABILITY RATING:	Directly Applicable
OBJECTIVE:	To provide a rapid field test method for determining if concrete has been properly consolidated.
DESCRIPTION:	A test method for determination of the degree of consolidation of fresh concrete is described. The method involves the use of nuclear gauge technology to determine relative density.
CRITICAL EVALUATION:	The test method is rapid, easy, and has direct application to high-quality airfield pavements for quality control during construction. The method may not be applicable to low-slump concrete due to difficulties in inserting the probes.
APPLICABILITY ISSUES:	None

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	2029
PRODUCT TITLE:	Sealer Effectiveness Methods
REPORT NUMBER(S) AND TITLE(S):	SHRP-S-327: Condition Evaluation of Concrete Bridges Relative to Reinforcement Corrosion, Volume 5: Methods for Evaluating the Effectiveness of Penetrating Sealers
SHRP CATEGORY:	Concrete and Structures
APPLICABILITY RATING:	Directly Applicable
OBJECTIVE:	To provide methods for determining the effectiveness of concrete sealers employed on bridge decks.
DESCRIPTION:	Two methods are described for evaluating the effectiveness of concrete penetrating sealers. The first is an electrical method, and the second is a water absorption method.
CRITICAL EVALUATION:	Although not directly related to FAA structures in that the technology is primarily employed for the evaluation of bridge decks, the methods themselves are entirely applicable to the evaluation of concrete sealers. In mitigation of D-cracking, sealers can be used to prevent further water intrusion through cracks and pores in the concrete and prevent saturation of the aggregate.
APPLICABILITY ISSUES:	None

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	2030
PRODUCT TITLE:	Chloride Content Test
REPORT NUMBER(S) AND TITLE(S):	SHRP-S-328: Condition Evaluation of Concrete Bridges Relative to Reinforcement Corrosion, Volume 6: Method for Field Determination of Total Chloride Content SHRP-S-331: Condition Evaluation of Concrete Bridges Relative to Reinforcement Corrosion, Volume 8: Procedure Manual
SHRP CATEGORY:	Concrete and Structures
APPLICABILITY RATING:	Not Applicable
OBJECTIVE:	Since chloride ion degradation of reinforcing steel in concrete bridges is a major problem in areas that employ salt as bridge deicing agents, this product provides a rapid field test for determining the level of chloride contamination in a bridge deck.
DESCRIPTION:	This product provides a rapid, inexpensive method for the determination of the chloride content in a concrete sample. The method entails the use of a specific ion probe to determine the concentration of chloride in a sample of powdered concrete.
CRITICAL EVALUATION:	None
APPLICABILITY ISSUES:	Chloride-containing compounds or any deicer considered to be corrosive to metal parts are not employed due to the potential for corrosion of aircraft parts.

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	2031
PRODUCT TITLE:	Permeability Test - Surface Air Flow
REPORT NUMBER(S) AND TITLE(S):	SHRP-S-330: Condition Evaluation of Concrete Bridges Relative to Reinforcement Corrosion, Volume 7: Method for Field Measurement of Concrete Permeability SHRP-S-331: Condition Evaluation of Concrete Bridges Relative to Reinforcement Corrosion, Volume 8: Procedure Manual
SHRP CATEGORY:	Concrete and Structures
APPLICABILITY RATING:	Directly Applicable
OBJECTIVE:	To provide a method for the rapid field measurement of concrete permeability.
DESCRIPTION:	A portable field device is described that applies a vacuum to the surface of the concrete and measures the air flow through the top 1/2 in. (1.25 cm) of the concrete.
CRITICAL EVALUATION:	This device is capable of determining the surface permeability of any concrete. Air permeability is of interest to airfield engineers since it relates directly to concrete durability.
APPLICABILITY ISSUES:	None

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	2032
PRODUCT TITLE:	Bridge Condition Evaluation Manual
REPORT NUMBER(S) AND TITLE(S):	SHRP-S-330: Condition Evaluation of Concrete Bridges Relative to Reinforcement Corrosion, Volume 7: Procedure Manual SHRP-S-331: Condition Evaluation of Concrete Bridges Relative to Reinforcement Corrosion, Volume 8: Procedure Manual
SHRP CATEGORY:	Concrete and Structures
APPLICABILITY RATING:	Not Applicable
OBJECTIVE:	To provide an up-to-date listing and description of current procedures for the evaluation and condition rating of bridge decks.
DESCRIPTION:	Lists procedures for the evaluation of bridge decks.
CRITICAL EVALUATION:	None
APPLICABILITY ISSUES:	This product is only for the evaluation of bridge decks.

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	2033
PRODUCT TITLE:	Manual on Chloride Removal
REPORT NUMBER(S) AND TITLE(S):	SHRP-S-347: Chloride Removal Implementation Guide
	SHRP-S-657: Electrochemical Chloride Removal and Protection of Concrete Bridge Components: Laboratory Studies
	SHRP-C-620: Evaluation of Norcure Process for Electrochemical Chloride Removal
	SHRP-S-669: Electrochemical Chloride Removal and Protection of Concrete Bridge Components: Field Studies
	SHRP-S-670: Control Criteria and Materials Performance Studies for Cathodic Protection of Reinforced Concrete
SHRP CATEGORY:	Concrete and Structures
APPLICABILITY RATING:	Not Applicable
OBJECTIVE:	To provide a current list of equipment and procedures necessary for the removal of chloride from concrete.
DESCRIPTION:	The types of equipment and the procedures employed for the electrochemical removal of chloride from bridge decks is detailed.
CRITICAL EVALUATION:	None
APPLICABILITY ISSUES:	Chloride-containing compounds or any deicer considered to be corrosive to metal parts are not employed due to the potential for corrosion of aircraft parts.

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	2034
PRODUCT NUMBER:	Cathodic Protection Manual
REPORT NUMBER(S) AND TITLE(S):	SHRP-S-372: Cathodic Protection of Highway Bridges: A Manual of Practice SHRP-S-310: Electrochemical Chloride Removal and Protection of Concrete Bridge Components SHRP-S-359: Technical Alert: Criteria for the Cathodic Protection of Reinforced Concrete Bridge Components SHRP-S-337: Cathodic Protection of Reinforced Bridge Elements: A State-of-the-Art Report SHRP-C/UWP-92-618: Cathodic Protection of Reinforced Concrete Bridge Components SHRP-ID/UFR-91-512: Feasibility Studies on Nondestructive Incorporation of a Conducting Polymer Anode Bed into Bridge Deck Concrete SHRP-ID/UFR-91-512: An Electrochemical Method for Detecting Ongoing Corrosion of Steel in a Concrete Structure with CP Applied SHRP-S-670: Control Criteria and Materials Performance Studies for Cathodic Protection of Reinforced Concrete SHRP-S-671: New Cathodic Protection Installations
SHRP CATEGORY:	Concrete
APPLICABILITY RATING:	Not Applicable
OBJECTIVE:	To provide a set of guidelines on the use of cathodic protection to prevent corrosion of bridge deck steel.
DESCRIPTION:	This product provides detailed explanations and guidelines for employing a variety of cathodic protection techniques. A set of standard specifications modeled after AASHTO guidelines is presented.
CRITICAL EVALUATION:	None
APPLICABILITY ISSUES:	Chloride-containing compounds or any deicer considered to be corrosive to metal parts are not employed due to the potential for corrosion of aircraft parts.

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	2035
PRODUCT TITLE:	Manual on Rapid Repair of Bridge Decks
REPORT NUMBER(S) AND TITLE(S):	SHRP-3-344: Concrete Bridge Protection and Rehabilitation: Chemical and Physical Techniques - Rapid Bridge Deck Protection, Repair, and Rehabilitation
SHRP CATEGORY:	Concrete and Structures
APPLICABILITY RATING:	Applicable with Minor Modifications
OBJECTIVE:	To provide a compilation of existing techniques, equipment, and materials for the rapid repair of failing bridge decks.
DESCRIPTION:	Various methods for the rapid protection and repair of bridge decks are presented along with the necessary equipment and materials. Methods include surface milling, polymer applications, high early-strength cementitious overlays, and partial-depth patching.
CRITICAL EVALUATION:	The methods and materials for the protection and repair of concrete are applicable to airfields. Although corrosion of steel is generally not a problem for airfields, preventing the ingree of water into the concrete is of interest for concrete durability (e.g., D-cracking and alkali-silica reactions).
APPLICABILITY ISSUES:	The techniques for concrete repair discussed in this product are intended for use on bridge decks but can be employed for airfield repair as well.

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	2036
PRODUCT TITLE:	Field Guide on Bridge Rehabilitation and Protection Options
REPORT NUMBER(S) AND TITLE(S):	SHRP-S-360: Concrete Bridge Protection, Repair and Rehabilitation Relative to Reinforcement Corrosion: A Methods Application Manual SHRP-S-658: Concrete Bridge Protection and Rehabilitation: Chemical and Physical Techniques SHRP-S-664: Concrete Bridge Protection and Rehabilitation: Chemical and Physical Techniques - Price and Cost Information SHRP-S-665: Concrete Bridge Protection and Rehabilitation: Chemical and Physical Techniques - Feasibility Studies of New Rehabilitation Techniques SHRP-S-666: Concrete Bridge Protection and Rehabilitation: Chemical and Physical Techniques - Corrosion Inhibitors and Polymers
SHRP CATEGORY:	Concrete and Structures
APPLICABILITY RATING:	Not Applicable
OBJECTIVE:	To provide a list of options for the highway engineer for repair and protection of bridge decks.
DESCRIPTION:	Various methods for the repair of bridge decks are presented along with the necessary equipment and materials for the repair project. The manual is designed to provide guidance for the highway engineer in selecting an appropriate method for bridge rehabilitation.
CRITICAL EVALUATION:	None
APPLICABILITY ISSUES:	This product primarily addresses corrosion of steel in concrete structures and, as such, is not applicable to airfield concrete repair.

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	2037
PRODUCT TITLE:	Manual for Selecting Bridge Rehabilitation and Protection Options
REPORT NUMBER(S) AND TITLE(S):	SHRP-S-377: Life-Cycle Cost Analysis for Protection and Rehabilitation of Concrete Bridges Relative to Reinforcement Corrosion SHRP-C/UFR-92-613: A Literature Review of Time-Deterioration Prediction Techniques
SHRP CATEGORY:	Concrete and Structures
APPLICABILITY RATING:	Not Applicable
OBJECTIVE:	To provide a manual detailing a list of options for selection of the most cost-effective procedure for repair and protection of bridge decks.
DESCRIPTION:	A set of methods are provided for determination of the most cost-effective and timely method for the type of distress needing repair is presented. This methodology is implemented in a handbook and computer program. The manual is designed to provide guidance for the highway engineer in selecting an appropriate method for bridge rehabilitation.
CRITICAL EVALUATION:	None
APPLICABILITY ISSUES:	This product is for bridge decks only.

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	2038
PRODUCT TITLE:	Computer Program For Bridge Rehabilitation and Protection Options
REPORT NUMBER(S) AND TITLE(S):	SHRP-C-406: Life-Cycle Cost Analysis for Protection and Rehabilitation of Concrete Bridges Relative to Reinforcement Corrosion
SHRP CATEGORY:	Concrete and Structures
APPLICABILITY RATING:	Not Applicable
OBJECTIVE:	To provide a computer program detailing a list of repair options for selecting the most cost-effective procedure for repair and protection of bridge decks.
DESCRIPTION:	A method is provided for determining the most cost-effective and timely repair technique for any particular type of distress. This methodology is implemented in a computer program. The manual is designed to provide guidance for the highway engineer in selecting an appropriate method for bridge rehabilitation.
CRITICAL EVALUATION:	None
APPLICABILITY ISSUES:	The manual is intended for use for bridge repair and is not applicable to airfield pavements.

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	2039
PRODUCT TITLE:	HWYCON - Concrete Expert System
REPORT NUMBER(S) AND TITLE(S):	SHRP-C/UWP-91-527: Expert/Knowledge-Based Systems For Cement and Concrete: State-of-the-art Report SHRP-C/UWP-91-527: Expert/Knowledge-Based Systems for Cement and Concrete: State-of-the-Art Report
SHRP CATEGORY:	Concrete and Structures
APPLICABILITY RATING:	Applicable with Minor Modifications
OBJECTIVE:	To provide a tool for the highway engineer that assists in the decision-making process pertaining to selection of a concrete repair process.
DESCRIPTION:	This is a menu-driven computer program that is designed to assist highway engineers in three areas: selection of materials and methods for pavement construction, diagnosis of pavement distresses, and selection of materials and methods for pavement rehabilitation. The program provides a list of source material (such as SHRP reports) dealing with concrete durability issues. A photographic database provides visual images of various concrete distresses.
CRITICAL EVALUATION:	The program is intended for applications to highway pavements and should not be used directly for airfield concrete pavements. However, it contains sections pertaining to concrete test methods and repair that may be of some use to the airfield pavement engineer.
APPLICABILITY ISSUES:	The program is primarily for application to concrete highway operations, but some of the information pertaining to concrete mixes, test methods, and repair may be useful to the airfield pavements engineers.

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	2040
PRODUCT TITLE:	Guidelines for Cathodic Protection
REPORT NUMBER(S) AND TITLE(S):	SHRP-S-670: Control Criteria and Materials Performance Studies for Cathodic Protection of Reinforced Concrete
SHRP CATEGORY:	Concrete and Structures
APPLICABILITY RATING:	Not Applicable
OBJECTIVE:	To provide a set of guidelines for the highway engineer to follow for the protection of bridge decks from chloride corrosion.
DESCRIPTION:	This manual provides a set of guidelines for use of cathodic protection of bridge decks.
CRITICAL EVALUATION:	None
APPLICABILITY ISSUES:	Cathodic protection of concrete on airfields is generally not necessary due to a lack of reinforcing steel in the concrete and the lack of use of corrosive deicing chemicals.

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	4001
PRODUCT TITLE:	Measuring Air Entrainment
REPORT NUMBER(S) AND TITLE(S):	SHRP-C-677: Fiber-Optic Airmeter
SHRP CATEGORY:	Concrete and Structures
APPLICABILITY RATING:	Directly Applicable
OBJECTIVE:	To provide a convenient method for measuring the air content of concrete during construction.
DESCRIPTION:	This technique employs the use of fiber-optic sensors which are placed in fresh or plastic concrete. The intensity of the reflected light from air bubbles is used to determine the content of air in the fresh concrete.
CRITICAL EVALUATION:	This technology is useful for determining the amount of air entrained in fresh concrete but suffers from weak probes that often fail during testing.
APPLICABILITY ISSUES:	This product has direct application to airfields in areas where air-entrained concrete is being used. The device can efficiently and quiclky measure the amount of entrained air which relates to the freeze-thaw durability of the concrete.

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	4003
PRODUCT TITLE:	Monitoring Cathodic Protection
REPORT NUMBER(S) AND TITLE(S):	SHRP-UFR-91-524: Evaluation of Electrochemical Impedance Techniques for Detecting Corrosion on Rebar in Reinforced Concrete
SHRP CATEGORY:	Concrete and Structures
APPLICABILITY RATING:	Not Applicable
OBJECTIVE:	To provide a method for monitoring bridge deck corrosion.
DESCRIPTION:	This device monitors bridge deck corrosion by employing ultra-low-frequency AC impedance spectroscopy (ULFACIS). It is rapid and easy to use, employing contact probes and a user-friendly software program.
CRITICAL EVALUATION:	None
APPLICABILITY ISSUES:	Cathodic protection of concretes on airfields is generally not necessary due to a lack of reinforcing steel in the concrete and the lack of use of corrosive deicing chemicals.

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	4009
PRODUCT TITLE:	Repairing Marine Structures
REPORT NUMBER(S) AND TITLE(S):	SHRP-S-405: Sprayed Zinc Galvanic Anodes for Concrete Marine Bridge Substructures
SHRP CATEGORY:	Concrete and Structures
APPLICABILITY RATING:	Not Applicable
OBJECTIVE:	Details a method for protection of concrete marine structures.
DESCRIPTION:	This product provides a description of the use of arc-sprayed zinc coatings that can be applied to a marine concrete structure to prevent corrosion due to the deleterious effects of saltwater.
CRITICAL EVALUATION:	None
APPLICABILITY ISSUES:	This product addresses the protection of concrete structures in contact with seawater and, as such, has little application to airfield pavements technology.

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APPENDIX C—STRATEGIC HIGHWAY RESEARCH PROGRAM HIGHWAY OPERATIONS PRODUCT REVIEWS

SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	3001
PRODUCT TITLE:	Snow Fence Guide
REPORT NUMBER(S) AND TITLE(S):	SHRP-H-320: Snow Fence Guide
SHRP CATEGORY:	Highway Operations
APPLICABILITY RATING:	Not Applicable
OBJECTIVE:	To provide guidance for design and placement of snow fences.
DESCRIPTION:	This guide provides details for proper design and placement of snow fences along highways to maximize snow retention and reduction of blowing snow in windy conditions. However, these devices are potential safety hazards since they may obstruct emergency landings and decrease visibility on the ground during fair weather.
CRITICAL EVALUATION:	None
APPLICABILITY ISSUES:	These devices are potential safety hazards since they may obstruct emergency landings and decrease visibility on the ground during fair weather.

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	3003
PRODUCT TITLE:	Pavement Repair Materials Guidelines
REPORT NUMBER(S) AND TITLE(S):	SHRP-H-349: Concrete Pavement Repair Manuals of Practice Manuals and Procedures for the Repair of Joint Seals in Concretes; Manuals and Procedures for the Rapid Repair of Partial-Depth Spalls in Concrete Pavements SHRP-H-348: Asphalt Pavement Repair Manuals of Practice Manuals and Procedures for Sealing and Filling Cracks in Asphalt-Surfaced Pavements; Manuals and Procedures for the Repair of Potholes in Asphalt-Surfaced Pavements
SHRP CATEGORY:	Highway Operations
APPLICABILITY RATING:	Applicable with Minor Modifications
OBJECTIVE:	To provide a concise, complete manual for good practices in the repair of joint seals and partial-depth spalling in concrete pavements. To provide a concise, complete manual for good practices in the repair of cracks and potholes in asphalt pavements.
DESCRIPTION:	The Concrete Pavement Repair Manual covers two specific areas of concrete repair: joint seals and partial-depth spalling. Guidelines for selection of sealants, backer rod, and primers are presented. Construction issues such as safety, joint preparation, sealant installation, and evaluation of sealant performance are included. The manual for spall repair covers planning and design considerations such as selection of materials for the design objective, methods for preparation of the repair area, and procedures for the spall repair. Both manuals also cover cost estimating and cost effectiveness of the repair procedure to be employed. The Asphalt Repair Manual covers two specific areas of repair: cracks and potholes. Guidelines for selection of crack sealants and primers are presented. Construction issues such as safety, crack preparation, sealant installation, and evaluation of sealant performance are included. The manual for pothole repair covers planning and design considerations such as selection of materials for the design objective, methods for preparation of the repair area, and procedures for the pothole repair. Both manuals also cover cost-estimating and cost-effectiveness of the repair procedure to be employed.

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CRITICAL EVALUATION: Provides a clear, concise manual for selection of sealant and spall-repair materials. Replacement of joint sealant and repair of spalls in aircraft parking areas should be conducted with fuel-resistant and hydraulic fluid-resistant materials. Provides a clear, concise manual for the selection of pothole repair materials. Pothole repair on airport pavements is generally not a serious problem. Application of these repair procedures will most often be necessary at smaller airfields that are constructed primarily of asphalt. Aircraft parking areas constructed with asphalt may need fuel-resistant sealants for crack repair.

APPLICABILITY ISSUES: This product has some applicability on airfields with concern for heavier loads and use of jet-fuel and hydraulic fluid-resistant sealers in aircraft parking areas.

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	3004
PRODUCT TITLE:	Robotic Crack-Filling Vehicle
REPORT NUMBER(S) AND TITLE(S):	SHRP-H-659: Fabrication and Testing of an Automated Crack Sealing Machine
SHRP CATEGORY:	Highway Operations
APPLICABILITY RATING:	Applicable with Minor Modification
OBJECTIVE:	To reduce the manpower and time associated with crack repair operations.
DESCRIPTION:	A robotic vehicle scans the pavement searching for cracks using vision sensors that are computer-controlled. Once a crack has been located, a robotic arm is extended to clean and fill the crack. The method is more consistent than a typical repair job and can be completed in less time.
CRITICAL EVALUATION:	This technology may shorten the time necessary for airfield crack-filling operations, thus reducing maintenance impact on airfield operations.
APPLICABILITY ISSUES:	Applicable with minor changes that include addressing potential problem areas such as jet fuel- and hydraulic-fluid resistant crack sealers for use in aircraft parking areas.

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	3005
PRODUCT TITLE:	Robotic Pothole Patching Vehicle
REPORT NUMBER(S) AND TITLE(S):	SHRP-H-674: Fabrication and Testing of Automatic Pothole Patching Machine
SHRP CATEGORY:	Highway Operations
APPLICABILITY RATING:	Directly Applicable
OBJECTIVE:	To reduce the manpower and time associated with pothole repair operations.
DESCRIPTION:	A one-person robotic vehicle can repair potholes without the person leaving the driver's seat. After locating the pothole and positioning the vehicle correctly, the edges of the pothole are cut, the loose fill is vacuumed, the cavity is dried using hot air, and the patching material is blown into the hole with considerable force and leveled flush with the pavement.
CRITICAL EVALUATION:	Potholes are generally not a problem on airfields due to lower traffic volumes.
APPLICABILITY ISSUES:	This technology may have some use on smaller airfields constructed primarily of asphalt.

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	3008
PRODUCT TITLE:	Ultrasonic Intrusion Alarm
REPORT NUMBER(S) AND TITLE(S):	SHRP-H-371: Maintenance Work-Zone Safety Devices - Development and Evaluation
SHRP CATEGORY:	Highway Operations
APPLICABILITY RATING:	Not Applicable
OBJECTIVE:	To evaluate devices for improving highway worker safety in traffic.
DESCRIPTION:	Several devices for improving work-zone safety are evaluated. These devices include: Opposing Traffic Lane Dividers, Portable Crash Cushion, Salt Spreader/Truck-Mounted Attenuator Interface, Queue-Length Detector, Snowplow Blade Markers, Ultrasonic Detection Alarm, Infrared Intrusion Alarm, Portable Rumble Strip, Portable Sign and Stand, Remotely Driven Vehicle, and Flashing Stop/Slow Paddle.
CRITICAL EVALUATION:	None
APPLICABILITY ISSUES:	Maintenance crews on airfields generally do not have similar hazards to traffic as do highway maintenance crews.

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	3009
PRODUCT TITLE:	Queue-Length Detector
REPORT NUMBER(S) AND TITLE(S):	SHRP-H-371: Maintenance Work-Zone Safety Devices - Development and Evaluation
SHRP CATEGORY:	Highway Operations
APPLICABILITY RATING:	Not Applicable
OBJECTIVE:	To evaluate devices for improving highway worker safety in traffic.
DESCRIPTION:	Several devices for improving work-zone safety are evaluated. These devices include: Opposing Traffic Lane Dividers, Portable Crash Cushion, Salt Spreader/Truck-Mounted Attenuator Interface, Queue-Length Detector, Snowplow Blade Markers, Ultrasonic Detection Alarm, Infrared Intrusion Alarm, Portable Rumble Strip, Portable Sign and Stand, Remotely Driven Vehicle, and Flashing Stop/Slow Paddle.
CRITICAL EVALUATION:	None
APPLICABILITY ISSUES:	Maintenance crews on airfields generally do not have similar hazards to traffic as do highway maintenance crews.

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	3010
PRODUCT TITLE:	Infrared Intrusion Alarm
REPORT NUMBER(S) AND TITLE(S):	SHRP-H-371: Maintenance Work-Zone Safety Devices - Development and Evaluation
SHRP CATEGORY:	Highway Operations
APPLICABILITY RATING:	Not Applicable
OBJECTIVE:	To evaluate devices for improving highway worker safety in traffic.
DESCRIPTION:	Several devices for improving work-zone safety are evaluated. These devices include: Opposing Traffic Lane Dividers, Portable Crash Cushion, Salt Spreader/Truck-Mounted Attenuator Interface, Queue-Length Detector, Snowplow Blade Markers, Ultrasonic Detection Alarm, Infrared Intrusion Alarm, Portable Rumble Strip, Portable Sign and Stand, Remotely Driven Vehicle, and Flashing Stop/Slow Paddle.
CRITICAL EVALUATION:	None
APPLICABILITY ISSUES:	Maintenance crews on airfields generally do not have similar hazards to traffic as do highway maintenance crews.

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	3011
PRODUCT TITLE:	Opposing Traffic Lane Divider
REPORT NUMBER(S) AND TITLE(S):	SHRP-H-371: Maintenance Work-Zone Safety Devices - Development and Evaluation
SHRP CATEGORY:	Highway Operations
APPLICABILITY RATING:	Not Applicable
OBJECTIVE:	To evaluate devices for improving highway worker safety in traffic.
DESCRIPTION:	Several devices for improving work-zone safety are evaluated. These devices include: Opposing Traffic Lane Dividers, Portable Crash Cushion, Salt Spreader/Truck-Mounted Attenuator Interface, Queue-Length Detector, Snowplow Blade Markers, Ultrasonic Detection Alarm, Infrared Intrusion Alarm, Portable Rumble Strip, Portable Sign and Stand, Remotely Driven Vehicle, and Flashing Stop/Slow Paddle.
CRITICAL EVALUATION:	None
APPLICABILITY ISSUES:	Maintenance crews on airfields generally do not have similar hazards to traffic as do highway maintenance crews.

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	3012
PRODUCT TITLE:	Multidirectional Barricade Sign
REPORT NUMBER(S) AND TITLE(S):	SHRP-H-371: Maintenance Work-Zone Safety Devices - Development and Evaluation
SHRP CATEGORY:	Highway Operations
APPLICABILITY RATING:	Not Applicable
OBJECTIVE:	To evaluate devices for improving highway worker safety in traffic.
DESCRIPTION:	Several devices for improving work-zone safety are evaluated. These devices include: Opposing Traffic Lane Dividers, Portable Crash Cushion, Salt Spreader/Truck-Mounted Attenuator Interface, Queue-Length Detector, Snowplow Blade Markers, Ultrasonic Detection Alarm, Infrared Intrusion Alarm, Portable Rumble Strip, Portable Sign and Stand, Remotely Driven Vehicle, and Flashing Stop/Slow Paddle.
CRITICAL EVALUATION:	None
APPLICABILITY ISSUES:	Maintenance crews on airfields generally do not have similar hazards to traffic as do highway maintenance crews.

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	3013
PRODUCT TITLE:	Remotely Driven Vehicle
REPORT NUMBER(S) AND TITLE(S):	SHRP-H-371: Maintenance Work-Zone Safety Devices - Development and Evaluation
SHRP CATEGORY:	Highway Operations
APPLICABILITY RATING:	Not Applicable
OBJECTIVE:	To evaluate devices for improving highway worker safety in traffic.
DESCRIPTION:	Several devices for improving work-zone safety are evaluated. These devices include: Opposing Traffic Lane Dividers, Portable Crash Cushion, Salt Spreader/Truck-Mounted Attenuator Interface, Queue-Length Detector, Snowplow Blade Markers, Ultrasonic Detection Alarm, Infrared Intrusion Alarm, Portable Rumble Strip, Portable Sign and Stand, Remotely Driven Vehicle, and flashing Stop/Slow Paddle.
CRITICAL EVALUATION:	None
APPLICABILITY ISSUES:	Maintenance crews on airfields generally do not have similar hazards to traffic as do highway maintenance crews.

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	3014
PRODUCT TITLE:	Portable Crash Cushion
REPORT NUMBER(S) AND TITLE(S):	SHRP-H-371: Maintenance Work-Zone Safety Devices - Development and Evaluation
SHRP CATEGORY:	Highway Operations
APPLICABILITY RATING:	Not Applicable
OBJECTIVE:	To evaluate devices for improving highway worker safety in traffic.
DESCRIPTION:	Several devices for improving work-zone safety are evaluated. These devices include: Opposing Traffic Lane Dividers, Portable Crash Cushion, Salt Spreader/Truck-Mounted Attenuator Interface, Queue-Length Detector, Snowplow Blade Markers, Ultrasonic Detection Alarm, Infrared Intrusion Alarm, Portable Rumble Strip, Portable Sign and Stand, Remotely Driven Vehicle, and Flashing Stop/Slow Paddle.
CRITICAL EVALUATION:	None
APPLICABILITY ISSUES:	Maintenance crews on airfields generally do not have similar hazards to traffic as do highway maintenance crews.

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	3015
PRODUCT TITLE:	Portable Rumble Strip
REPORT NUMBER(S) AND TITLE(S):	SHRP-H-371: Maintenance Work-Zone Safety Devices - Development and Evaluation
SHRP CATEGORY:	Highway Operations
APPLICABILITY RATING:	Not Applicable
OBJECTIVE:	To evaluate devices for improving highway worker safety in traffic.
DESCRIPTION:	Several devices for improving work-zone safety are evaluated. These devices include: Opposing Traffic Lane Dividers, Portable Crash Cushion, Salt Spreader/Truck-Mounted Attenuator Interface, Queue-Length Detector, Snowplow Blade Markers, Ultrasonic Detection Alarm, Infrared Intrusion Alarm, Portable Rumble Strip, Portable Sign and Stand, Remotely Driven Vehicle, and flashing Stop/Slow Paddle.
CRITICAL EVALUATION:	None
APPLICABILITY ISSUES:	Maintenance crews on airfields generally do not have similar hazards to traffic as do highway maintenance crews.

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	3016
PRODUCT TITLE:	Flashing Stop/Slow Paddle
REPORT NUMBER(S) AND TITLE(S):	SHRP-H-371: Maintenance Work-Zone Safety Devices - Development and Evaluation
SHRP CATEGORY:	Highway Operations
APPLICABILITY RATING:	Not Applicable
OBJECTIVE:	To evaluate devices for improving highway worker safety in traffic.
DESCRIPTION:	Several devices for improving work-zone safety are evaluated. These devices include: Opposing Traffic Lane Dividers, Portable Crash Cushion, Salt Spreader/Truck-Mounted Attenuator Interface, Queue-Length Detector, Snowplow Blade Markers, Ultrasonic Detection Alarm, Infrared Intrusion Alarm, Portable Rumble Strip, Portable Sign and Stand, Remotely Driven Vehicle, and Flashing Stop/Slow Paddle.
CRITICAL EVALUATION:	None
APPLICABILITY ISSUES:	Maintenance crews on airfields generally do not have similar hazards to traffic as do highway maintenance crews.

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	3017
PRODUCT TITLE:	Portable All-Terrain Sign Stand
REPORT NUMBER(S) AND TITLE(S):	SHRP-H-371: Maintenance Work-Zone Safety Devices - Development and Evaluation
SHRP CATEGORY:	Highway Operations
APPLICABILITY RATING:	Not Applicable
OBJECTIVE:	To evaluate devices for improving highway worker safety in traffic.
DESCRIPTION:	Several devices for improving work-zone safety are evaluated. These devices include: Opposing Traffic Lane Dividers, Portable Crash Cushion, Salt Spreader/Truck-Mounted Attenuator Interface, Queue-Length Detector, Snowplow Blade Markers, Ultrasonic Detection Alarm, Infrared Intrusion Alarm, Portable Rumble Strip, Portable Sign and Stand, Remotely Driven Vehicle, and flashing Stop/Slow Paddle.
CRITICAL EVALUATION:	None
APPLICABILITY ISSUES:	Maintenance crews on airfields generally do not have similar hazards to traffic as do highway maintenance crews.

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	3018
PRODUCT TITLE:	Radar for Pavement Subsurface Condition
REPORT NUMBER(S) AND TITLE(S):	SHRP-H-672: Development of Ground-Penetrating Radar Equipment for Detecting Pavement Condition for Preventive Maintenance SHRP-UWP-91-513: Measuring Systems and Instrumentation for Evaluating the Effectiveness of Pavement Maintenance
SHRP CATEGORY:	Highway Operations
APPLICABILITY RATING:	Applicable with Minor Modifications
OBJECTIVE:	To develop a nondestructive method of assessing subsurface conditions using Ground Penetrating Radar (GPR).
DESCRIPTION:	The GPR system transmits and receives radar frequencies that allow layers as thin as 38.1 mm to be detected. This allows rapid analysis of the thickness of the various layers of a pavement. Different frequencies must be employed for the efficient and accurate analysis of different types and thicknesses of pavements. The systems can be used to identify buried utilities and other subsurface objects.
CRITICAL EVALUATION:	This is relatively new technology that has large potential for analysis of FAA pavement structures. The resolution of the technique is now sufficient for accurate determination of different pavement layer thicknesses and analysis of subsurface features.
APPLICABILITY ISSUES:	GPR is relatively new technology that is just beginning to be widely applied as more powerful systems that have application to a variety of pavement types and thicknesses become available. The newer systems may be better able to handle a variety of pavement types and thickness than early GPR prototypes. The major modification necessary for application to airfield pavements technology is the higher power required for penetrating thick pavements.

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	3019
PRODUCT TITLE:	Seismic Pavement Analyzer Method
REPORT NUMBER(S) AND TITLE(S):	SHRP-H-374: Seismic Pavement Analyzer Operations Manual with Technical Specifications SHRP-H-375: Development and Testing of a Seismic Pavement Analyzer
SHRP CATEGORY:	Highway Operations
APPLICABILITY RATING:	Applicable with Minor Modifications
OBJECTIVE:	To develop a nondestructive method using seismic wave technology to assess the condition of a pavement.
DESCRIPTION:	The system consists of a low-frequency (up to 1 kHz) and a high-frequency (up to 50 kHz) generator, load cells, five accelerometers, and three velocity transducers. This device is mounted on a trailer and can be towed behind a car or truck. The system can detect voids under joints of rigid pavements, delamination of overlays, cracking, and asphalt aging. The device can be used to determine the need for preventive maintenance and should be very useful in scheduling maintenance on pavement structures.
CRITICAL EVALUATION:	This is new technology which is still in the formative stages but holds considerable promise for evaluation of airfield pavements. The particular frequencies, load cell arrangements, and accelerometer and transducer types may require some changes for analysis of thick, heavy-duty pavements.
APPLICABILITY ISSUES:	The technique is applicable to airfield pavements but may require minor changes to the equipment used to probe thicker, heavy-duty pavements.

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	3020
PRODUCT TITLE:	Handbook on Deicer Test Methods
REPORT NUMBER(S) AND TITLE(S):	SHRP-H-332: Handbook of Test Methods for Evaluating Chemical Deicers SHRP-H-308: Evaluation Procedures for Deicing Chemicals and Improved Sodium Chloride
SHRP CATEGORY:	Highway Operations
APPLICABILITY RATING:	Not Applicable
OBJECTIVE:	To establish a set of criteria and test methods for evaluating chemical deicers.
DESCRIPTION:	A comprehensive literature survey was conducted to locate potential chemical deicers and the various test methods employed to evaluate these materials. Sixty-two test methods are described for evaluating the eight principal performance characteristics of these materials. These characteristics range from the materials physicochemical characteristics to health and safety issues.
CRITICAL EVALUATION:	None
APPLICABILITY ISSUES:	Potential applicability issues include the possibility of corrosion and fouling of aircraft, friction on runways after application, and environmental considerations due to runoff. Chemical methods for deicing airfield pavement surfaces are typically not employed for safety reasons.

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	3021
PRODUCT TITLE:	Salt Spreader Truck-Mounted Attenuator
REPORT NUMBER(S) AND TITLE(S):	SHRP-H-371: Maintenance Work-Zone Safety Devices - Development and Evaluation
SHRP CATEGORY:	Highway Operations
APPLICABILITY RATING:	Not Applicable
OBJECTIVE:	To improve the safety of salt spreaders by mounting a crash cushion on the rear end of the vehicle that also functions as a salt spreader.
DESCRIPTION:	A modified salt spreader is described that has a dual function as a crash attenuation device. Poor visibility in snowy, windy conditions demands that a slow-moving vehicle such as a salt spreader has a crash attenuation device on the rear of the vehicle to attempt to prevent serious injury in the case of a rear-end collision.
CRITICAL EVALUATION:	None
APPLICABILITY ISSUES:	Deicing procedures on airfield pavements are generally not employed for safety and corrosion concerns.

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	3022
PRODUCT TITLE:	Snowplow Cutting Edge
REPORT NUMBER(S) AND TITLE(S):	SHRP-H-346: Improved Cutting Edges for Ice Removal
SHRP CATEGORY:	Highway Operations
APPLICABILITY RATING:	Directly Applicable
OBJECTIVE:	To improve the design of snowplow cutting blades for more efficient removal of snow and ice from pavement surfaces.
DESCRIPTION:	An improved cutting edge is described that is more efficient at removal of ice and packed snow from the pavement surface than previous designs. The blade edge is constructed from tungsten carbide and has a small clearance angle between the edge and the pavement.
CRITICAL EVALUATION:	None
APPLICABILITY ISSUES:	In areas where snowplows are employed for snow and ice removal from airfield traffic areas, these new blades constitute a significant improvement over old designs.

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	3023
PRODUCT TITLE:	Road Weather Information Systems
REPORT NUMBER(S) AND TITLE(S):	SHRP-H-350: Road Weather Information Systems Volume 1: Research Report SHRP-H-351: Road Weather Information Systems Volume 2: Implementation Guide
SHRP CATEGORY:	Highway Operations
APPLICABILITY RATING:	Not Applicable
OBJECTIVE:	To provide guidance for snow and ice removal operations using local weather predictions for cost reduction.
DESCRIPTION:	A synopsis of roadway snow and ice removal operations is presented along with the use of local weather prediction for target areas. The results of field tests for determining the location of road weather information stations (RWIS) is also presented.
CRITICAL EVALUATION:	None
APPLICABILITY ISSUES:	This technology is useful for highway systems that require efficient use of roadway snow and ice removal operations over large geographic areas.

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	3024
PRODUCT TITLE:	Anti-Icing Operations Guide
REPORT NUMBER(S) AND TITLE(S):	SHRP-H-385: Development of Anti-Icing Technology
SHRP CATEGORY:	Highway Operations
APPLICABILITY RATING:	Not Applicable
OBJECTIVE:	To provide a better understanding of conditions for anti-icing operations and efficient methods of implementation.
DESCRIPTION:	Studies were performed by nine state highway agencies determined that the proper time for application of anti-icing agents is immediately after the road begins to ice. This timely application was shown to prevent the reformation of the ice-pavement bond more effectively than if a substantial buildup of ice occurred before application of a deicer.
CRITICAL EVALUATION:	None
APPLICABILITY ISSUES:	Potential applicability issues include the possibility of corrosion and fouling of aircraft, friction on runways after application, and environmental considerations due to runoff. Chemical methods for deicing airfield pavement surfaces are typically not employed for safety reasons.

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	3025
PRODUCT TITLE:	Snow Fence Engineering Design Manual
REPORT NUMBER(S) AND TITLE(S):	SHRP-H-381: Design Guidelines for the Control of Blowing and Drifting Snow
SHRP CATEGORY:	Highway Operations
APPLICABILITY RATING:	Not Applicable
OBJECTIVE:	Provide an improved system for the design of snow fences to control blowing snow and for reducing the concentration of air-blown snow.
DESCRIPTION:	Snow fences can be employed around highways and airfields to prevent snow buildup on runways and to increase ground visibility by prevention of blowing snow. This study demonstrates the effective use of snow fences and how these devices are important safety devices when properly constructed and placed.
CRITICAL EVALUATION:	None
APPLICABILITY ISSUES:	These devices are potential safety hazards since they may obstruct emergency landings and decrease visibility on the ground during fair weather.

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	3026
PRODUCT TITLE:	Snowplow Scoop
REPORT NUMBER(S) AND TITLE(S):	Not Available
SHRP CATEGORY:	Highway Operations
APPLICABILITY RATING:	Directly Applicable
OBJECTIVE:	To design an improved snowplow blade for facilitating the removal of snow from the blade surface.
DESCRIPTION:	A 25.4-mm-thick scoop of ultra-high molecular weight polyethylene that attaches to the front of almost any existing snowplow blade is described. This blade improves the efficiency of older blades by smoothing the flow of snow onto the moldboard, reducing the force on the plow, and saving fuel.
CRITICAL EVALUATION:	None
APPLICABILITY ISSUES:	This device can be utilized on snowplows where snow and ice removal from aircraft operating areas is necessary.

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	3027
PRODUCT TITLE:	Snowplow Design Manual
REPORT NUMBER(S) AND TITLE(S):	Not Available
SHRP CATEGORY:	Highway Operations
APPLICABILITY RATING:	Directly Applicable
OBJECTIVE:	To design improved snowplows for rapid removal of snow and ice from pavement surfaces while reducing operating costs.
DESCRIPTION:	Computer simulations of various snowplow blade designs were conducted to determine the most efficient blade designs. These designs were then constructed and tested to determine the most efficient and cost-effective design. Various designs can be utilized depending on the particular mode of operation: high cast, log cast, high speed, or low speed.
CRITICAL EVALUATION:	None
APPLICABILITY ISSUES:	These new snowplow designs are more efficient than current snow plows and may result in cost and time savings for snow removal.

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	3030
PRODUCT TITLE:	Anti-icing Equipment Evaluation
REPORT NUMBER(S) AND TITLE(S):	SHRP-H-385: Development of Anti-Icing Technology
SHRP CATEGORY:	Highway Operations
APPLICABILITY RATING:	Not Applicable
OBJECTIVE:	To determine the effectiveness of spreader equipment in controlling dosage rates and spray patterns.
DESCRIPTION:	Studies were performed to determine how the spray pattern and dosage rate affects anti-icing.
CRITICAL EVALUATION:	None
APPLICABILITY ISSUES:	Deicing procedures on airfield pavements are generally not employed for safety and corrosion concerns.

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	3031
PRODUCT TITLE:	Anti-icing Application Rates
REPORT NUMBER(S) AND TITLE(S):	SHRP-H-385: Development of Anti-Icing Technology
SHRP CATEGORY:	Highway Operations
APPLICABILITY RATING:	Applicable with Minor Modifications
OBJECTIVE:	To determine proper application rates and times for optimum snow and ice removal, prevention of snow and ice buildup, and cost efficiency.
DESCRIPTION:	Studies performed by nine state highway agencies determined that the proper time for application of anti-icing agents is immediately after the road begins to ice. The application of the anti-icing agent immediately after icing has begun prevents the reformation of the ice-pavement bond more effectively than if a substantial buildup of ice occurred.
CRITICAL EVALUATION:	None
APPLICABILITY ISSUES:	Deicing procedures on airfield pavements are generally not employed for safety and corrosion concerns.

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	3032
PRODUCT TITLE:	Anti-Icing Chemical Evaluation
REPORT NUMBER(S) AND TITLE(S):	SHRP-H-385: Development of Anti-Icing Technology
SHRP CATEGORY:	Highway Operations
APPLICABILITY RATING:	Not Applicable
OBJECTIVE:	To determine the efficiency of different chemical deicers.
DESCRIPTION:	Application of deicing agents immediately prior to formation of the ice-pavement bond has drastically affected the formation of ice sheets on the pavement. Deicing application times, dosage rates, and frequency have been evaluated to determine the best times for anti-icing operations.
CRITICAL EVALUATION:	None
APPLICABILITY ISSUES:	Deicing procedures on airfield pavements are generally not employed for safety and corrosion concerns.

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	3033
PRODUCT TITLE:	Manual on Rating Preventive Maintenance
REPORT NUMBER(S) AND TITLE(S):	SHRP-H-322: Development of a Procedure to Rate the Application of Preventive Maintenance Treatments SHRP-H-348: Asphalt Pavement Repair Manuals of Practice Manuals and Procedures for Sealing and Filling Cracks in Asphalt-Surfaced Pavements Manuals and Procedures for the Repair of Potholes in Asphalt-Surfaced Pavements SHRP-H-358: Pavement Maintenance Effectiveness
SHRP CATEGORY:	Highway Operations
APPLICABILITY RATING:	Applicable with Major Modifications
OBJECTIVE:	To establish a rating scheme for quantifying the diverse factors involved in pavement maintenance.
DESCRIPTION:	The purpose of the manual is to provide a rating method or procedure to quantify the quality of application of preventive maintenance treatments for flexible pavements. Three maintenance treatments selected for this study were chip seals, slurry seals, and crack sealing. To rate the treatment quality, information pertinent to the application was collected. This included a number of diverse variables such as application temperatures, application rates, humidity, pavement cleanliness, aggregate moisture content, etc. A rating tree was developed to evaluate the variables and criteria for each treatment. Individual rating trees were generated through a combination of decision tree theory and utility theory. The trees rate the variables individually and then combine the individual variable measures to provide an overall rating for the treatment. This overall rating provided by the rating tree is indicative of how well the treatment was applied and possibly will be helpful as an indicator of future performance.
CRITICAL EVALUATION:	Analysis of the rating schemes allowed a set of specifications for proper application to be drafted. Excluding crack sealing, these specifications have limited use on major airfields but could potentially be utilized on small airfields where chip or slurry seals are allowed. The rating system is only for the quality of application of the pavement seal and not for the performance or expected performance. These methods cannot be used to compare the effectiveness of different pavement treatments but does allow for a standardized procedure for rating the quality of application of a pavement maintenance technique.

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APPLICABILITY ISSUES:	Since pavement maintenance treatments are not routinely employed on airfield pavements, these rating trees have limited use. However, they may have some applicability for rating fuel-resistant sealers.

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	3034
PRODUCT TITLE:	Specifications for Preventive Maintenance
REPORT NUMBER(S) AND TITLE(S):	SHRP-H-380: Making Pavement Maintenance More Effective - Training Supplement SHRP-H-358: Pavement Maintenance Effectiveness
SHRP CATEGORY:	Highway Operations
APPLICABILITY RATING:	Applicable with Minor Modifications
OBJECTIVE:	To provide a set of specifications for the application of pavement maintenance treatments.
DESCRIPTION:	This product provides a set of specifications to be followed during the application of pavement maintenance treatments for both flexible and rigid pavements in different climatic regions. A compilation of the specifications are provided in SHRP report H-322. The specifications are used to ensure that the application of the treatment is performed under conditions suitable for a quality application. These specifications are presented in a construction bid format.
CRITICAL EVALUATION:	Except for the crack sealing, these methods have limited use on major airfields but could potentially be utilized on small airfields where chip or slurry seals are allowed. The rating system is only for the quality of application of the pavement maintenance treatment and not for the performance or expected performance.
APPLICABILITY ISSUES:	Only the procedures and specifications for crack sealing have applicability to airfield pavements. These specifications can be utilized to ensure that the contractor follows strict procedures on the preparation of cracks and on placement of sealant material. These procedures may also have some application for evaluation of fuel-resistant sealers.

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	3035
PRODUCT TITLE:	Epoxy Core Test for Void Distribution
REPORT NUMBER(S) AND TITLE(S):	SHRP-H-348: Asphalt Pavement Repair Manuals of Practice SHRP-H-358: Pavement Maintenance Effectiveness
SHRP CATEGORY:	Highway Operations
APPLICABILITY RATING:	Directly Applicable
OBJECTIVE:	To facilitate undersealing operations by providing indications of void size prior to grouting and by providing a quality assurance tool after grouting.
DESCRIPTION:	Prior to the undersealing operation, either a neat epoxy (dyed red) or an epoxy-sand mixture is poured into access holes that penetrate through the full thickness of the concrete slab. The volume of epoxy provides an indication of the volume of void that has formed underneath. This information is useful as a performance evaluation tool because it indicates the severity of void formation. After the grout has hardened, cores that extend down to the base course can be removed and inspected. If the core includes red epoxy, the inspector knows that the initial void (prior to undersealing) extended at least to that particular location. If the core also shows signs of grout beneath the red epoxy, the inspector knows that the grout was able to reach that core location. A thick layer of grout beneath the red epoxy would indicate that the slab was probably lifted.
CRITICAL EVALUATION:	This test can be employed for evaluating pavement performance and for determining the effectiveness of undersealing operations. Due to the requirement for core holes in addition to those for normal grouting procedures, this test would most likely be used in selected cases.
APPLICABILITY ISSUES:	None

(Sheet 1 of 1)

SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	4006
PRODUCT TITLE:	Customized Weather Prediction System
REPORT NUMBER(S) AND TITLE(S):	SHRP-H-333: Intelligent and Localized Weather Prediction
SHRP CATEGORY:	Highway Operations
APPLICABILITY RATING:	Not Applicable
OBJECTIVE:	To provide a weather prediction system for improving the logistics for snow and ice control on highways.
DESCRIPTION:	A localized weather prediction system that accounts for local terrain and weather reports for improving the response of local operators that are resonsible for control of snow and ice buildup on highways.
CRITICAL EVALUATION:	This technology is useful for highway systems that require efficient use of roadway snow and ice removal operations.
APPLICABILITY ISSUES:	None

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APPENDIX D—STRATEGIC HIGHWAY RESEARCH PROGRAM PAVEMENT ENGINEERING PRODUCT REVIEWS

SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	4002
PRODUCT TITLE:	Capacitance Strip-Weigh-in Motion Sensor
REPORT NUMBER(S) AND TITLE(S):	SHRP-UFR-91-518: A Study of Road Damage Due to Dynamic Wheel Loads Using a Load Measuring Mat
SHRP CATEGORY:	Pavement Engineering
APPLICABILITY RATING:	Applicable with Major Modifications
OBJECTIVE:	To determine the feasibility of using weigh-in motion sensors for determining dynamic wheel loads from heavy vehicles.
DESCRIPTION:	This device can measure the weight of a vehicle as it passes over a capacitance strip placed in the vehicle's path. The actual load of a vehicle moving at highway speeds can be determined.
CRITICAL EVALUATION:	This device is designed for highway loads and cannot be directly applied to measuring heavy aircraft weights. However, this device could be employed to determine aircraft weights for aircraft on smaller airfields.
APPLICABILITY ISSUES:	Due to the lower weights of highway vehicles compared to large aircraft, this product would have little use on major airports but may have utility for measuring aircraft loads during taxi on smaller airports.

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	4008
PRODUCT TITLE:	Software for Measuring Pavement Layer Thickness
REPORT NUMBER(S) AND TITLE(S):	SHRP-P-397: Ground Penetrating Radar Surveys to Characterize Pavement Layer Thickness Variations at GPS Sites
SHRP CATEGORY:	Pavement Engineering
APPLICABILITY RATING:	Directly Applicable
OBJECTIVE:	To provide a user-friendly software package for the determination of pavement layer thicknesses from ground-penetrating radar (GPR) data.
DESCRIPTION:	The software provides a rapid analysis of GPR signals and determines the pavement layer thicknesses at specified intervals.
CRITICAL EVALUATION:	The software is useful for displaying the data from the SHRP GPR system; however, there are several sources of GPR display software that may be employed to display these types of data. However, the accuracy of this technology for airfields has not been evaluated.
APPLICABILITY ISSUES:	GPR is a relatively new technology that is just beginning to be widely applied as more powerful systems that have application to a variety of pavement types and thicknesses become available. There are several sources of GPR display software available.

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	5001
PRODUCT TITLE:	LTPP Information Management Systems (IMS)
REPORT NUMBER(S) AND TITLE(S):	SHRP-P-621: Development of the LTPP Climatic Database SHRP-P-679: Long-Term Pavement Performance Information Management System (LTPP): Five-Year Report
SHRP CATEGORY:	Pavement Engineering
APPLICABILITY RATING:	Applicable with Major Modifications
OBJECTIVE:	To construct a user-friendly and easily accessible database for managing the vast amount of information gathered for the Long-Term Pavement Performance survey.
DESCRIPTION:	A database has been constructed to help manage the large amount of information being generated by the LTPP. This includes climatic information as well as pavement data.
CRITICAL EVALUATION:	Some of the climatic data may be of use.
APPLICABILITY ISSUES:	The database has been set up for highway applications but contains a large amount of weather information that may be of limited use to airport officials.

(Sheet 1 of 1)

SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	5003
PRODUCT TITLE:	Falling Weight Deflectometer (FWD) Relative Calibration
REPORT NUMBER(S) AND TITLE(S):	SHRP-P-652: Falling Weight Deflectometer Relative Calibration Analysis SHRP-P-654: SHRP Procedure for Temperature Correction of Maximum Deflections
SHRP CATEGORY:	Pavement Engineering
APPLICABILITY RATING:	Applicable with minor modifications
OBJECTIVE:	To provide a relative calibration method for comparison of deflections obtained from different FWD units.
DESCRIPTION:	A statistical comparison of deflections from different FWD units is performed to determine sensor integrity. This process is conducted using the FWDCAL software (SHRP Product 5006). A special mounting bracket for location of the LVDT sensors is necessary and is available from the FWD manufacturer. This is to ensure that all testing sensors are in the same location and receive the same impulse during calibration. The sensors are rotated through different positions to ensure consistency of response.
CRITICAL EVALUATION:	The loads used for the calibration procedures may not be sufficient for airfield pavement structures and may require minor changes for calibration of units for analysis of airfield pavement loads.
APPLICABILITY ISSUES:	None

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	5004
PRODUCT TITLE:	Falling Weight Deflectometer (FWD) Reference Calibration
REPORT NUMBER(S) AND TITLE(S):	SHRP-P-634: Analysis of Section Homogeneity, Non-Representative Test Pit and Section Data, and Structural Capacity (FWDCHECK Version 2.00) Volume II - User's Guide SHRP-P-635: Analysis of Section Homogeneity, Non-Representative Test Pit and Section Data, and Structural Capacity (FWDCHECK Version 2.00) Volume III - Program Listing
SHRP CATEGORY:	Pavement Engineering
APPLICABILITY RATING:	Applicable with minor modifications
OBJECTIVE:	To provide a reference calibration method for comparison to an independent standard.
DESCRIPTION:	This method utilizes a technique for calibration of individual FWDs using independent references according to NIST standards. This process is performed using the FWDREFCL program (SHRP Product 5005).
CRITICAL EVALUATION:	The loads used for the calibration procedures may not be sufficient for airfield pavement structures and may require minor changes for calibration of units for analysis of airfield pavement loads.
APPLICABILITY ISSUES:	None

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	5005
PRODUCT TITLE:	FWDREFCAL Program for Calibration
REPORT NUMBER(S) AND TITLE(S):	SHRP-P-634: Analysis of Section Homogeneity, Non-Representative Test Pit and Section Data, and Structural Capacity (FWDCHECK Version 2.00) Volume II - User's Guide SHRP-P-635: Analysis of Section Homogeneity, Non-Representative Test Pit and Section Data, and Structural Capacity (FWDCHECK Version 2.00) Volume III - Program Listing
SHRP CATEGORY:	Pavement Engineering
APPLICABILITY RATING:	Applicable with minor modifications
OBJECTIVE:	To provide a user-friendly software package for implementation of the SHRP FWD reference calibration.
DESCRIPTION:	This software utilizes a NIST reference standard for comparison to deflections from individual FWDs. The software provides a set of adjustment factors for manipulation of FWD response that ensures accurate measurements.
CRITICAL EVALUATION:	The reference standard can be used directly for calibration of FWD systems intended for use on airfield pavements.
APPLICABILITY ISSUES:	None

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	5006
PRODUCT TITLE:	FWDCAL Program for Calibration - FWD Relative Calibration
REPORT NUMBER(S) AND TITLE(S):	SHRP-P-634: Analysis of Section Homogeneity, Non-Representative Test Pit and Section Data, and Structural Capacity (FWDCHECK Version 2.00) Volume II - User's Guide SHRP-P-635: Analysis of Section Homogeneity, Non-Representative Test Pit and Section Data, and Structural Capacity (FWDCHECK Version 2.00) Volume III - Program Listing
SHRP CATEGORY:	Pavement Engineering
APPLICABILITY RATING:	Applicable with minor modifications
OBJECTIVE:	To provide a user-friendly software package for conducting relative FWD calibrations.
DESCRIPTION:	The FWDCAL software is designed to provide a statistical analysis of variance that allows the identification of error sources (i.e., sensor position, individual sensor deflection, and random error). The software advises the operator on what type of correction is needed, if any, for proper calibration.
CRITICAL EVALUATION:	The parameters employed in the software are intended for highway loads and may not be applicable to airfield applications.
APPLICABILITY ISSUES:	None

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	5007
PRODUCT TITLE:	FWDCHECK program for Quality Assurance
REPORT NUMBER(S) AND TITLE(S):	SHRP-P-633: Analysis of Section Homogeneity, Non-Representative Test Pit and Section Data, and Structural Capacity (FWDCHECK Version 2.00) Volume I - Technical Report SHRP-P-634: Analysis of Section Homogeneity, Non-Representative Test Pit and Section Data, and Structural Capacity (FWDCHECK Version 2.00) Volume II- User's Guide SHRP-P-635: Analysis of Section Homogeneity, Non-Representative Test Pit and Section Data, and Structural Capacity (FWDCHECK Version 2.00) Volume III - Program Listing
SHRP CATEGORY:	Pavement Engineering
APPLICABILITY RATING:	Applicable with minor modifications
OBJECTIVE:	To provide a software package for preliminary evaluation of FWD deflection data from LTPP sites.
DESCRIPTION:	The FWDCHECK software checks for section homogeneity, anomalous data points, and proper calculations of slab thickness and subgrade modulus for rigid pavements. The software checks the FWD data to ensure that the collected data is valid for use in pavement management.
CRITICAL EVALUATION:	The software is optimized for highway uses and may not be applicable for analysis of airfield pavements.
APPLICABILITY ISSUES:	None

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	5008
PRODUCT TITLE:	FWDCHECK Program for Quality Assurance
REPORT NUMBER(S) AND TITLE(S):	SHRP-UWP-92-615: Data Readability and Completeness FWDSCAN Version 1.30 Program Background and User's Guide
SHRP CATEGORY:	Highway Operations
APPLICABILITY RATING:	Applicable with minor modifications
OBJECTIVE:	To provide a software package that displays FWD deflection data in an orderly manner and checks data for completeness.
DESCRIPTION:	The FWDSCAN software provides a quick field check of the integrity of the FWD data. The software checks the deflection, temperature, and calibration factors to insure that all are within acceptable limits.
CRITICAL EVALUATION:	The software is optimized for highway uses and may not be applicable for analysis of airfield pavements.
APPLICABILITY ISSUES:	None

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	5009
PRODUCT TITLE:	Manual for FWD Testing
REPORT NUMBER(S) AND TITLE(S):	SHRP-P-661: Manual for FWD Testing in the Long-Term Pavement Performance Program
SHRP CATEGORY:	Highway Operations
APPLICABILITY RATING:	Applicable with minor modifications
OBJECTIVE:	To provide a manual for proper use of falling weight deflectometers for use in SHRP LTPP studies.
DESCRIPTION:	The manual provides guidelines on the use and operation of FWDs to ensure reliable, consistent data output. Information on use of the FWD includes: testing of asphalt surfaces and jointed concrete surfaces, selection of test locations, drop sequences, accurate temperature measurement, field data checks, and calibration.
CRITICAL EVALUATION:	The manual is intended for use with systems optimized for highway pavements and may not be applicable to airfield pavements.
APPLICABILITY ISSUES:	None

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	5011
PRODUCT TITLE:	PROFCAL Program - Profile Quality Assurance
REPORT NUMBER(S) AND TITLE(S):	SHRP-P-639: Comparison of the SHRP Profilometers SHRP-P-378: Manual for Profile Measurement: Operational Field Guidelines
SHRP CATEGORY:	Pavement Engineering
APPLICABILITY RATING:	Applicable with Major Modification
OBJECTIVE:	To provide a user-friendly software program for the calibration of profilometers.
DESCRIPTION:	This package is part of the PROQUAL software for IBM PC and compatibles. Comparison of automated and manual profiles can be accomplished using this package. In addition, the software monitors calibration of the instrument and provides a warning to signal that relcalibration is necessary. However, this software package makes use of the International Roughness Index (IRI) which is based on automobiles and not aircraft. Therefore, this software must be used with caution and may only be employed for calibration purposes.
CRITICAL EVALUATION:	This software could potentially be utilized by FAA airport operations as a calibration tool for profilometers.
APPLICABILITY ISSUES:	This software may require some form of rewrite or modification because it makes use of the IRI, which is not used in its present form by the FAA.

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	5012
PRODUCT TITLE:	PROFCHK Program - Profile Quality Assurance
REPORT NUMBER(S) AND TITLE(S):	SHRP-P-639: Comparison of the SHRP Profilometers SHRP-P-378: Manual for Profile Measurement: Operational Field Guidelines
SHRP CATEGORY:	Pavement Engineering
APPLICABILITY RATING:	Applicable with Major Modifications
OBJECTIVE:	To compile profile statistics from profilometer data for pavement engineers.
DESCRIPTION:	This package is part of the PROQUAL software for IBM PC and compatibles. This software provides a summary of profile data and statistics for the pavement engineer. However, much of this information is in the form of International Roughness Index (IRI) which is based on automobiles and not aircraft. Therefore, this software will be of limited use to FAA airport personnel.
CRITICAL EVALUATION:	For application to the FAA, the IRI cannot be utilized in its present formulation. However, raw profile data can still be used.
APPLICABILITY ISSUES:	This software may require some form of rewrite or modification because it makes use of the IRI, which is not used in its present form by the FAA.

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	5013
PRODUCT TITLE:	PROFSCAN Program - Profile Quality Assurance
REPORT NUMBER(S) AND TITLE(S):	SHRP-P-639: Comparison of the SHRP Profilometers SHRP-P-378: Manual for Profile Measurement: Operational Field Guidelines
SHRP CATEGORY:	Pavement Engineering
APPLICABILITY RATING:	Applicable with Major Modifications
OBJECTIVE:	To check profile statistics for inconsistencies.
DESCRIPTION:	This package is part of the PROQUAL software for IBM PC and compatibles. PROFSCAN checks for variations in the IRI to ensure consistent runs and checks for large variations in profile data that may indicate errors in the measurements. However, much of this information is in the form of International Roughness Index (IRI) indexes, which is based on automobiles and not aircraft. Therefore, this software will be of limited use to FAA airport personnel.
CRITICAL EVALUATION:	For application to the FAA, the IRI cannot be utilized in its present formulation. However, raw profile data can still be used.
APPLICABILITY ISSUES:	This software may require some form of rewrite or modification because it makes use of the IRI, which is not used in its present form by the FAA.

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	5014
PRODUCT TITLE:	Profile Measurement Manual
REPORT NUMBER(S) AND TITLE(S):	SHRP-P-378: Manual for Profile Measurement: Operational Field Guidelines
SHRP CATEGORY:	Pavement Engineering
APPLICABILITY RATING:	Applicable with Major Modifications
OBJECTIVE:	To provide guidance for the operation of a profilometer and reduction of its data.
DESCRIPTION:	This manual describes the collection of profile data and the use of the PROQUAL software for IBM PC and compatibles. However, much of the software output is in the form of International Roughness Index (IRI) indexes, which is based on automobiles and not aircraft. Therefore, this software will be of limited use to FAA airport personnel.
CRITICAL EVALUATION:	For application to the FAA, the IRI cannot be utilized in its present formulation. However, raw profile data can still be used.
APPLICABILITY ISSUES:	This software may require some conversion or modification because it makes use of the IRI, which is not used in its present form by the FAA.

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	5015
PRODUCT TITLE:	Dipstick Profile Software
REPORT NUMBER(S) AND TITLE(S):	SHRP-P-639: Comparison of the SHRP Profilometers SHRP-P-378: Manual for Profile Measurement: Operational Field Guidelines
SHRP CATEGORY:	Pavement Engineering
APPLICABILITY RATING:	Directly Applicable
OBJECTIVE:	To provide a software program for the easy management of manual transverse profile data collected using the FACE Dipstick[7].
DESCRIPTION:	The program calculates rut depth according to the wire method and allows comparison of one transverse profile to another.
CRITICAL EVALUATION:	The software output is generic in nature and, therefore,should be able to be used directly by FAA airport personnel.
APPLICABILITY ISSUES:	None

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	5016
PRODUCT TITLE:	Distress Identification Manual
REPORT NUMBER(S) AND TITLE(S):	SHRP-P-398: Distress Identification Manual for the Long-Term Pavement Performance Project, Appendix B SHRP-P-653: Accreditation for the Long-term Pavement Performance Studies Pavement Distress Raters
SHRP CATEGORY:	Pavement Engineering
APPLICABILITY RATING:	Applicable with Minor Modification
OBJECTIVE:	To provide a concise, clear manual for the accurate identification of various forms of pavement distress for the Long-Term Pavement Performance Project (LTPP).
DESCRIPTION:	The most common distresses that occur in both asphalt and jointed and continuous concrete pavements are described along with a severity ratings guide. Extensive use of photographs is intended to aid the reader. The guide is designed to remove as much of the subjectivity in the rating as possible for the purpose of providing a consistent interpretation of pavement distresses for the LTPP. Appendices are included for generalized distress data forms, profile measurement, and faulting measurements (for concrete slabs using the Georgia faultmeter).
CRITICAL EVALUATION:	The manual provides a clear description (including numerous photographs) of each of the more common forms of pavement distresses and may be useful to FAA for training of personnel for spotting various pavement distresses. Airport related distresses (e.g., fuel spills) are not covered in this manual.
APPLICABILITY ISSUES:	Airport pavement distresses such as fuel spillage are not considered in this manual.

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	5019
PRODUCT TITLE:	Resilient Modulus of Asphalt Pavement
REPORT NUMBER(S) AND TITLE(S):	Available as draft protocol P-07 from FHWA SHRP-P-687: SHRP-LTPP Materials Characterization: Five-Year Report, Appendix I
SHRP CATEGORY:	Pavement Engineering
APPLICABILITY RATING:	Applicable with Minor Modifications
OBJECTIVE:	To standardize the testing methodology for measuring the resilient modulus of an asphalt pavement specimen or core.
DESCRIPTION:	Due to a large deviation of test results from different laboratories in testing similar specimens, a set of testing specifications that laboratories must follow has been drafted. These specifications encompass equipment, sample positioning, load guidance, and specimen size. The adherence to these specifications is intended to ensure consistency in testing between laboratories. The specifications are currently being reviewed for ASTM and AASHTO specifications.
CRITICAL EVALUATION:	This procedure standardizes the testing techniques, equipment, materials, and procedures for obtaining better accuracy and precision between laboratories performing these tests.
APPLICABILITY ISSUES:	Minor changes in testing conditions such as the magnitude of the applied load may need refinement for application to airfield pavements.

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	5020
PRODUCT TITLE:	Resilient Modulus of Soils and Aggregates
REPORT NUMBER(S) AND TITLE(S):	Available as AASHTO test method T-294-92I
SHRP CATEGORY:	Pavement Engineering
APPLICABILITY RATING:	Applicable with Minor Modifications
OBJECTIVE:	To standardize the testing methodology for measuring the resilient modulus of a soil or aggregate specimen.
DESCRIPTION:	Current AASHTO pavement design procedures require a value for the resilient modulus of the pavement base layer; however, no standard test method for the measurement exists. This product proposes a set of specifications that must be followed for conducting the resilient modulus test on a soil specimen. The test requires that a repeat-load, electro-hydraulic system must be used and a set of strict sample preparation procedures must be followed.
CRITICAL EVALUATION:	This procedure standardizes the testing techniques, equipment, materials, and procedures for obtaining better accuracy and precision between laboratories performing these tests.
APPLICABILITY ISSUES:	Minor changes to reflect the magnitude of applied loads may be necessary for application to airfield pavements.

(Sheet 1 of 1)

SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	5021
PRODUCT TITLE:	Guide to Field Material Sampling and Handling
REPORT NUMBER(S) AND TITLE(S):	SHRP-P-687: SHRP-LTPP Materials Characterization: Five-Year Report SHRP-LTPP-OG-006: SHRP-LTPP Guide to Field Material Sampling, Testing, and Handling
SHRP CATEGORY:	Pavement Engineering
APPLICABILITY RATING:	Directly Applicable
OBJECTIVE:	To standardize the sampling procedures for gathering pavement cores at Long-term Pavement Performance (LTPP) sites.
DESCRIPTION:	This guide provides details for drilling and sampling of pavements to ensure standardized sampling and handling procedures for collection of specimens at LTPP sites. The manual describes procedures for sampling of pavement surfaces, base, and subgrades, as well as quality control measures. Various equipment necessary for sampling is described in detail. The guide is currently under review by AASHTO as a standard practice.
CRITICAL EVALUATION:	This guide provides a valuable source for procedures to use when sampling pavements and could be employed by FAA personnel.
APPLICABILITY ISSUES:	None

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	5022
PRODUCT TITLE:	Examining Asphalt Pavement Cores
REPORT NUMBER(S) AND TITLE(S):	SHRP-P-687: SHRP-LTPP Materials Characterization: Five-Year Report
SHRP CATEGORY:	Pavement Engineering
APPLICABILITY RATING:	Directly Applicable
OBJECTIVE:	To standardize the procedures for examining asphalt pavement cores.
DESCRIPTION:	No standard currently exists for the examination of asphalt pavement cores. This guide provides standard procedures for visual examination of cores for stripping, voids and cracks, and aggregate shape.
CRITICAL EVALUATION:	The methods employed are the same as that for an airfield pavement.
APPLICABILITY ISSUES:	None

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER: 5023

PRODUCT TITLE: Examining Concrete Pavement Cores

REPORT NUMBER(S) AND TITLE(S): SHRP-P-687: SHRP-LTPP Materials Characterization: Five-Year Report

SHRP CATEGORY: Pavement Engineering

APPLICABILITY RATING: Directly Applicable

OBJECTIVE: To standardize the sampling procedures for examining concrete pavement cores.

DESCRIPTION: No standard currently exists for the examination of concrete pavement cores. This guide provides standard procedures for visual examination of cores for distress, voids, and cracks, and aggregate shape. Layer thicknesses are measured at three points along the core using bench-mounted calipers. This guide is currently under evaluation by AASHTO for adoption as a standard.

CRITICAL EVALUATION: The methods employed are the same as those for an airfield pavement.

APPLICABILITY ISSUES: None

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	5024
PRODUCT TITLE:	Fine-Aggregate Particle Shape
REPORT NUMBER(S) AND TITLE(S):	Available as AASHTO test method TP33-93
SHRP CATEGORY:	Pavement Engineering
APPLICABILITY RATING:	Directly Applicable
OBJECTIVE:	To provide a methodology for the characterization of fine aggregate obtained from pavement cores.
DESCRIPTION:	Procedures for characterization of particle shape and texture and for estimating void ratio and specific gravity of fine aggregate particles are presented. The tests can be conducted on aggregate recovered from cores for forensic analysis.
CRITICAL EVALUATION:	Poor fine-aggregate characteristics are related to the permanent deformation response of asphalt mixtures used in roads. The methods are applicable to the FAA for forensic analysis of pavement failure and may be useful for identifying aggregate characteristics relating to permanent deformation of asphalt concretes. Aggregate gradations employed for airfield mixes require crushed stone and may include a higher percentage of larger stone and less natural sand than highway mixes; however, the methods used for characterization of the fine-aggregate portion are useful.
APPLICABILITY ISSUES:	None

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	5025
PRODUCT TITLE:	Laboratory Guide for Testing of Pavement Samples
REPORT NUMBER(S) AND TITLE(S):	SHRP-P-687: SHRP-LTPP Materials Characterization: Five-Year Report SHRP-LTPP-OG-006: SHRP-LTPP Guide to Field Material Sampling, Testing, and Handling
SHRP CATEGORY:	Pavement Engineering
APPLICABILITY RATING:	Directly Applicable
OBJECTIVE:	To provide a guide for the collection, handling, and testing of field specimens collected for laboratory analysis for use in the SHRP-LTPP project.
DESCRIPTION:	A manual for the proper sampling and handling procedures for collection of field samples for laboratory testing is presented. Information is provided on how the samples collected from LTPP sites were acquired.
CRITICAL EVALUATION:	The manual should provide good practices for the collection of samples from the field destined for laboratory testing.
APPLICABILITY ISSUES:	None

(Sheet 1 of 1)

SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	5026
PRODUCT TITLE:	Visual Examination of Asphalt Stripping
REPORT NUMBER(S) AND TITLE(S):	SHRP-P-687: SHRP-LTPP Materials Characterization: Five-Year Report SHRP-LTPP-OG-006: SHRP-LTPP Guide to Field Material Sampling, Testing, and Handling
SHRP CATEGORY:	Pavement Engineering
APPLICABILITY RATING:	Directly Applicable
OBJECTIVE:	To provide a set of guidelines for the visual examination of asphalt cores for determination of the amount of moisture-induced damage.
DESCRIPTION:	Guidelines are presented for examination of asphalt cores for moisture-induced damage. The percentage of asphalt stripped from aggregate surfaces can be estimated.
CRITICAL EVALUATION:	The procedures for examination of cores from both airfields and highways are identical.
APPLICABILITY ISSUES:	None

(Sheet 1 of 1)

SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	5028
PRODUCT TITLE:	Proficiency Testing for Modulus
REPORT NUMBER(S) AND TITLE(S):	SHRP-P-651: Layer Moduli Backcalculation Procedure SHRP-P-655: SHRP's Layer Backcalculation Procedures
SHRP CATEGORY:	Pavement Engineering
APPLICABILITY RATING:	Directly Applicable
OBJECTIVE:	To provide information on the variability and proficiency of testing procedures for modulus of pavement materials obtained by falling weight deflectometer (FWD).
DESCRIPTION:	Various laboratories were employed for testing of pavement materials for modulus. This information is employed for comparison of modulus values determined from FWD measurements and for precision determination of the test methods. Users of the FWD will also know significant sources of variability and typical variances for modulus data.
CRITICAL EVALUATION:	This information should be useful for comparison of FWD-based modulus to those values determined from actual pavement samples and for precision of the testing procedures employed.
APPLICABILITY ISSUES:	None

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	5029
PRODUCT TITLE:	Proficiency Testing for Concrete Cores
REPORT NUMBER(S) AND TITLE(S):	SHRP-P-636: Portland Cement Concrete Core Proficiency Sample Program
SHRP CATEGORY:	Pavement Engineering
APPLICABILITY RATING:	Directly Applicable
OBJECTIVE:	To provide information on the variability and proficiency of testing procedures for characteristics of concrete cores.
DESCRIPTION:	Various laboratories were employed for testing of pavement materials for modulus of elasticity, Poisson's ratio, split tensile strength, and compressive strength. This information is employed for precision determination of the test methods.
CRITICAL EVALUATION:	The data on the precision of the testing methods can be used directly by the FAA if employed in forensic pavement analysis. Personnel testing the concrete cores will know significant sources of variability and typical variances for results.
APPLICABILITY ISSUES:	None

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SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	5030
PRODUCT TITLE:	Proficiency Testing for Moisture Content
REPORT NUMBER(S) AND TITLE(S):	SHRP-P-619: Soil Moisture Proficiency Sample Testing Program
SHRP CATEGORY:	Pavement Engineering
APPLICABILITY RATING:	Directly Applicable
OBJECTIVE:	To provide information on the variability and proficiency of testing procedures for moisture content of soils and aggregates.
DESCRIPTION:	Various laboratories were employed for testing of soils and aggregates for moisture content using AASHTO method T-265. This information is employed for determination of precision limits for the test procedure.
CRITICAL EVALUATION:	This should provide information to the airfield engineer on the reliablity of soil moisture analyses using the techniques employed for the SHRP-LTPP program.
APPLICABILITY ISSUES:	None

(Sheet 1 of 1)

SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	5031
PRODUCT TITLE:	Modified Georgia Faultmeter Operating Guide
REPORT NUMBER(S) AND TITLE(S):	SHRP-P-338: Distress Identification Manual for the Long-Term Pavement Performance Project, Appendix C
SHRP CATEGORY:	Pavement Engineering
APPLICABILITY RATING:	Directly Applicable
OBJECTIVE:	To provide a manual on the operation of the Georgia digital faultmeter.
DESCRIPTION:	The Georgia digital faultmeter is designed to measure the height of concrete faulting. It is light, portable, easy to use, and can measure faulting in a positive or negative direction. The manual provides information on proper use, including calibration.
CRITICAL EVALUATION:	The faultmeter can be used to measure faulting on any pavement with concrete slabs.
APPLICABILITY ISSUES:	None

(Sheet 1 of 1)

SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	5032
PRODUCT TITLE:	Photographic Distress Surveys
REPORT NUMBER(S) AND TITLE(S):	SHRP-P-642: Distress Interpretation from 35-mm Film for the LTPP Experiments SHRP-P-660: Photographic Pavement Distress Record Collection and Transverse Profile Analysis
SHRP CATEGORY:	Pavement Engineering
APPLICABILITY RATING:	Directly Applicable
OBJECTIVE:	To provide a sound procedure for obtaining photographs of pavement distress for distress identification.
DESCRIPTION:	This procedure details steps for obtaining high-quality photographic images of pavement distresses. The night-only procedure requires a boom mounted camera having a 3.96-m-wide view. The method is faster than manual surveys and provides a detailed record of pavement distress.
CRITICAL EVALUATION:	This method could be employed for airfield pavement surveys especially in high-traffic airports since the operation is conducted at night.
APPLICABILITY ISSUES:	None

(Sheet 1 of 1)

SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	5034
PRODUCT TITLE:	Traffic Monitoring Data Reduction Software
REPORT NUMBER(S) AND TITLE(S):	Software Package Available From TRB
SHRP CATEGORY:	Pavement Engineering
APPLICABILITY RATING:	Applicable with Major Modifications
OBJECTIVE:	To provide a consistency to the storage, manipulation, and display of traffic volumes.
DESCRIPTION:	The software allows summaries of daily and annual traffic volumes and loads. The procedures used are consistent with the ASTM Traffic Monitoring Standards and AASHTO Guidelines.
CRITICAL EVALUATION:	The processes and concepts used for managing traffic data between highways and airports are similar; however, this software has been created for the express purpose of managing data from the SHRP-LTPP studies and cannot be applied directly to airport traffic monitoring without significant revisions.
APPLICABILITY ISSUES:	The software concepts are useful for managing traffic data at airports but are optimized for use on the SHRP-LTPP pavements.

(Sheet 1 of 1)

SHRP PRODUCT FACT SHEET

PRODUCT NUMBER: 5035

PRODUCT TITLE: LTPP Traffic Monitoring Database

REPORT NUMBER(S) AND TITLE(S): CD-ROM Available from TRB

SHRP CATEGORY: Pavement Engineering

APPLICABILITY RATING: Not Applicable

OBJECTIVE: To provide a database of traffic volumes, loads, and vehicle classification at SHRP LTPP sites.

DESCRIPTION: The data collected from LTPP sites is maintained by the Transportation Research Board as the National Traffic Monitoring Database. More than 800 sites are monitored throughout the United States and Canada. Data input are traffic volumes and times and wheel loads from weigh-in-motion sensors for individual commercial vehicles. These data can be used to generate equivalent single-axle loads (ESALs)

CRITICAL EVALUATION: None

APPLICABILITY ISSUES: The database contains highway traffic volumes, etc. from SHRP-LTPP studies.

(Sheet 1 of 1)

SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	5037
PRODUCT TITLE:	FWD Calibration Stations
REPORT NUMBER(S) AND TITLE(S):	SHRP-P-633: Analysis of Section Homogeneity, Non-Representative Test Pit and Section Data, and Structural Capacity (FWDCHECK Version 2.00) Volume I - Technical Report SHRP-P-634: Analysis of Section Homogeneity, Non-Representative Test Pit and Section Data, and Structural Capacity (FWDCHECK Version 2.00) Volume II- User's Guide SHRP-P-635: Analysis of Section Homogeneity, Non-Representative Test Pit and Section Data, and Structural Capacity (FWDCHECK Version 2.00) Volume III - Program Listing
SHRP CATEGORY:	Pavement Engineering
APPLICABILITY RATING:	Applicable with minor modifications
OBJECTIVE:	To provide calibration stations for falling weight deflectometers (FWD) for state agencies.
DESCRIPTION:	These stations allow FWD owners to bring their FWD devices to one of four regional calibration stations for calibration and comparison with other FWDs.
CRITICAL EVALUATION:	These stations provide a check of sensor response, calibrate the sensors for deflection to relevant loads, and check the precision of the responses to other FWD systems. The loads necessary for evaluation of thick airfield pavements may be larger than required for most highway pavements. Sensor spacing and placement may also be different.
APPLICABILITY ISSUES:	None

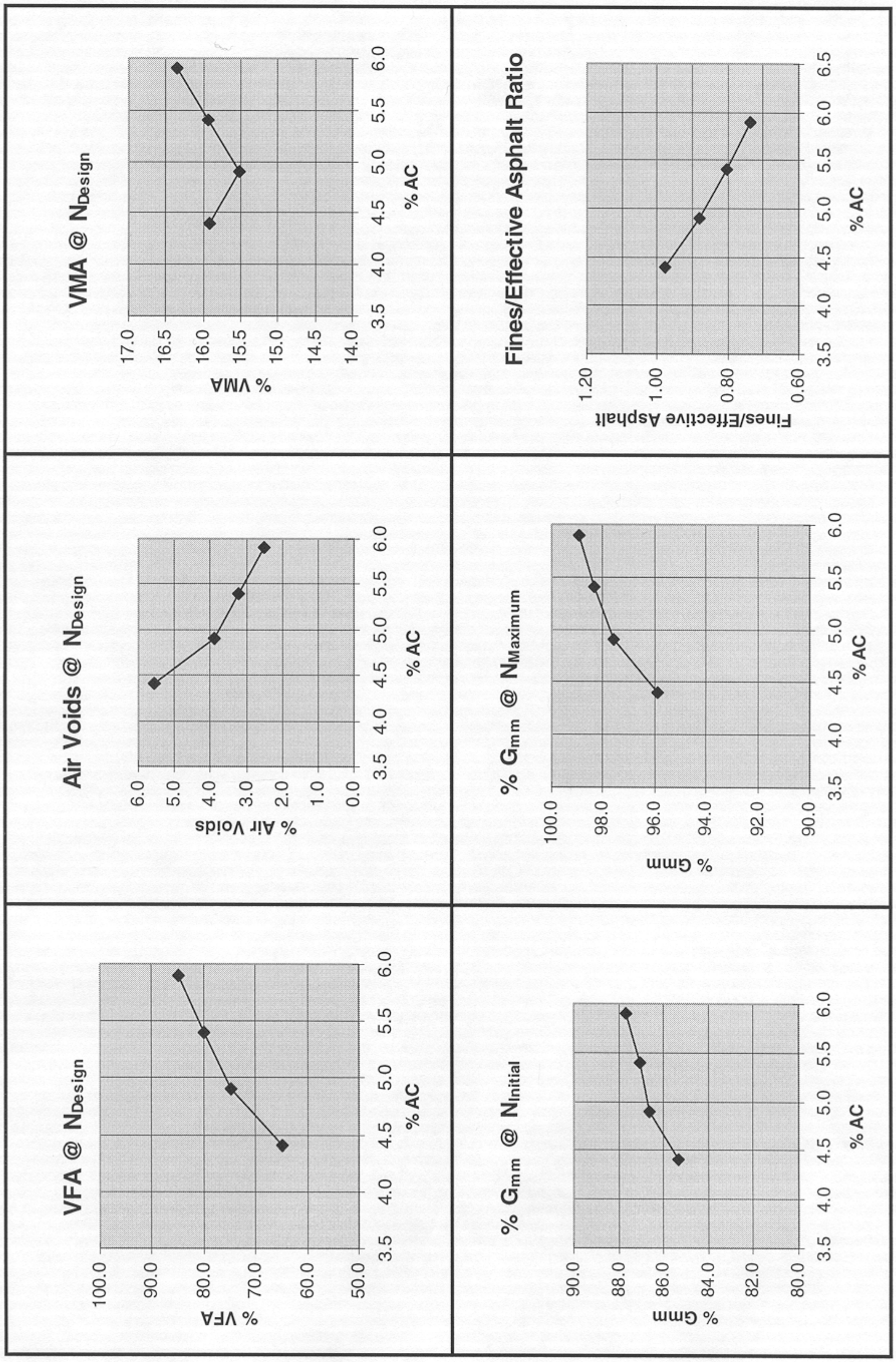
(Sheet 1 of 1)

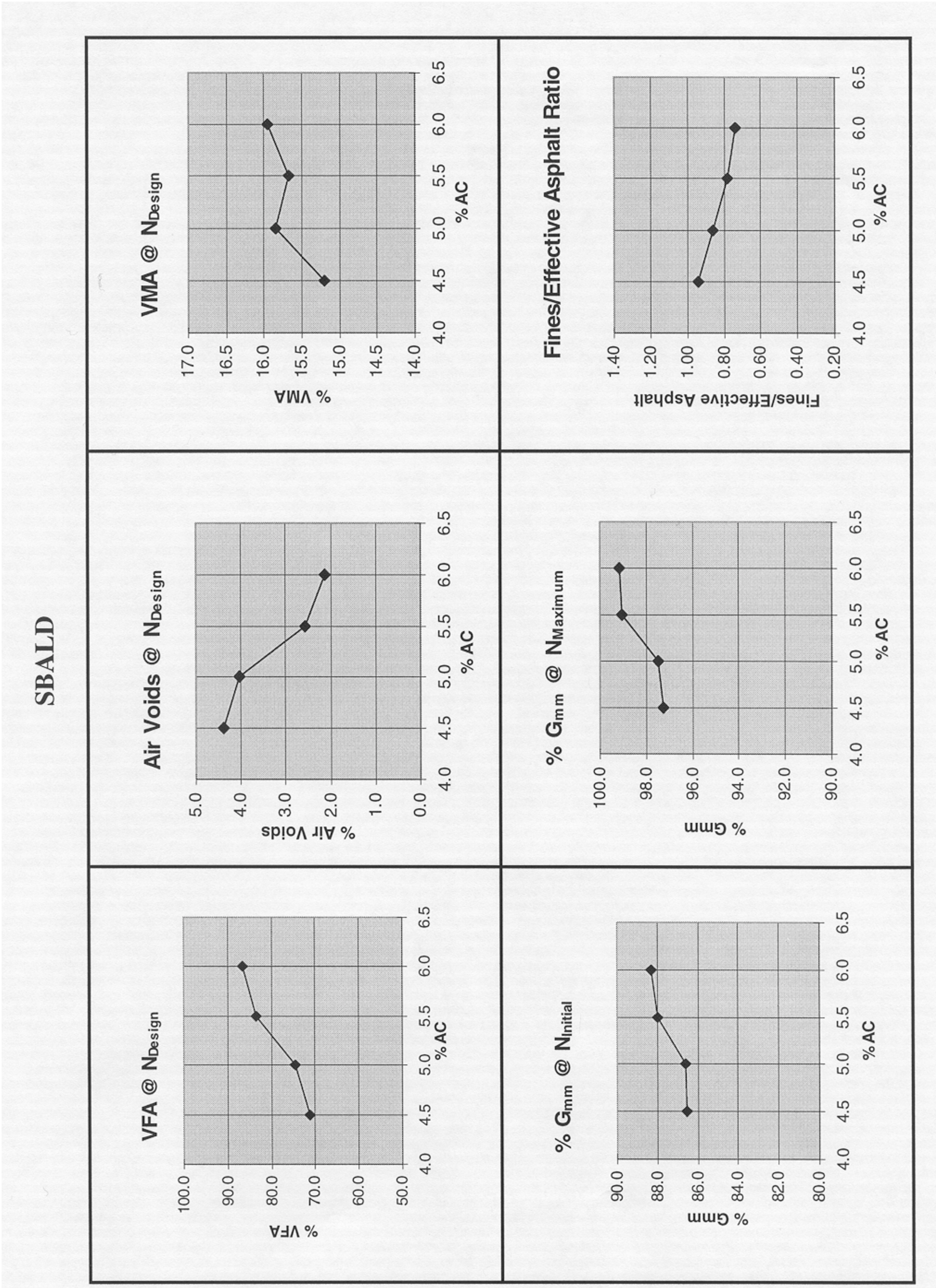
SHRP PRODUCT FACT SHEET

PRODUCT NUMBER:	5040
PRODUCT TITLE:	IMS Microcomputer System
REPORT NUMBER(S) AND TITLE(S):	Report not available
SHRP CATEGORY:	Pavement Engineering
APPLICABILITY RATING:	Not Applicable
OBJECTIVE:	To provide a personal computer-based program for managing information from the LTPP survey.
DESCRIPTION:	A personal computer-based, user-friendly software package that allows access to the information in the LTPP survey.
CRITICAL EVALUATION:	None
APPLICABILITY ISSUES:	The software is useful only for the evaluation of SHRP-LTPP data.

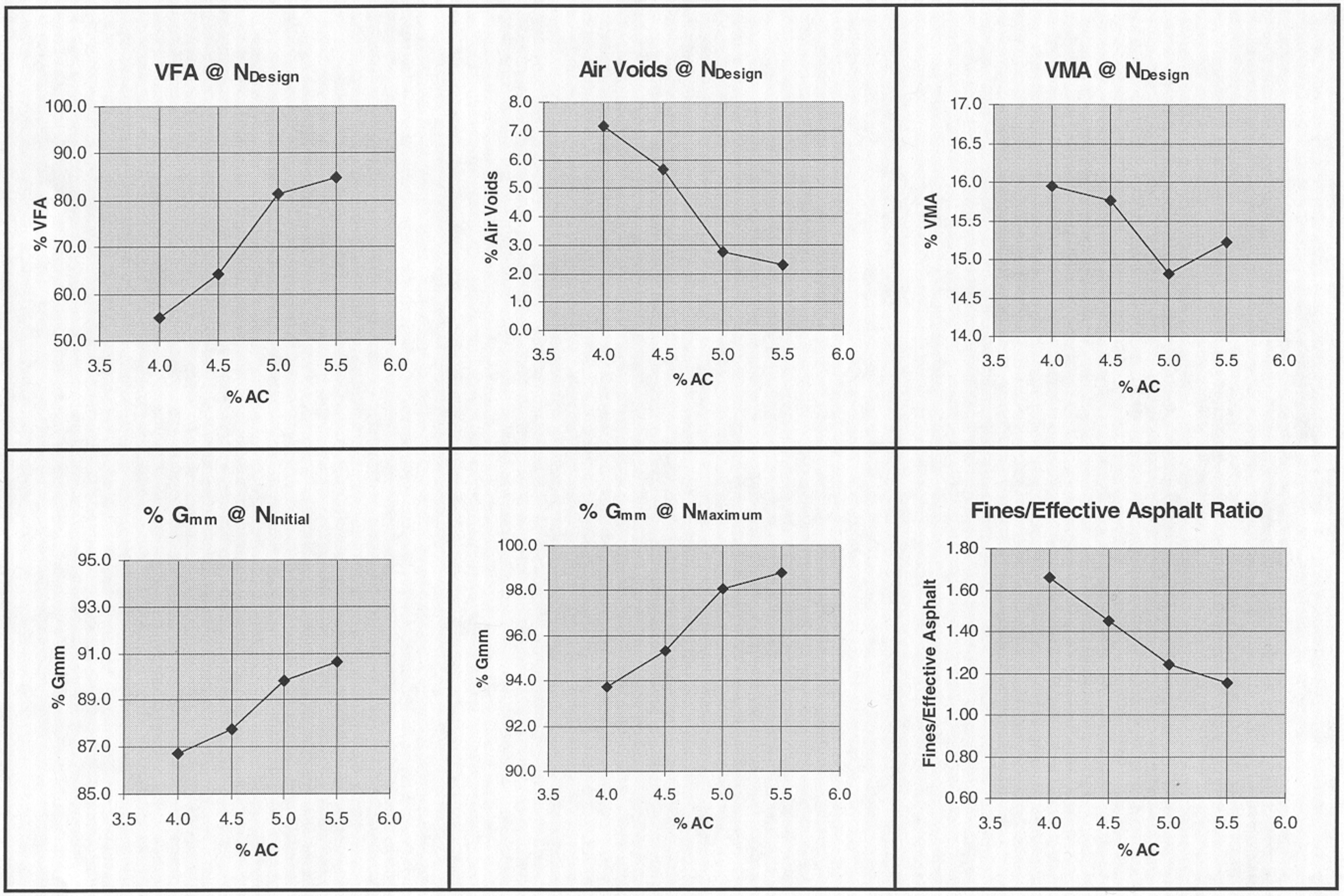
(Sheet 1 of 1)

SAALD

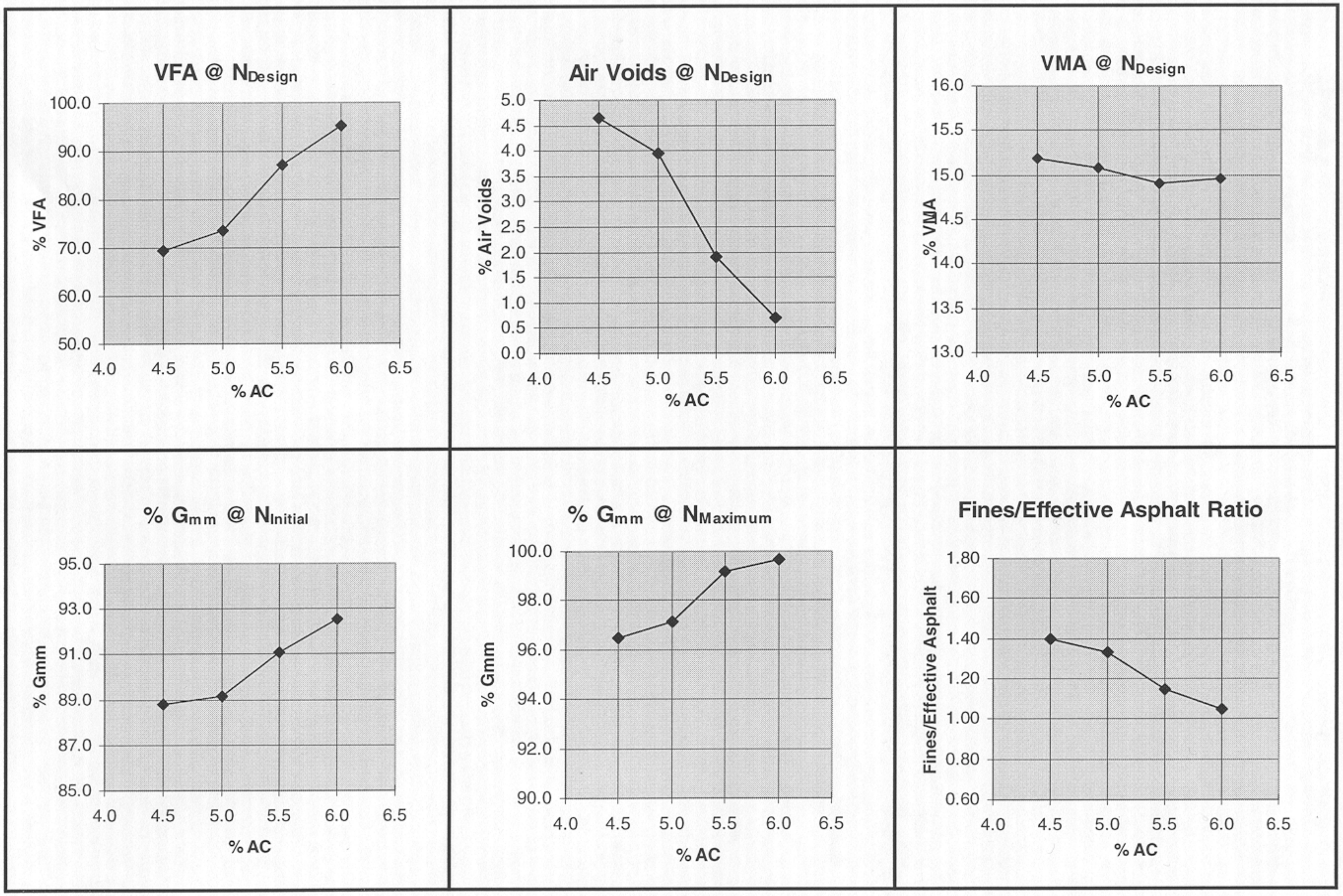

VMA @ N_{Design}
% VMA
% AC
Air Voids @ N_{Design}
% Air Voids
% AC
VFA @ N_{Design}
% VFA
% AC
Fines/Effective Asphalt Ratio
Fines/Effective Asphalt
% AC
% G_{mm} @ $N_{Maximum}$
% Gmm
% AC
% G_{mm} @ $N_{Initial}$
% Gmm
% AC


SBALD
VFA @ N_Design
% VFA
% AC
Air Voids @ N_Design
% Air Voids
% AC
VMA @ N_Design
% VMA
% AC
% Gmm @ N_Initial
% Gmm
% AC
% Gmm @ N_Maximum
% Gmm
% AC
Fines/Effective Asphalt Ratio
Fines/Effective Asphalt
% AC

SABLD

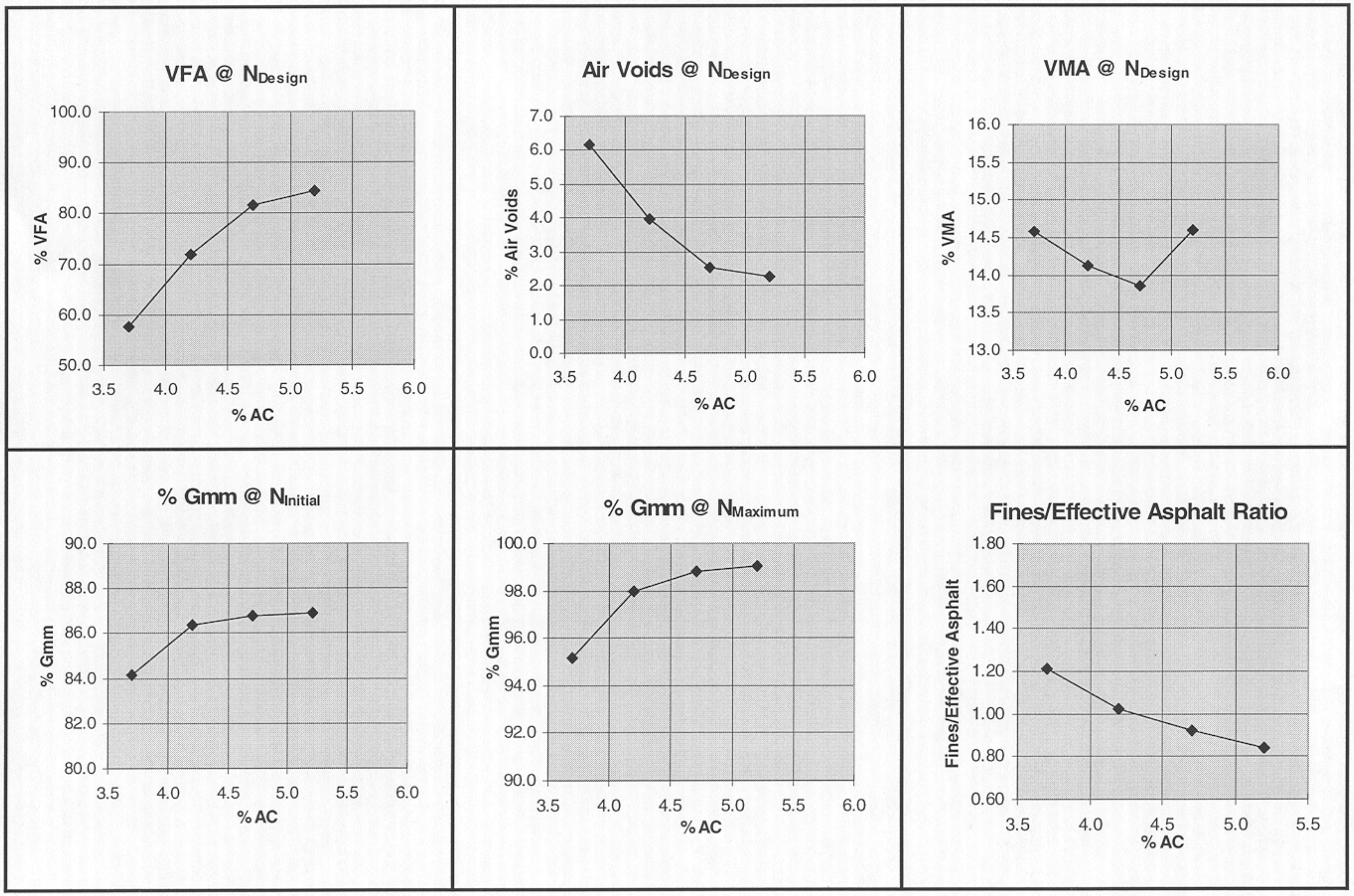

VFA @ N_{Design}
% VFA
100.0
90.0
80.0
70.0
60.0
50.0
3.5
4.0
4.5
5.0
5.5
6.0
% AC
Air Voids @ N_{Design}
% Air Voids
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
% AC
VMA @ N_{Design}
% VMA
17.0
16.5
16.0
15.5
15.0
14.5
14.0
% AC
% G_{mm} @ $N_{Initial}$
% Gmm
95.0
93.0
91.0
89.0
87.0
85.0
% AC
% G_{mm} @ $N_{Maximum}$
% Gmm
100.0
98.0
96.0
94.0
92.0
90.0
% AC
Fines/Effective Asphalt Ratio
Fines/Effective Asphalt
1.80
1.60
1.40
1.20
1.00
0.80
0.60
% AC

SBBLD



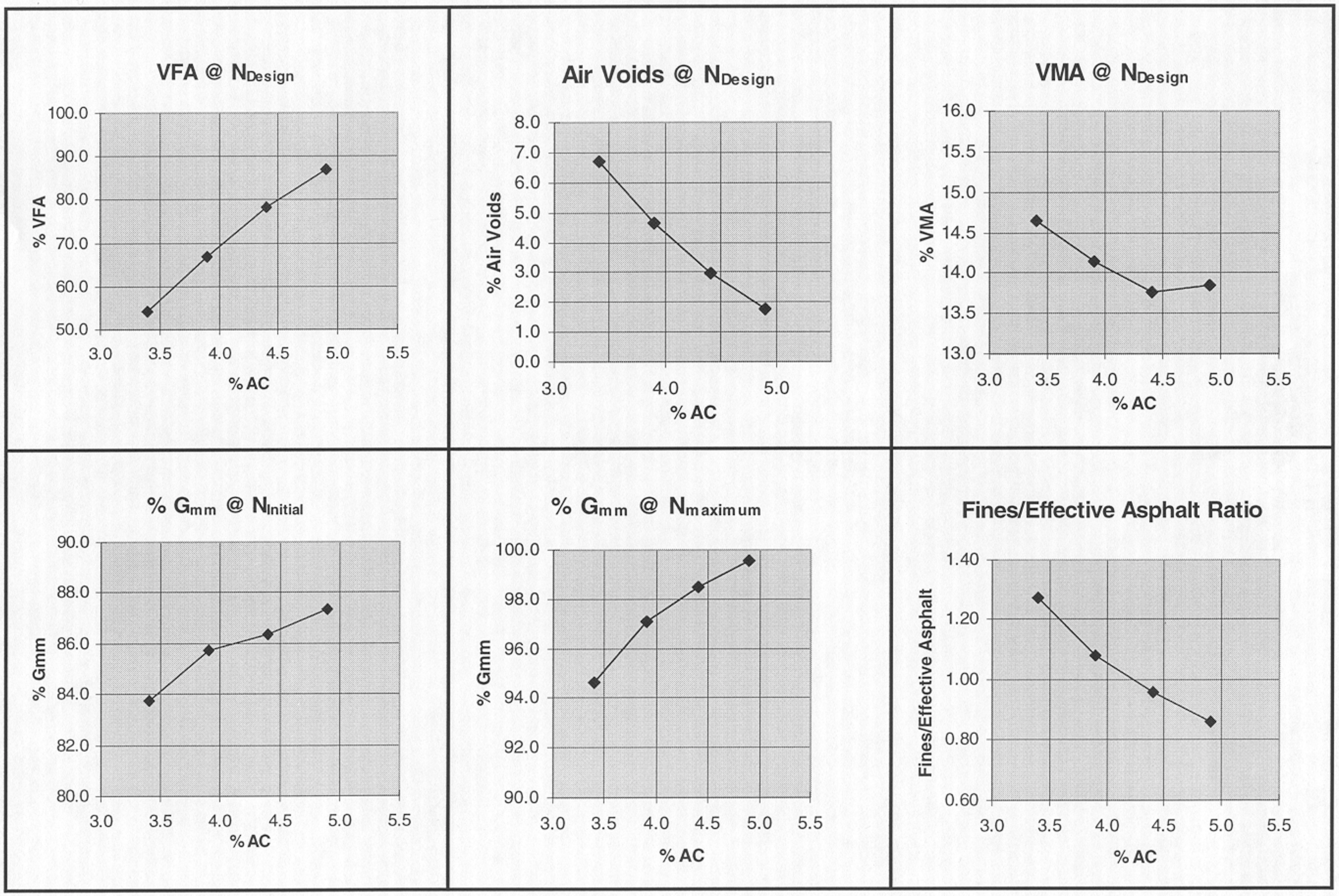
VFA @ N_{Design}
% VFA
% AC
Air Voids @ N_{Design}
% Air Voids
% AC
VMA @ N_{Design}
% VMA
% AC
% G_{mm} @ $N_{Initial}$
% Gmm
% AC
% G_{mm} @ $N_{Maximum}$
% Gmm
% AC
Fines/Effective Asphalt Ratio
Fines/Effective Asphalt
% AC

SAAHD



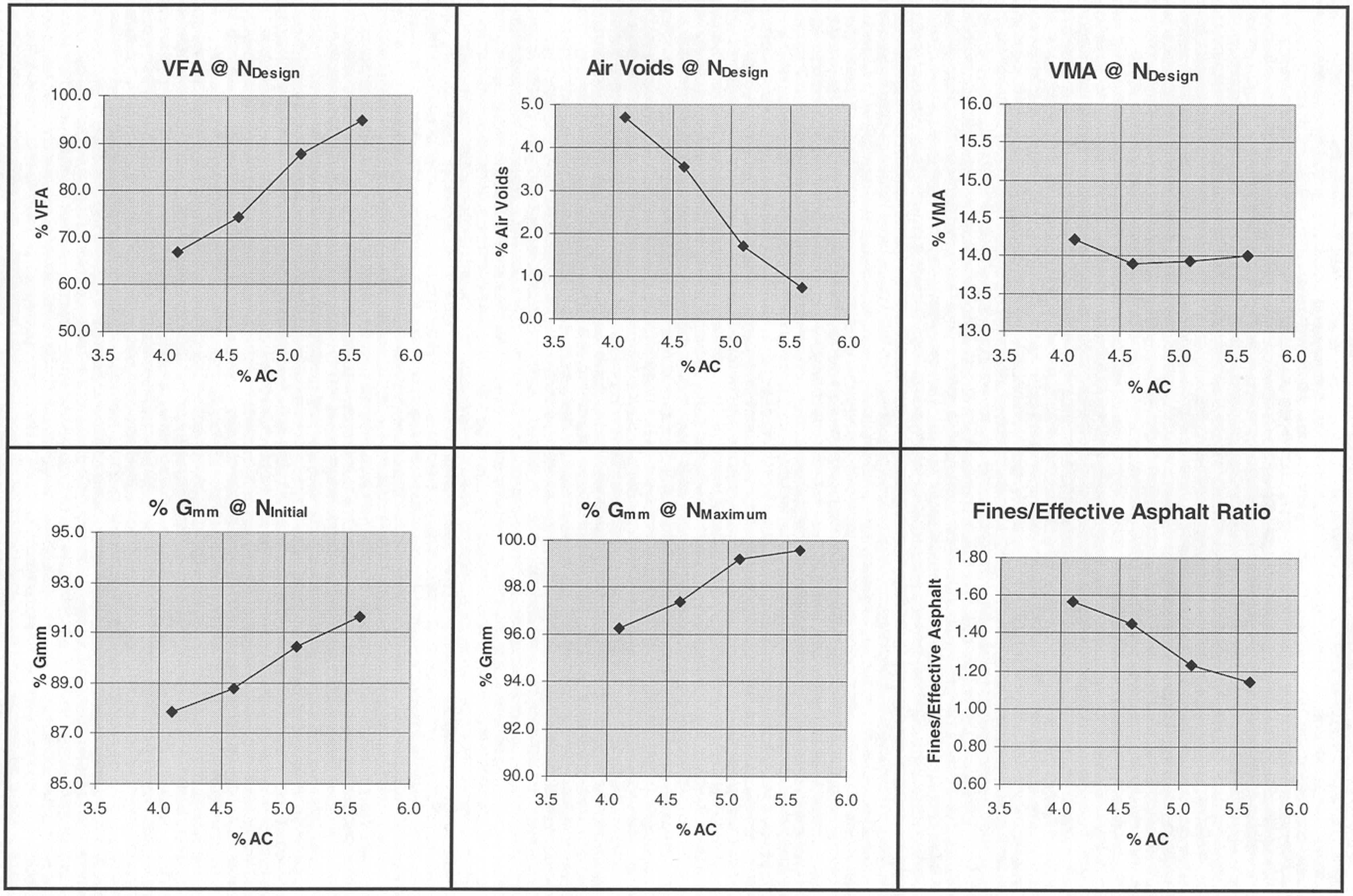
VFA @ N Design
% VFA
% AC
Air Voids @ N Design
% Air Voids
% AC
VMA @ N Design
% VMA
% AC
% Gmm @ N Initial
% Gmm
% AC
% Gmm @ N Maximum
% Gmm
% AC
Fines/Effective Asphalt Ratio
Fines/Effective Asphalt
% AC

SBAHD



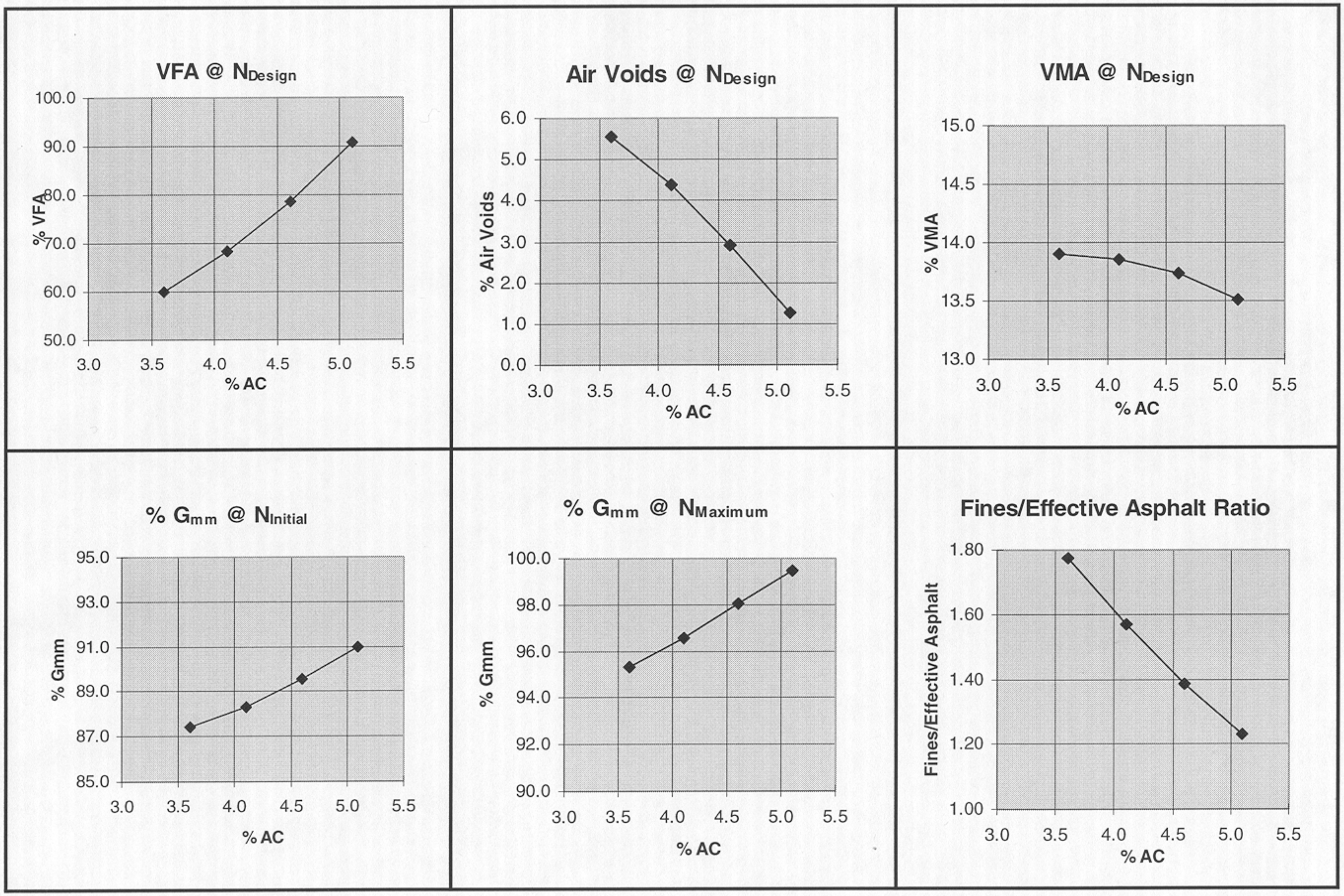
VFA @ N_{Design}
% VFA
% AC
Air Voids @ N_{Design}
% Air Voids
% AC
VMA @ N_{Design}
% VMA
% AC
% G_{mm} @ $N_{Initial}$
% Gmm
% AC
% G_{mm} @ $N_{maximum}$
% Gmm
% AC
Fines/Effective Asphalt Ratio
Fines/Effective Asphalt
% AC

SABHD



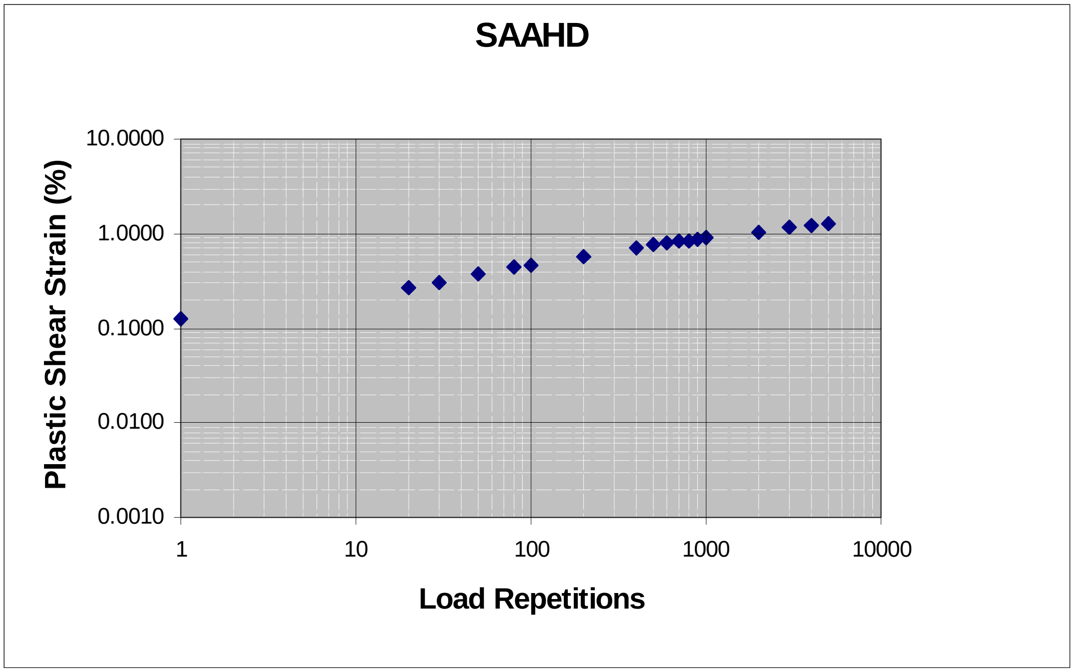
VFA @ NDesign
% VFA
% AC
Air Voids @ NDesign
% Air Voids
% AC
VMA @ NDesign
% VMA
% AC
% Gmm @ NInitial
% Gmm
% AC
% Gmm @ NMaximum
% Gmm
% AC
Fines/Effective Asphalt Ratio
Fines/Effective Asphalt
% AC

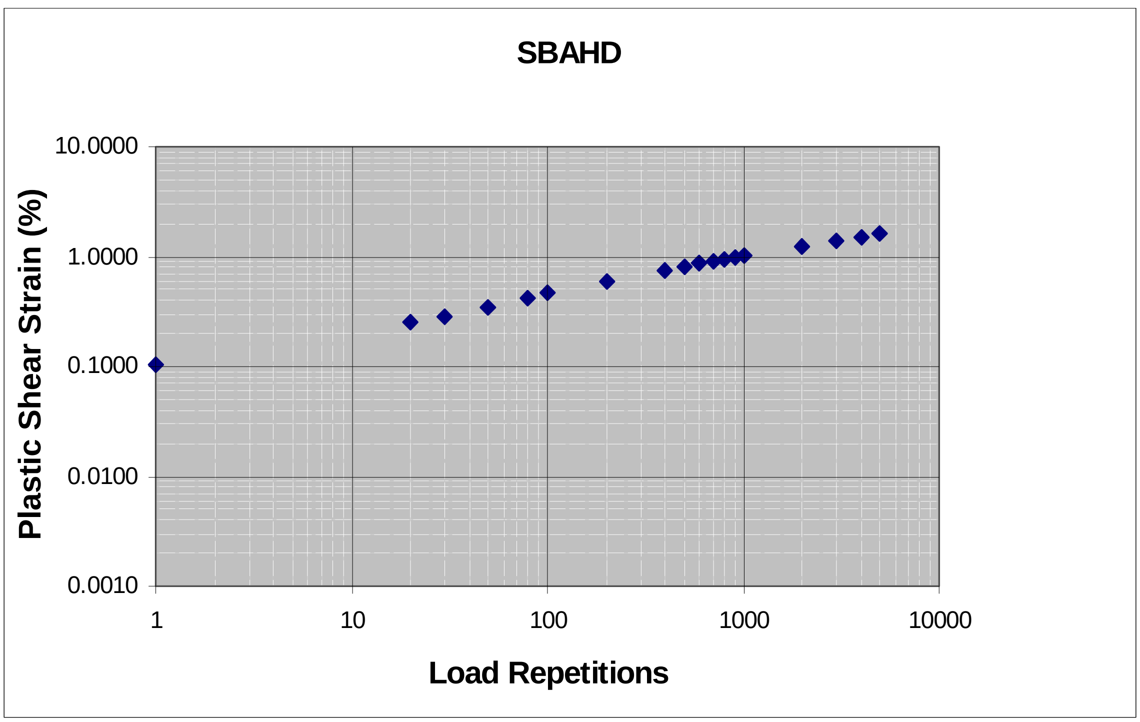
SBBHD

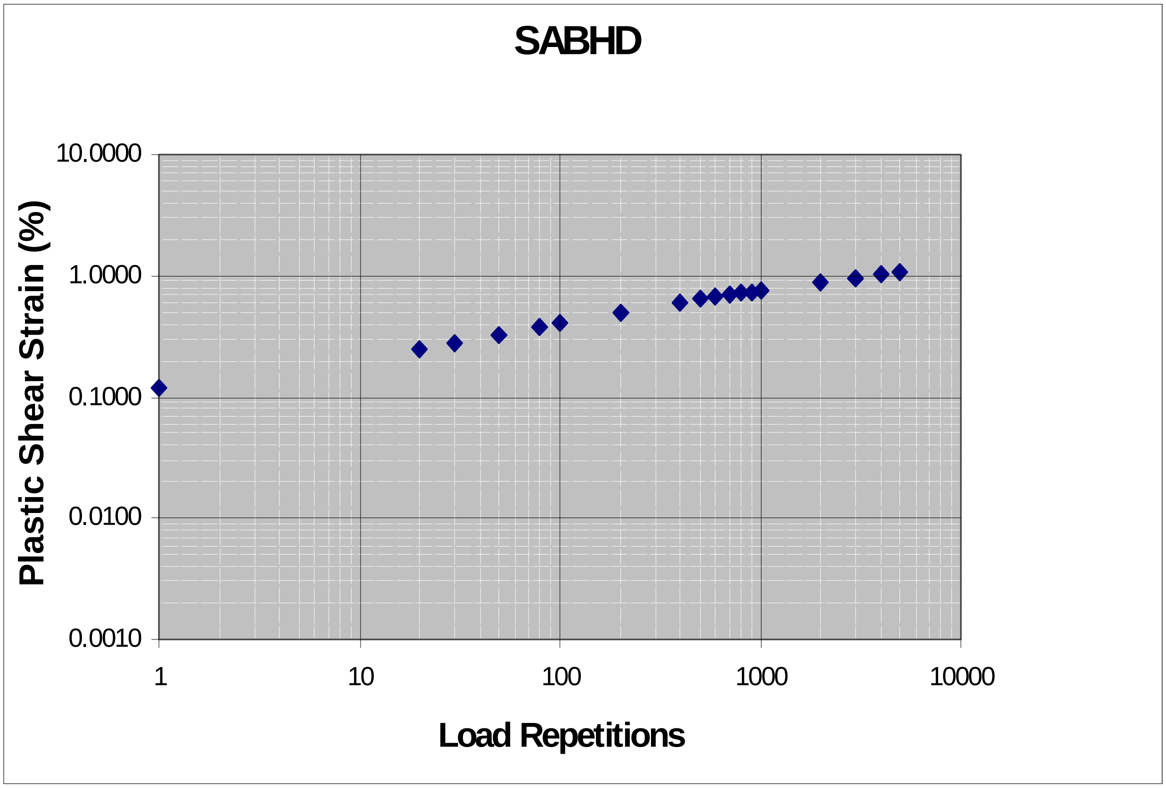


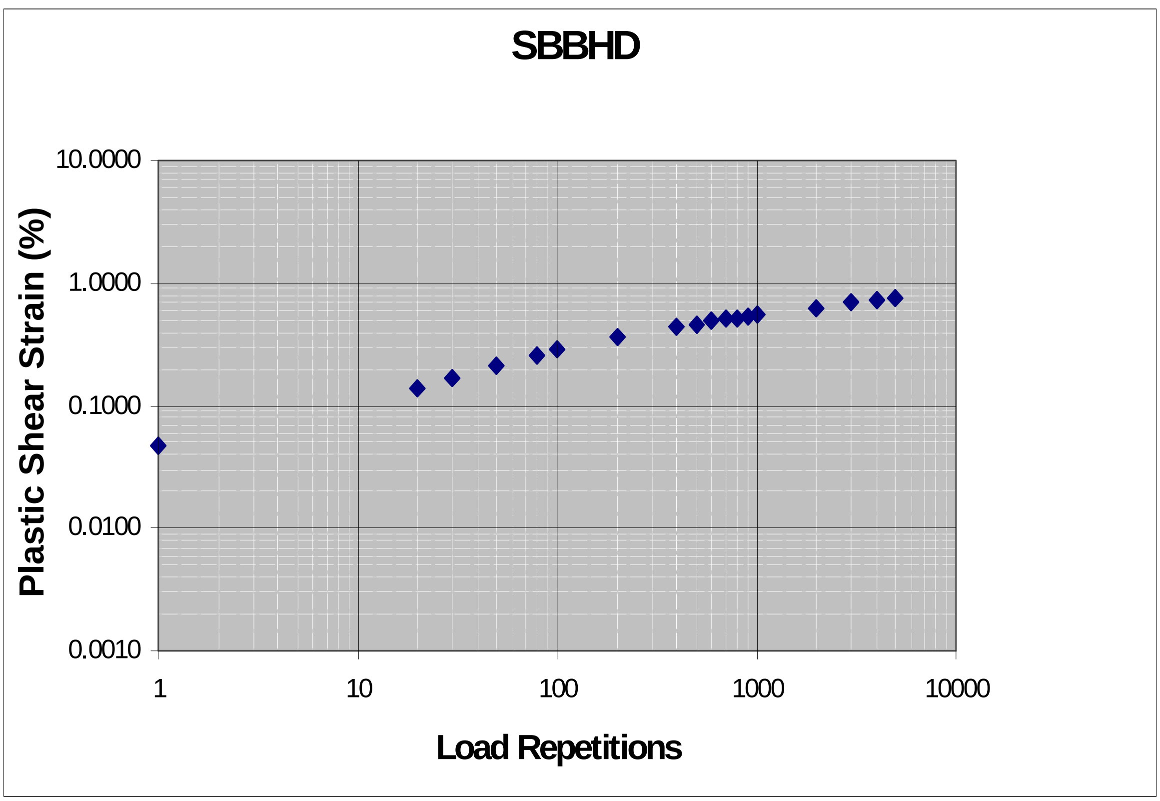
VFA @ NDesign
% VFA
% AC
Air Voids @ NDesign
% Air Voids
% AC
VMA @ NDesign
% VMA
% AC
% Gmm @ NInitial
% Gmm
% AC
% Gmm @ NMaximum
% Gmm
% AC
Fines/Effective Asphalt Ratio
Fines/Effective Asphalt
% AC

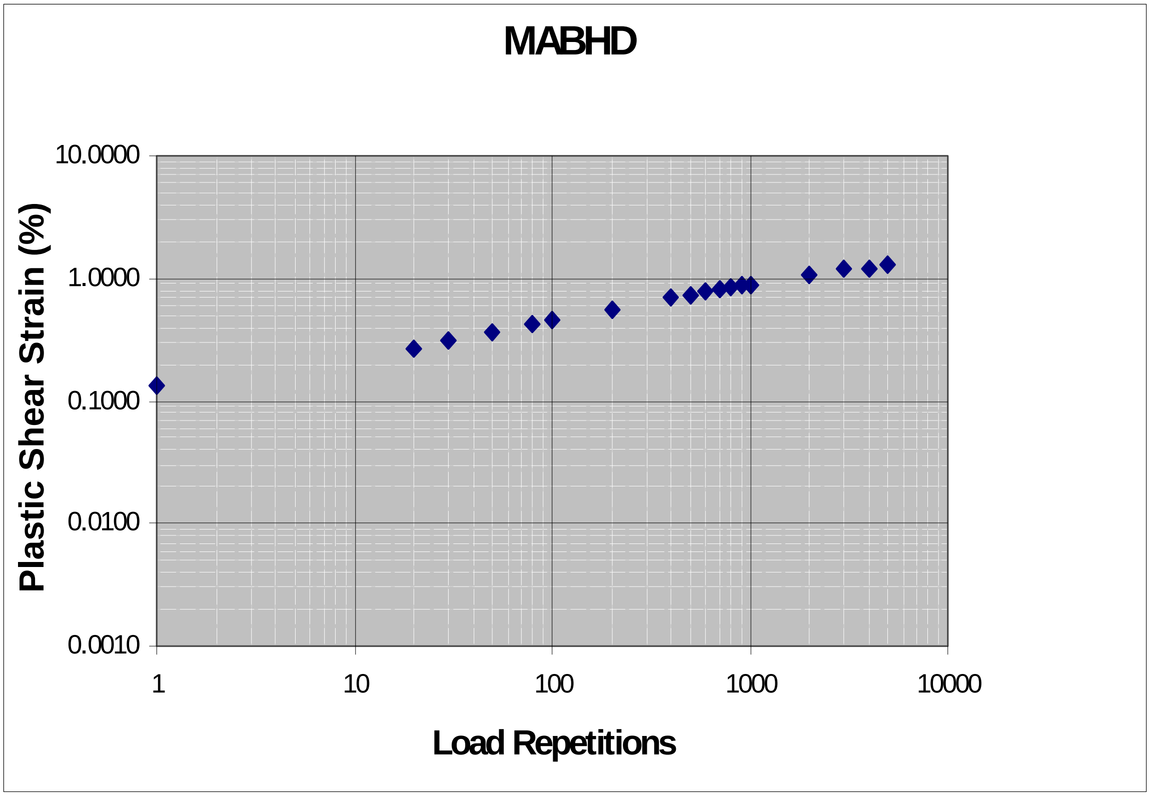
APPENDIX F—REPEATED SIMPLE SHEAR AT CONSTANT HEIGHT TEST RESULTS

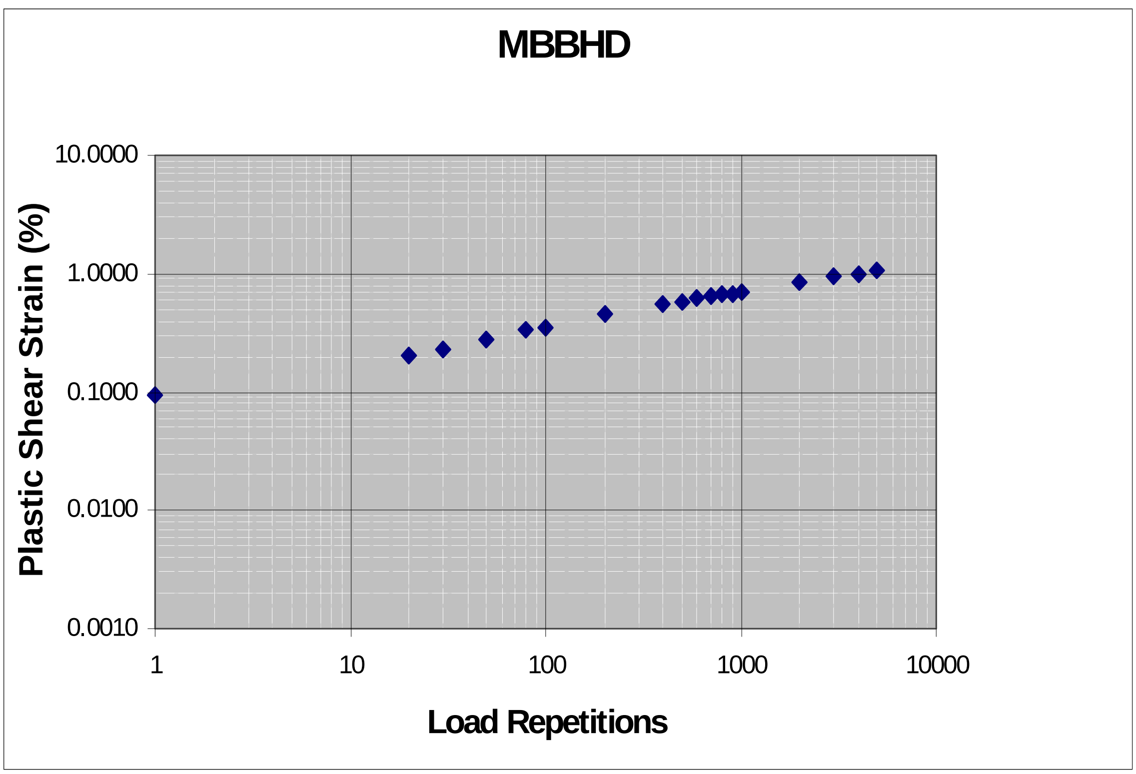




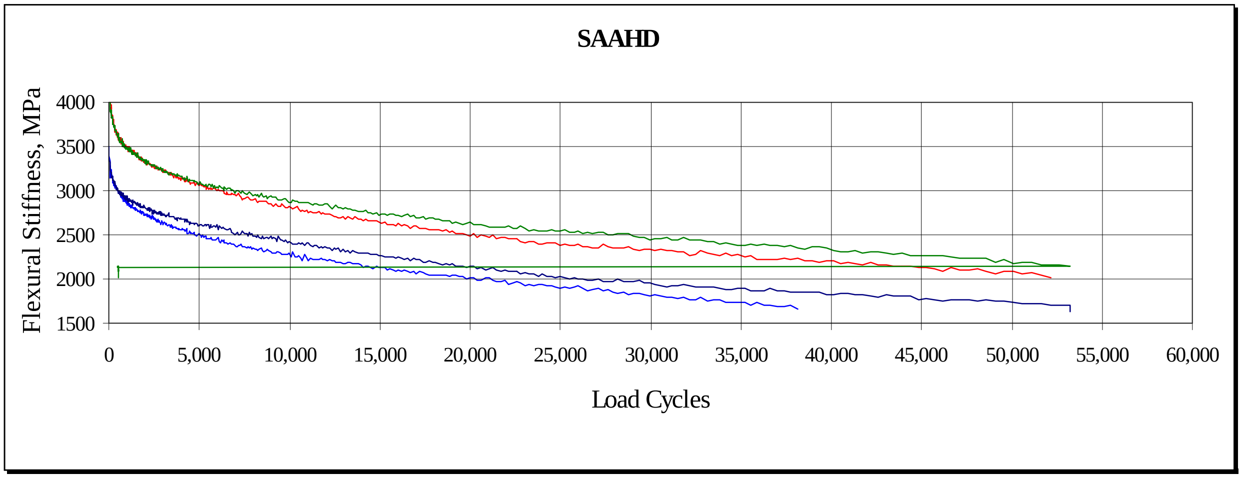

SABHD
Plastic Shear Strain (%)
10.0000
1.0000
0.1000
0.0100
0.0010
1
10
100
1000
10000
Load Repetitions

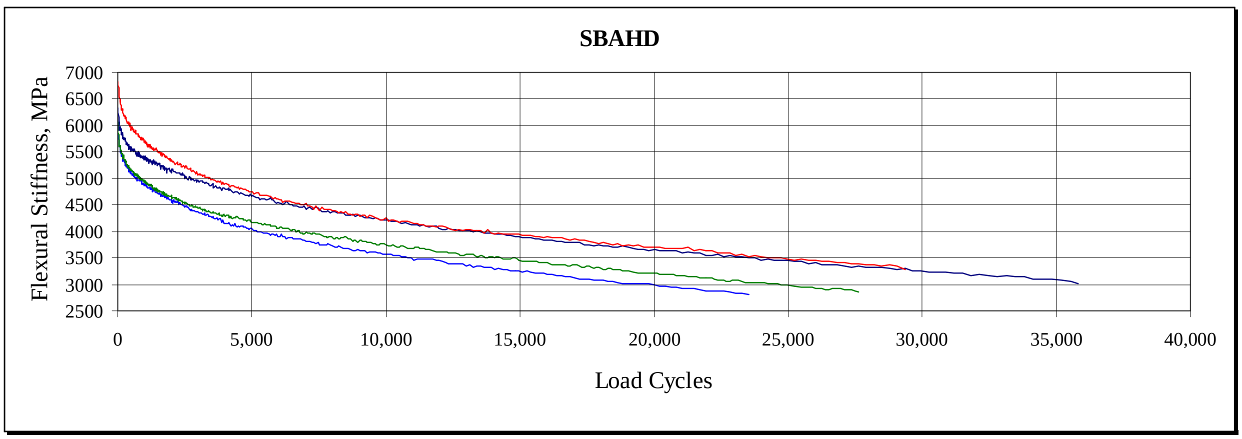

SBBHD
Plastic Shear Strain (%)
10.0000
1.0000
0.1000
0.0100
0.0010
1
10
100
1000
10000
Load Repetitions

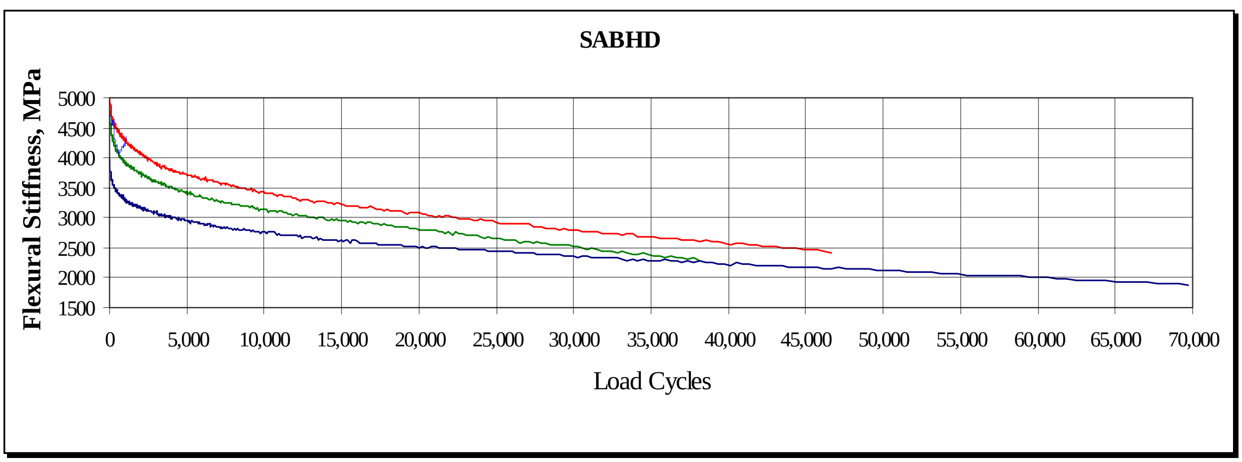

MABHD
Plastic Shear Strain (%)
10.0000
1.0000
0.1000
0.0100
0.0010
1
10
100
1000
10000
Load Repetitions

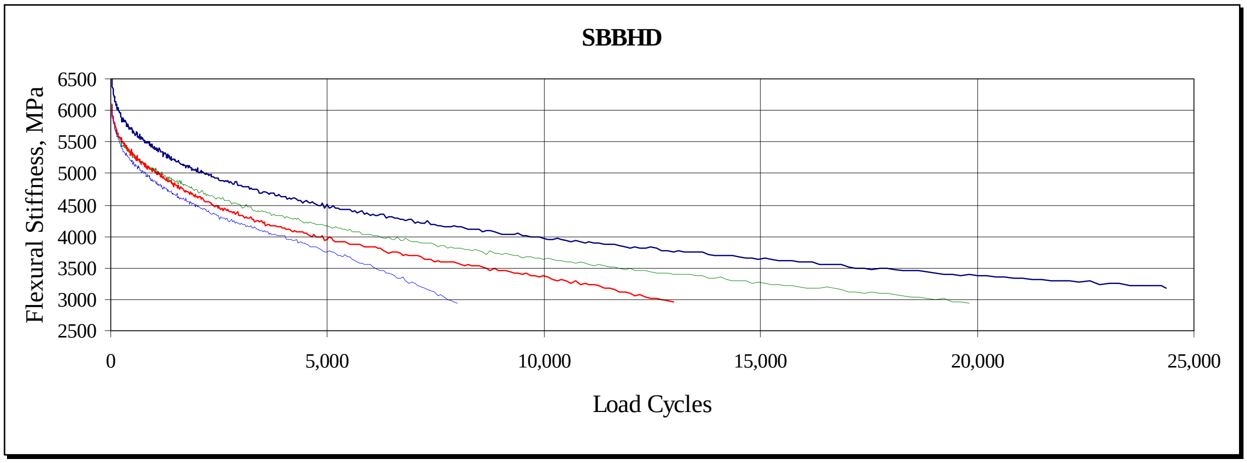

MBBHD
Plastic Shear Strain (%)
10.0000
1.0000
0.1000
0.0100
0.0010
1
10
100
1000
10000
Load Repetitions

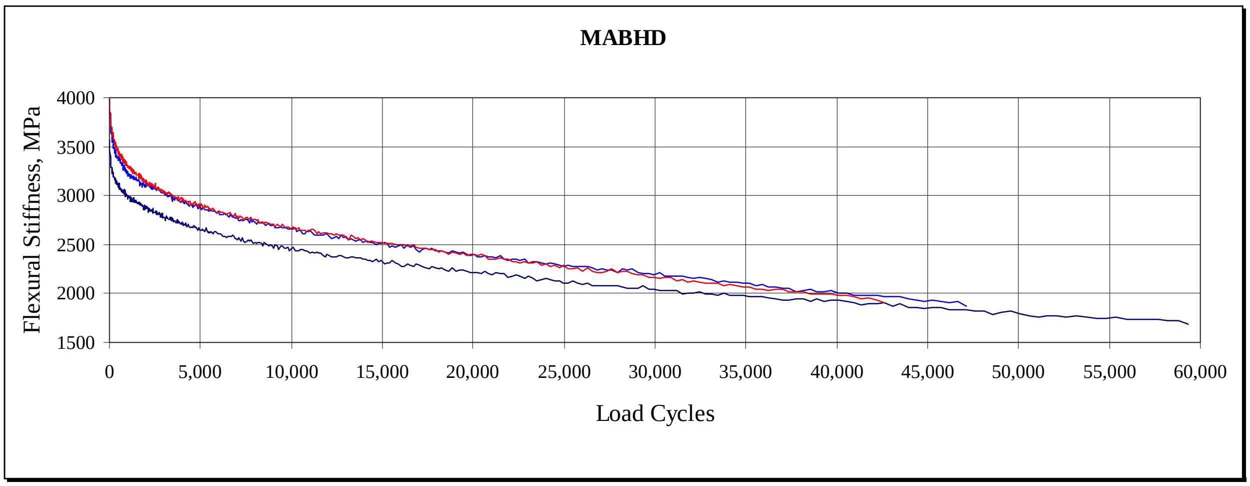
APPENDIX G—FLEXURAL BEAM FATIGUE TEST RESULTS

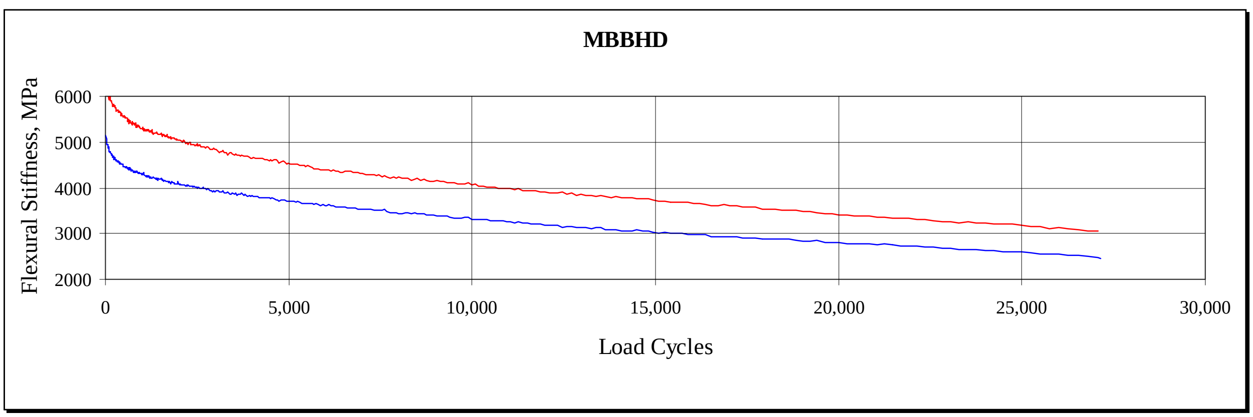




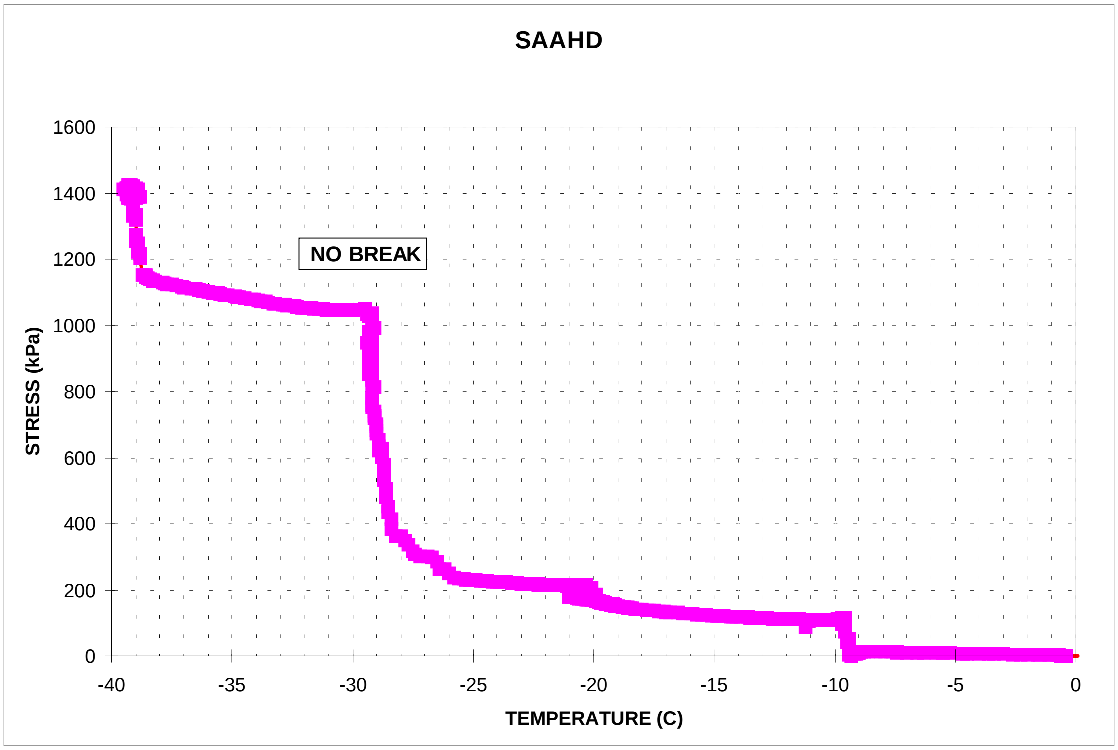


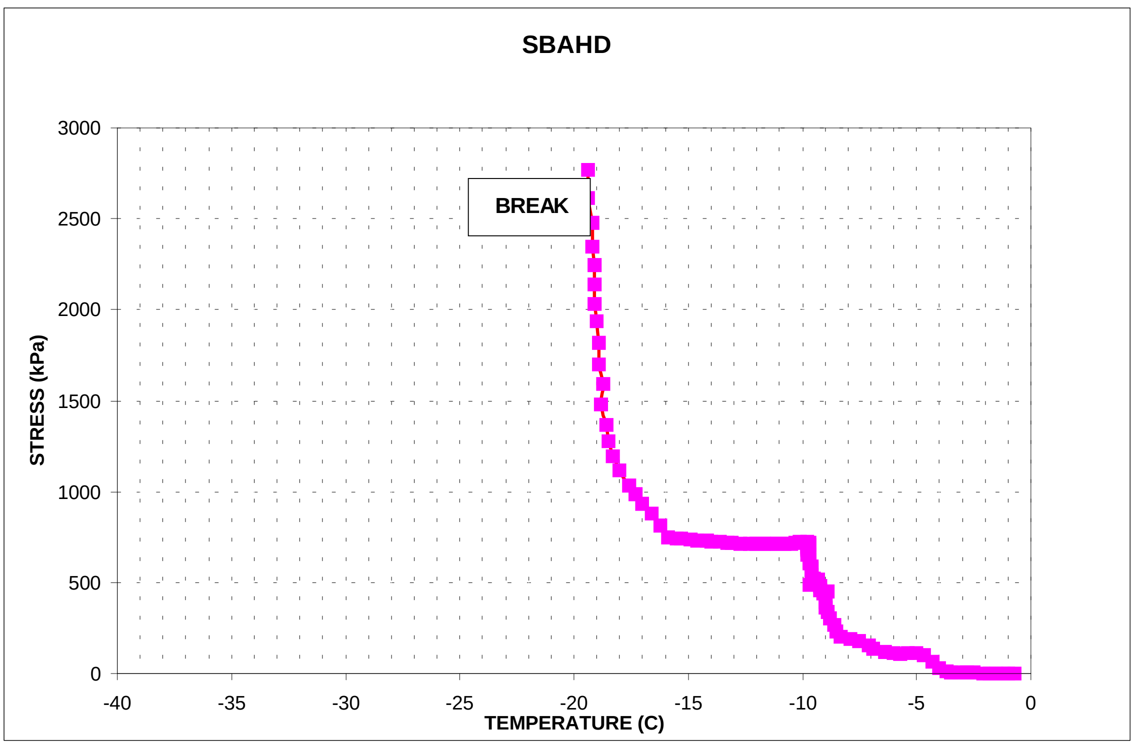

SBBHD
Flexural Stiffness, MPa
6500
6000
5500
5000
4500
4000
3500
3000
2500
0
5,000
10,000
15,000
20,000
25,000
Load Cycles

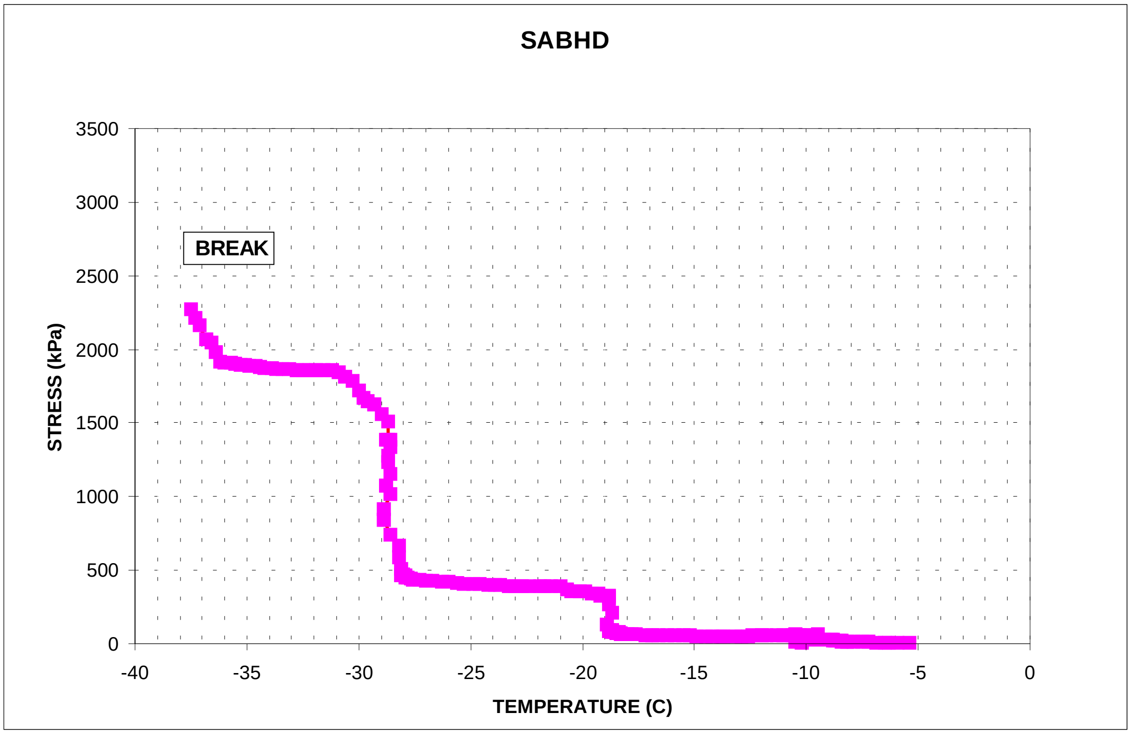

MABHD
Flexural Stiffness, MPa
4000
3500
3000
2500
2000
1500
0
5,000
10,000
15,000
20,000
25,000
30,000
35,000
40,000
45,000
50,000
55,000
60,000
Load Cycles

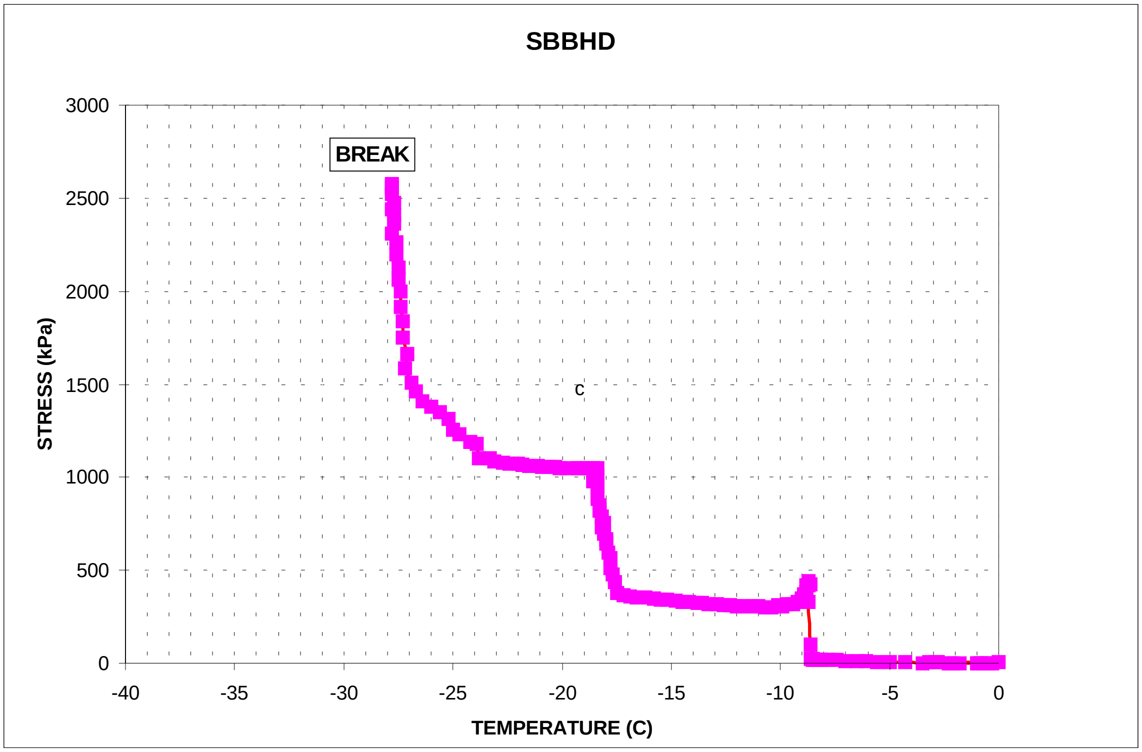

MBBHD
Flexural Stiffness, MPa
6000
5000
4000
3000
2000
0
5,000
10,000
15,000
20,000
25,000
30,000
Load Cycles

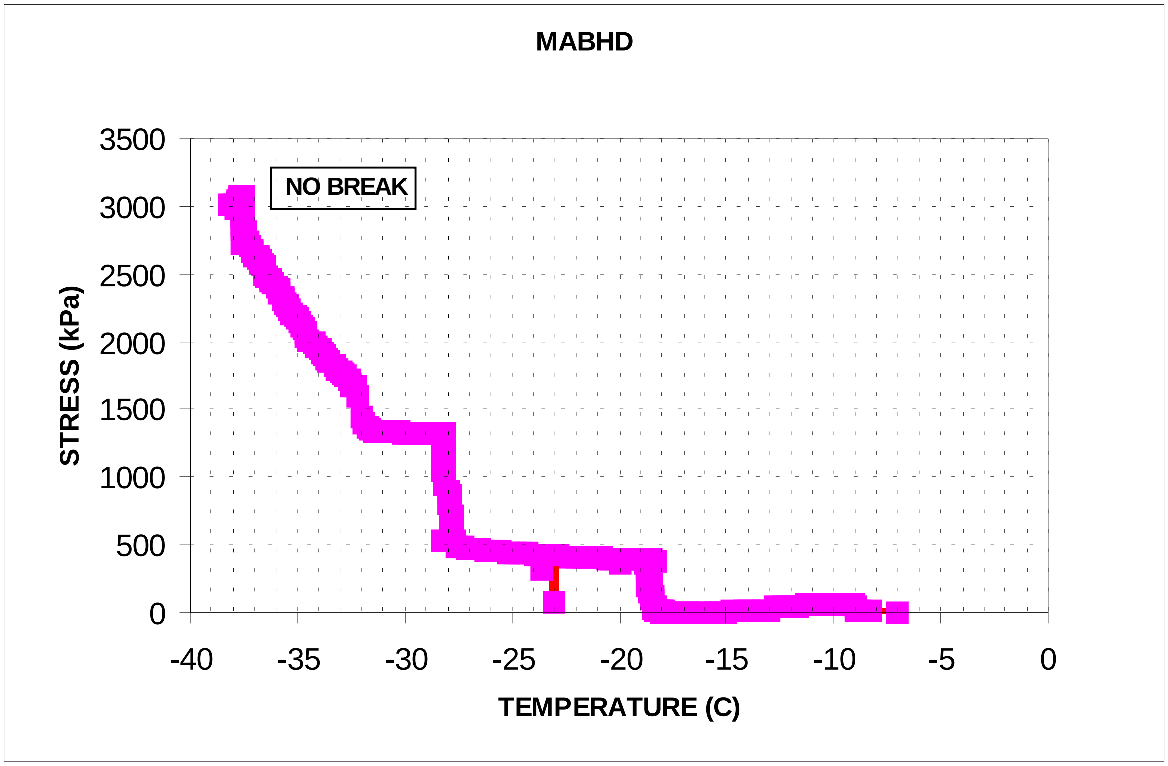
APPENDIX H—THERMAL STRESS RESTRAINED SPECIMEN TEST RESULTS

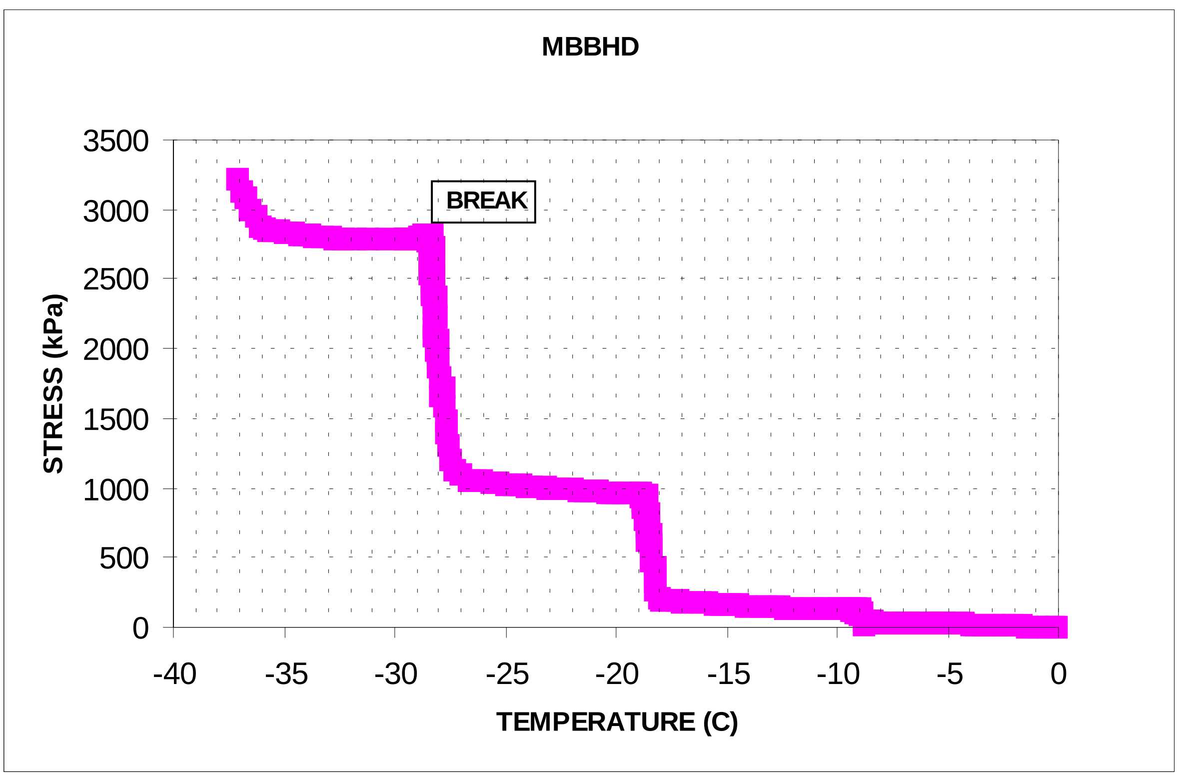





SABHD
BREAK
STRESS (kPa)
3500
3000
2500
2000
1500
1000
500
0
-40
-35
-30
-25
-20
-15
-10
-5
0
TEMPERATURE (C)


SBBHD
BREAK
c
STRESS (kPa)
3000
2500
2000
1500
1000
500
0
-40
-35
-30
-25
-20
-15
-10
-5
0
TEMPERATURE (C)


MABHD
NO BREAK
STRESS (kPa)
3500
3000
2500
2000
1500
1000
500
0
-40
-35
-30
-25
-20
-15
-10
-5
0
TEMPERATURE (C)


MBBHD
BREAK
STRESS (kPa)
3500
3000
2500
2000
1500
1000
500
0
-40
-35
-30
-25
-20
-15
-10
-5
0
TEMPERATURE (C)