FINAL REPORT FHWA/NC/2004-11

NCDOT RESEARCH PROJECT HWY-2001-15

Material Characterization and Performance Properties of Superpave Mixtures

by

Akhtarhusein A. Tayebali, Ph.D., P.E.

Yuanxiong Huang

May 31, 2004

Department of Civil Engineering

North Carolina State University

Technical Report Documentation Page

1. Report No. **FHWA/NC/2004-11**	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle **Material Characterization and Performance Properties of Superpave Mixtures**		5. Report Date **May 31, 2004** 6. Performing Organization Code
7. Author(s) **A. A. Tayebali, and Y. X. Huang**		8. Performing Organization Report No.
9. Performing Organization Name and Address **Department of Civil Engineering North Carolina State University Raleigh, NC 27695-7908**		10. Work Unit No. (TRAIS) 11. Contract or Grant No.
12. Sponsoring Agency Name and Address **North Carolina Department of Transportation Research and Analysis Group 1 South Wilmington Street Raleigh, North Carolina 27601**		13. Type of Report and Period Covered **Final Report 01/01/2001-12/31/2003** 14. Sponsoring Agency Code **2001-15**
15. Supplementary Notes:		

16. Abstract

The primary objectives of this research study was to characterize properties of two NCDOT Superpave mixes with regard to fatigue distress, and to develop phenomenological fatigue relationships for these mixes based on various levels of strain, asphalt content, air void content, and temperatures. Of particular importance was the sensitivity of the Superpave mixes to asphalt content and air void content that are usually expected in-situ.

Fatigue characterization of typical pavement sections using NCDOT fatigue models and using mechanistic analysis procedure suggests that the pavement fatigue life is sensitive to the mix variables and test temperatures considered in this study. A decrease in asphalt content by 0.5-percent (by wt. of mix) results in decrease of 18 to 25-percent fatigue life. An increase in 2% air void content reduced pavement life by about 40% for SP 12.5-mm mixes, and by almost 60% for SP 19-mm mixes. An increase in temperature was found to result in decrease in fatigue life of pavement section under consideration, although, fatigue testing was conducted in controlled-strain mode-of-loading. A 5°C increase in temperature results in about 25-percent reduction in pavement life. Based on the overall result of the analysis, it appears that SP 19-mm mix is more sensitive to mix and test variables as compared to the SP 12.5-mm mix.

17. Key Words Mechanistic design, fatigue testing, shear testing, axial testing, pavement design	18. Distribution Statement		
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 175	22. Price

Form DOT F 1700.7 (8-72) **Reproduction of completed page authorized**

Disclaimer

The contents of this report reflect the views and opinions of the author(s) and not necessarily the views of the University. The authors are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of either the North Carolina Department of Transportation or the Federal Highway Administration at the time of publication. This report does not constitute a standard, specification, or regulation.

Acknowledgements

The authors extend sincere appreciation to the authorities of the North Carolina Department of Transportation (NCDOT) for funding this project. Thanks to Mr. Mustansir Kadibhai, P.E., and Mr. Chris Bacchi, P.E., who was instrumental in coordinating the procurement of the materials and field samples.

Thanks are due to Priya Nimbole, Moreshwar Kulkarni, and Kevin Fischer, for their assistance in fabricating rolling wheel samples. Steven Wade, departmental mechanic, has been helpful in fabrication of molds for slab compaction, and maintaining the rolling wheel compactor in running condition.

Executive Summary

The primary objectives of this research study were to characterize properties of two NCDOT Superpave mixes with regard to fatigue distress, and to develop phenomenological fatigue relationships for these mixes based on various levels of strain, asphalt content, air void content, and temperatures. Of particular importance was the sensitivity of the Superpave mixes to asphalt content and air void content that are usually expected in-situ.

Materials used in this study were same as those used for the SPS-9A Project 370900, Highway US-1 in Sanford, NC. Based on the raw materials obtained, verification of the JMF was conducted for both SP 12.5-mm and SP 19-mm mixes. It was found that both mixes conformed to the JMF volumetric requirements. Based on the mix design, laboratory specimens were fabricated using a rolling wheel compactor.

Axial and shear dynamic stiffness data shows both stiffness measures to be sensitive to all mix variables. However, analysis of laboratory fatigue data indicated that the initial flexural stiffness was not sensitive to either asphalt content or aggregate gradation. However, the flexural stiffness was found to be dependent on strain level, especially at higher temperatures, suggesting that the specimen was undergoing damage early on. For this reason, a two step test procedure is recommended for future fatigue testing:

1. the initial flexure stiffness should be measured at strain level small enough so as not to induce damage to the specimen; and
2. subject the specimen to fatigue testing at the desired strain level.

For laboratory fatigue data, it was observed that in general, for the same strain level, increase in temperature increased laboratory fatigue life. This behavior is typical for the controlled-strain mode-of-loading applied in laboratory. However, conventional wisdom generally suggests that fatigue life of in-situ pavement section should increase

with decrease in temperature. This was shown to be the case during the mechanistic analysis of typical pavement sections. Therefore, having laboratory test data on asphalt mixes is necessary for characterizing fatigue behavior; however, laboratory testing must be interpreted appropriately using mechanistic analyses to determine how mixes are likely to perform in the pavement structure under anticipated traffic loads and environmental conditions.

Fatigue characterization of typical pavement sections using NCDOT fatigue models and using mechanistic analysis procedure suggests the following:

- Pavement fatigue life is sensitive to the mix variables and test temperatures considered in this study.
- NCDOT fatigue models yield fatigue life similar to those obtained using SHRP fatigue model. However, NCDOT models are sensitive to temperature (in the range of 15 to 25°C), whereas the SHRP fatigue model per-se, was not sensitive to temperature.
- An increase in temperature results in decrease in fatigue life of pavement section under consideration. A 5°C increase in temperature results in about 25-percent reduction in pavement life.
- NCDOT Superpave mixes are sensitive to asphalt content. A decrease in asphalt content by 0.5-percent (by wt. of mix) results in decrease of 18 to 25-percent fatigue life.
- NCDOT mixes are also sensitive to air void content as expected. An increase in 2% air void content will reduce pavement life by about 40% for SP 12.5-mm mixes, and by almost 60% for SP 19-mm mixes.
- Based on the overall result of analysis, it appears that SP 19-mm mix is more sensitive to mix variables as compared to the SP 12.5-mm mix.

Table of Contents

DISCLAIMER II

ACKNOWLEDGEMENTS III

EXECUTIVE SUMMARY IV

TABLE OF CONTENTS VI

LIST OF TABLES X

LIST OF FIGURES XIII

LIST OF ABBREVIATIONS AND SYMBOLS XVII

1. INTRODUCTION 1

1.1 Background 1

1.2 Research need 3

1.3 Objectives and scope of the study 3

2. MIX DESIGN VERIFICATION AND SPECIMEN FABRICATION 5

2.1 JMF Verification 5

2.1.1 Gradation requirement 5

2.1.2 Volumetric analysis for asphalt mixes 5

2.2 Specimen Fabrication 6

3. FATIGUE TESTING 11

3.1 Objective 11

3.2 Mix and Test Variables 11

3.3 Fatigue test results and discussion 13

3.3.1 Fatigue test results 13

3.3.2 Discussion of test results 13

4. STATISTICAL ANALYSIS OF FATIGUE TEST RESULTS 28

4.1 Introduction 28

4.2 GLM analysis for fatigue life (N_f) 30

4.2.1 Effect of asphalt content and aggregate gradation 30

4.2.2 The effect of temperature on fatigue life 31

4.2.3 Effect of air void on fatigue life 32

4.2.4 Effect of strain level 33

4.3 Analysis of Initial Flexural Stiffness S_0 33

4.3.1 Effect of temperature, air void content and gradation and asphalt content on S_0 34

4.3.2 Effect of strain level on S_0 35

4.4 Regenerating data 35

4.5 Summary 36

5. AXIAL FREQUENCY SWEEP TESTING 52

5.1 Introduction 52

5.2 Experiment design 53

5.3 Axial frequency sweep test 53

5.4 Analysis of axial stiffness 54

5.4.1 Surrogate models for axial stiffness 54

5.4.2 Surrogate models for phase angle 55

5.5 Summary 56

6. SHEAR FREQUENCY SWEEP TESTING 67

6.1 Introduction *67*

6.2 Experiment design *68*

6.3 Shear frequency sweep test results *68*

6.4 Analysis of shear stiffness *69*

6.4.1 Surrogate models for shear stiffness 69

6.4.2 Surrogate models for phase angle 70

6.5 Relationships between axial and shear modulus *70*

6.6 Shear frequency sweep test for field cores *71*

6.7 Summary *72*

7. FATIGUE MODELS AND PROCEDURE FOR FATIGUE ANALYSIS 84

7.1 Introduction *84*

7.2 Fatigue models *84*

7.3 Fatigue analysis of typical pavement sections *86*

7.3.1 Traffic loading and temperature consideration 86

7.3.2 Design pavement structure 87

7.3.3 Analysis procedure 87

7.4 Effect of mix variables and temperature on fatigue life of pavement section *88*

7.4.1 Effect of asphalt concrete layer thickness 89

7.4.2 Effect of mix variables and temperature 89

7.5 Summary *91*

8. SUMMARY AND CONCLUSIONS 100

REFERENCES 104

APPENDIX A. 106

APPENDIX B. FATIGUE TEST DATA 108

APPENDIX C. ADJUSTED FATIGUE DATA BASED ON GLM 114

APPENDIX D. AXIAL FREQUENCY SWEEP TEST DATA.................................... 119

APPENDIX E. SHEAR FREQUENCY SWEEP TEST DATA................................... 134

APPENDIX F. SHEAR FREQUENCY SWEEP TEST RESULTS, FIELD CORES.. 154

List of Tables

TABLE 2-1 SOURCE AND PROPORTION OF MATERIAL USED 7

TABLE 2-2 GRADATION ANALYSIS FOR SP 12.5-MM GRADATION 7

TABLE 2-3 GRADATION ANALYSIS FOR SP 19-MM GRADATION 7

TABLE 2-4 SUPERPAVE HOT MIX ASPHALT JOB MIX FORMULAS 8

TABLE 2-5 RICE SPECIFIC GRAVITY 8

TABLE 2-6 VOLUMETRICS FOR MIX TYPES SP 12.5-MM AND SP 19-MM 8

TABLE 2-7 VOLUMETRICS FOR SP 12.5-MM AND SP 19-MM 8

TABLE 3-1 FEATURES OF THE EXPERIMENTAL STUDY 16

TABLE 4-1 PEARSON CORRELATION COEFFICIENT (R) MATIX 37

TABLE 4-2 RESULTS OF FORWARD AND STEPWISE SELECTION METHOD ON N_F 37

TABLE 4-3 RESULTS OF BACKWARD ELIMINATION METHOD ON N_F 38

TABLE 4-4 GRADATION EFFECT ON FATIGUE LIFE 38

TABLE 4-5 THE EFFECT OF AIR VOID CONTENT ON FATIGUE LIFE 38

TABLE 4-6 RESULTS OF GLM FOR INITIAL FLEXURAL STIFFNESS S_0 IN FULL MODEL 39

TABLE 4-7 RESULTS OF FORWARD AND STEPWISE SELECTION METHOD FOR S_0 40

TABLE 4-8 RESULTS OF BACKWARD ELIMINATION METHOD FOR S_0 40

TABLE 4-9 AVERAGE EFFECTS OF TEST VARIABLES 41

TABLE 5-1 MIX AND TEST VARIABLES FOR AFST EXPERIMENT DESIGN 57

TABLE 5-2 SUMMARY OF REGRESSION ANALYSIS FOR $|E^*|$ AT 10 HZ 57

TABLE 5-3 SUMMARY OF REGRESSION ANALYSIS FOR $|E^*|$ AT VARIABLE FREQUENCY 58

Table 5-4 Summary of Regression Analysis for |E"| at Varible Frequency........ 58
Table 5-5 Summary of Regression Analysis for Axial Phase Angle 58
Table 6-1 Mix and Test Variables for FSCH Experiment Design 73
Table 6-2 Summary of Statistical Analysis for $|G^*|$ at 10 Hz 73
Table 6-3 Summary of Statistical Analysis for $|G^*|$ at Variable Frequency..... 74
Table 6-4 Summary of Statistical Analysis for |G"| at Variable Frequency..... 74
Table 6-5 Summary of Statistical Analysis for Phase Angle.............................. 74
Table 6-6 Summary of Statistical Analysis for $|E^*|$ versus $|G^*|$ 75
Table 6-7 Summary of Statistical Analysis for |E"| versus |G"| 75
Table 6-8 Average Shear Test Data for Field Samples, SP 12.5-mm Mix 75
Table 6-9 Average Shear Test Data for Field Samples, SP 19-mm Mix 76
Table 6-10 Comparison of Test Data between Lab and Field Samples 76
Table 7-1 Summary of Analysis of N_F with $|E^*|$, SP 12.5-mm Mix 93
Table 7-2 Summary of Analysis of NF with E", SP 12.5-mm Mix 93
Table 7-3 Summary of Regression Analysis of N_F with $|E^*|$, SP 19-mm Mix............. 93
Table 7-4 Summary of Regression Analysis of N_F with E", SP 19-mm Mix.............. 93
Table 7-5 Summary of General Regression Analysis of N_F with $|E^*|$..................... 94
Table 7-6 Summary of General Regression Analysis of N_F with E" 94
Table 7-7 Surface Layer Thickness vs. N_{supply}, SP 12.5-mm Mix.............................. 94
Table 7-8 Fatigue Life of SP 12.5-mm Mix with Optimum AC.................................... 95
Table 7-9 Fatigue Life of SP 12.5-mm Mix with Optimum -0.5% AC 95
Table 7-10 Fatigue Life of SP 19-mm Mix with Optimum AC....................................... 95
Table 7-11 Fatigue Life of SP 19-mm Mix with Optimum-0.5% AC 96

TABLE 7-12 COMPARISON OF FATIGUE LIFE FOR OPT. AC AND OPT.-0.5% AC 96

TABLE 7-13 EFFECT OF AIR VOID CONTENT ON FATIGUE LIFE 97

TABLE 7-14 EFFECT OF TEMPERATURE ON FATIGUE LIFE 97

List of Figures

Figure 1-1 Schematic of superpave performance prediction 2

Figure 1-2 Summary of research approach 4

Figure 2-1 (a)-(f) Gradation analysis 9

Figure 2-2 Final gradation for SP 12.5-mm gradation 10

Figure 2-3 Final gradation for SP 19-mm gradation 10

Figure 3-1 Stiffness vs. number of cycles for beam 1 in slab 2 at 15°C 17

Figure 3-2 Stiffness vs. number of cycles for beam 7 in slab 26 at 25°C 17

Figure 3-3 (a)-(c) Effect of asphalt content on fatigue life for SP 12.5-mm mixes, T=15°C 18

Figure 3-4 (a)-(c) Effect of asphalt content on fatigue life for SP 12.5-mm mixes, T=20°C 18

Figure 3-5 (a)-(c) Effect of asphalt content on fatigue life for SP 12.5-mm mixes, T=25°C 19

Figure 3-6 (a)-(f) Effect of asphalt content on fatigue life for SP 19-mm mixes 20

Figure 3-7 (a)-(c) Effect of gradation on fatigue life for optimum asphalt content, T=15°C 21

Figure 3-8 (a)-(c) Effect of gradation on fatigue life for optimum asphalt content, T=20°C 21

Figure 3-9 (a)-(c) Effect of gradation on fatigue life for optimum asphalt content, T=25°C 22

FIGURE 3-10 (A)-(C)EFFECT OF GRADATION ON FATIGUE LIFE FOR OPTIMUM-0.5% ASPHALT CONTENT, T=15°C 22
FIGURE 3-11 (A)-(C)EFFECT OF GRADATION ON FATIGUE LIFE FOR OPTIMUM-0.5% ASPHALT CONTENT, T=15°C 23
FIGURE 3-12 (A)-(C)EFFECT OF GRADATION ON FATIGUE LIFE FOR OPTIMUM-0.5% ASPHALT CONTENT, T=25°C 23
FIGURE 3-13 EFFECT OF AIR VOIDS ON FATIGUE LIFE FOR SP 12.5-MM MIXES 24
FIGURE 3-14 EFFECT OF AIR VOIDS ON FATIGUE LIFE FOR SP 19-MM MIXES 25
FIGURE 3-15 EFFECT OF TEMPERATURE ON FATIGUE LIFE FOR SP 12.5-MM MIXES 26
FIGURE 3-16 EFFECT OF TEMPERATURE ON FATIGUE LIFE FOR SP 19-MM MIXES 27
FIGURE 4-1 EFFECT OF ASPHALT CONTENT AND GRADATION ON N_F, V_A=4%, T=25°C 42
FIGURE 4-2 EFFECT OF ASPHALT CONTENT AND GRADATION ON N_F, V_A =6%, T=25°C 42
FIGURE 4-3 EFFECT OF ASPHALT CONTENT AND GRADATION ON N_F, V_A =8%, T =25°C 43
FIGURE 4-4 EFFECT OF ASPHALT CONTENT AND GRADATION ON N_F, V_A =4%, T=20°C 43
FIGURE 4-5 EFFECT OF ASPHALT CONTENT AND GRADATION ON N_F, V_A =6%, T =20°C 44
FIGURE 4-6 EFFECT OF ASPHALT CONTENT AND GRADATION ON N_F, V_A =8%, T=20°C 44
FIGURE 4-7 EFFECT OF ASPHALT CONTENT AND GRADATION ON N_F, V_A =4%, T=15°C 45
FIGURE 4-8 EFFECT OF ASPHALT CONTENT AND GRADATION ON N_F, V_A =6%, T=15°C 45
FIGURE 4-9 EFFECT OF ASPHALT CONTENT AND GRADATION ON N_F, V_A =8%, T=15°C 46
FIGURE 4-10 EFFECT OF TEMPERATURE ON N_F, V_A = 4% 46
FIGURE 4-11 EFFECT OF TEMPERATURE ON N_F, V_A = 6% 47
FIGURE 4-12 EFFECT OF TEMPERATURE ON N_F, V_A = 8% 47
FIGURE 4-13 EFFECT OF AIR VOID CONTENT ON N_F FOR SP 12.5-MM MIX 48

Figure 4-14 Effect of air void content on N_F for SP 19-mm mix 48
Figure 4-15 Effect of air void content and temperature on initial stiffness for SP 12.5-mm with optimum AC, 400 μ-strain 49
Figure 4-16 Effect of air void content and temperature on initial stiffness for SP 12.5-mm with optimum minus 0.5-percent AC, 400 μ-strain 49
Figure 4-17 Effect of air void content and temperature on initial stiffness for SP 19-mm with optimum AC, 400 μ-strain 50
Figure 4-18 Effect of air void content and temperature on initial stiffness for SP 19-mm with optimum minus 0.5-percent AC, 400 μ-strain 50
Figure 4-19 Comparison of initial average stiffness for different mixtures.. 51
Figure 5-1 Dimension of specimen for axial frequency sweep test 60
Figure 5-2 Axial stiffness versus frequency for SP 19-mm mixes 61
Figure 5-3 Axial stiffness versus frequency for SP 12.5-mm mixes 62
Figure 5-4 Master curves for SP 12.5-mm with optimum AC, 20°C 63
Figure 5-5 Master curves for SP 12.5-mm with optimum -0.5% AC, 20°C 63
Figure 5-6 Master curves for SP 19-mm with optimum AC, 20°C.............................. 64
Figure 5-7 Master curves for SP 19-mm with optimum-0.5% AC, 20°C..................... 64
Figure 5-8 Comparison between calculated and measured phase angle for SP 12.5-mm mixes 65
Figure 5-9 Comparison between calculated and measured phase angle for SP 19-mm mixes 66
Figure 6-1 Shear stiffness versus frequency for SP 12.5-mm mixes 78
Figure 6-2 Shear stiffness versus frequency for SP 19-mm mixes 79

Figure 6-3 Master curves for SP 12.5-mm mix with optimum AC, 20°C 80

Figure 6-4 Master curves for SP 12.5-mm mix with optimum minus 0.5-percent AC, 20°C 80

Figure 6-5 Master curves for SP 19-mm mix with optimum AC, 20°C 81

Figure 6-6 Master curves for SP 19-mm mix with optimum minus 0.5-percent AC, 20°C 81

Figure 6-7 Master curve for SP 12.5-mm mix with average V_A = 7.5%, 20°C 82

Figure 6-8 Master curve for SP 19-mm mix with average V_A = 7.9%, 20°C 82

Figure 6-9 Field $|G^*|$ versus lab $|G^*|$ at 10 Hz 83

Figure 6-10 Field phase angle versus lab phase angle at 10 Hz 83

Figure 7-1 Pavement structure for SP 12.5-mm mix 98

Figure 7-2 Pavement structure for SP 19-mm mix 98

Figure 7-3 Surface layer thickness vs. N_{supply} 99

List of Abbreviations and Symbols

AC	Asphalt Concrete/Asphalt Content
AFST	Axial Frequency Sweep Test
$\|E^*\|$	Dynamic axial stiffness
E''	Axial loss stiffness
FSCH	Frequency Sweep test at Constant Height
G_{mm}	Theoretical Maximum Specific Gravity (ASTM D2041)
$\|G^*\|$	Dynamic shear stiffness
G''	Shear loss stiffness
GLM	General Linear Model
JMF	Job Mix Formula
MTS	Material Test System
NCDOT	North Carolina Department of Transportation
N_{demand}	Pavement life in ESALs
N_f	Laboratory fatigue life
N_{supply}	Pavement fatigue life
PG	Performance Graded
S_0	Initial flexural stiffness at 10 Hz frequency
S_0''	Initial flexural loss stiffness at 10 Hz frequency
SGC	Superpave Gyratory Compactor
SST	Simple Shear Testing machine
SUPERPAVE™	SUperior PERforming PAVEments
UTM	Universal Testing Machine
ϕ	Phase angle

1. Introduction

1.1 Background

The update of the AASHTO Pavement Design Guide Currently under development is geared to promote the use of a "Mechanistic/Empirical" design procedure. The mechanistic approach to design (for both new pavements and overlays) involves the prediction of performance—the manifestation and severity of distresses during the life of pavements.

There are several integrated steps required in the prediction of performance using mechanistic procedure. One such approach to performance prediction is schematically shown in Figure 1-1 [1]. The mechanistic portion of this approach consists of Pavement Response Models (stress, strain and/or deflections) and the Pavement Distress Models. For a given pavement section and climatic conditions the pavement distress model translates the stresses, strains and deflections induced by traffic loading to degree of distress (fatigue cracking, rutting, thermal cracking, etc.) manifestation using the laboratory evaluated materials property and performance testing. The mechanistically evaluated laboratory performance predictions are translated using empirical "transfer functions" (commonly known as shift factors) for in-situ pavement performance predictions.

In lieu of actual materials characterization using laboratory tests, there are several Material Property Models as well as Distress Models available or under development by many agencies such as AASHTO design guide and Superpave mix analysis models. However, these material property models are rarely applicable directly to local situations as the HMA mix parameters continually vary based on the location of the project under consideration. For the distress models, the development of relationship(s) between pavement response and distress prediction as well as the determination of the empirical transfer functions need to be developed based on local experience for asphalt mixes, which is the responsibility of individual state highway agencies.

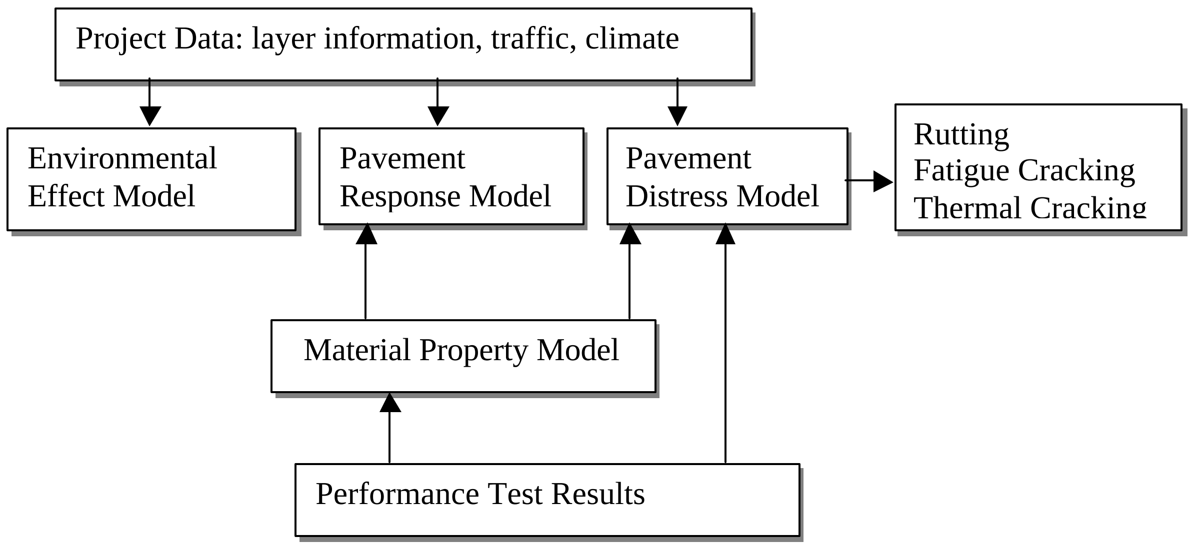


Figure 1-1 Schematic of Superpave Performance Prediction [1]

In addition to design of new pavements and overlays, the mechanistic design approach can also be an extremely useful tool for two other purposes – 1) selection of appropriate asphalt content, and 2) forensic analysis. For a satisfactory performance of a given pavement section under consideration, the selected asphalt mixture must be able to withstand traffic loading (ESAL's) without experiencing excessive distresses. In a mechanistic design approach, the traffic loading can be directly related to the acceptable distress criterion and the asphalt mixture characteristics—asphalt content, air voids and aggregate type and gradation. In forensic analysis, it is possible to assess penalty in cases of premature pavement failure or non-compliance of job specification for construction of HMA pavements under the quality management system. Such a mechanistic forensic procedure was successfully used in 1998 by NCDOT [2] to determine the extent of loss of pavement life and assessing appropriate penalty for a pavement section in Rutherford County, NC where the contractor had failed to use required anti-strip additive in HMA.

Details of mechanistic approach to forensic analysis of pavement sections can be found in a report prepared by Tayebali, et al., [2].

1.2 Research need

The need for this research project was based on the introduction of Superpave mixes for use in all divisions of NCDOT. The key question that arises is with regard to the sensitivity of the NCDOT Superpave mixes to fatigue distress due to: 1) variation in asphalt content normally encountered in construction of asphalt pavements; and 2) change in aggregate gradation. It is also expected that other mix and test variables will affect the fatigue performance of the mixes.

1.3 Objectives and scope of the study

The objectives of this research study were to characterize properties of two NCDOT Superpave mixes, and to develop phenomenological fatigue relationships for these mixes based on various levels of strain, asphalt content, air void content, and temperatures. This study includes laboratory investigation of a SP 12.5-mm and a SP 19-mm intermediate mixes at moderate temperatures of 15°C, 20°C and 25°C where predominant fatigue cracking is expected to be significant.

Specific work tasks that were considered are following:

1. Verify the job mix formula (JMF) provided by NCDOT for the SP 12.5-mm and SP 19-mm mixes.
2. For the design optimum AC content and an asphalt content 0.5% less than optimum, prepare rolling wheel compacted slabs to manufacture flexural beam specimens 15-in by 2.5-in by 2-in, and 6-in diameter cylindrical specimens for fatigue testing and shear stiffness characterization, respectively. Two 6-in long prismatic specimens were also sawed from the slab for axial stiffness characterization. Slabs were compacted to achieve 3 air void levels corresponding to 4, 6, and 8-percent.

3. Conduct flexural fatigue testing on beam specimens at 15°C, 20°C, and 25°C at 3 different strain levels to develop fatigue curves for the various mixtures.
4. For the core specimens, conduct shear frequency sweep test at the 3 temperatures and at frequencies ranging from 0.1 to 15Hz.
5. For the prismatic beam specimens, conduct axial frequency sweep test at the 3 temperatures and at frequencies ranging from 0.1 to 15 Hz.
6. Obtain a limited number of cores from the field for shear frequency sweep test.
7. Analyze the test results and develop fatigue distress models; and axial and shear stiffness models.
8. Develop a pavement and overlay design analysis procedure based on typical pavement cross section encountered in North Carolina.
9. Prepare a final report for NCDOT.

This study was conducted in three specific tasks corresponding directly to the objectives stated earlier. Figure 1-2 provides the work plan for the project.

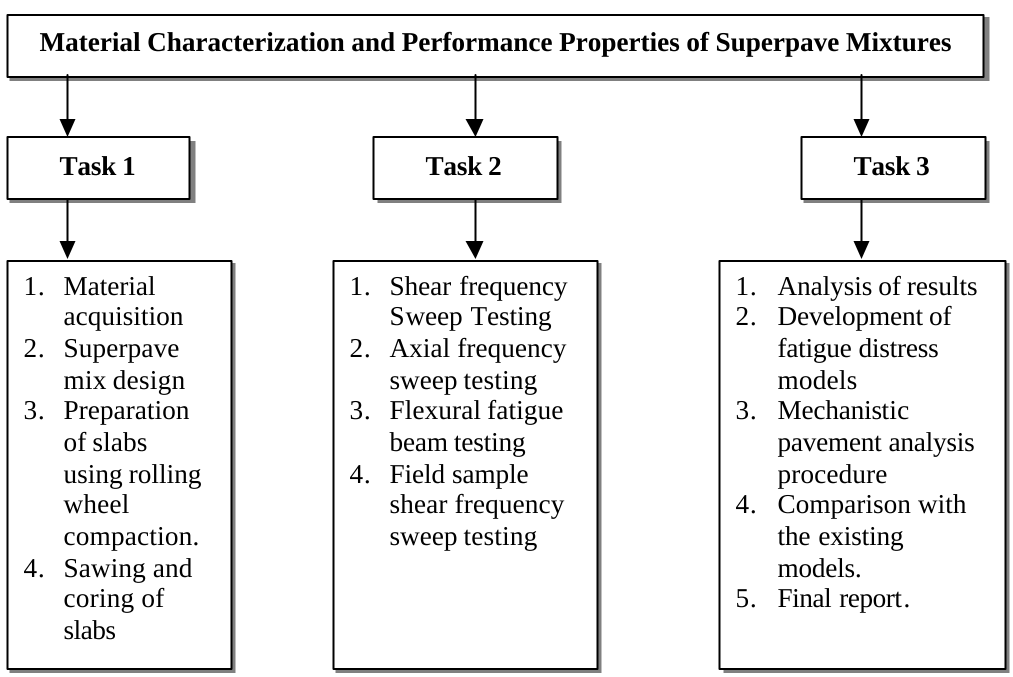


Figure 1-2 Summary of research approach

2. Mix Design Verification and Specimen Fabrication

2.1 JMF Verification

This section deals with the verification of the job mix formula (JMF) including the volumetric properties for the SP 12.5-mm and SP 19-mm mixes obtained from NCDOT. The NCDOT JMFs are attached in Appendix A.

2.1.1 Gradation requirement

Table 2-1 shows the source and proportion required for blending of the material for the SP 12.5-mm and SP 19-mm mixes. These materials are the same as ones used for the SPS-9A Project 370900, Highway US-1, Northbound, in Sanford, NC.

Several blending trials were conducted to achieve the required gradation. One problem that was encountered was that when using the first batch of screenings material obtained, the required gradation could not be achieved as shown in Figure 2-1. This was corrected by obtaining new screenings material. Table 2-2 and Table 2-3 show the final gradations used for 12.5-mm and 19-mm aggregates, which are also shown in Figure 2-2 and Figure 2-3.

2.1.2 Volumetric analysis

With the aggregate gradation shown previously, AC mixes were prepared using PG 64-22 Citgo Wilmington asphalt, and compacted using the Superpave Gyratory Compactor (SGC). Asphalt contents used were as per the JMF: 5.2-percent by wt. of mix for 12.5-mm gradation and 4.7-percent by wt. of mix for 19-mm gradation.

Table 2-4 summarizes the volumetric properties from the JMF. For the mixes prepared in laboratory, the Rice Specific Gravity, and the volumetric properties are summarized in Table 2-5 through Table 2-7. Although there are some minor differences in volumetric properties obtained in lab vs. the JMF, in general, these mixes are fairly similar.

2.2 Specimen Fabrication

Three types of specimens were required for testing in this project: flexure beam specimens (15-inches by 2-inches by 2.5-inches); cylindrical specimens (6-inches diameter by 2-inches height) and prismatic specimens (6-inches by 2-inches by 2.5 inches). These specimens were sawn or cored from rolling wheel compacted slabs of 24-inches by 24-inches size. The air voids for the compacted slabs were targeted to 4, 6, and 8-percent. However, it should be noted that actual air void content for individual specimens varied. Details for the air void contents of individual specimens will be given later when describing results for each test type.

Table 2-1 Source and proportion of material used

Supplier	Location/Source	Material	SP 12.5-mm Blend (%)	SP 19-mm Blend (%)
Martin Marietta	Lemon Springs Quarry	#67	15.0	50.0
Martin Marietta	Lemon Springs Quarry	#78	55.0	22.0
Martin Marietta	Lemon Springs Quarry	REG. SCRGS.	19.0	17.0
Lee Paving Company	Rambeaut Pit	N. SAND	10.0	10.0
		Baghouse fines	1.0	1.0

Table 2-2 Gradation analysis for SP 12.5-mm gradation

Sieve size (U.S. Designation)	Sieve size mm	Sample 1 % passing	Sample 2 % passing	Average % passing	Target % passing
3/4"	19	100	100	100	100
1/2"	12.5	95.4	95.2	95	94
3/8"	9.5	83.3	82.2	83	84
4	4.75	48.2	45.0	47	43
8	2.36	30.2	29.2	30	29
16	1.18	23.7	23.1	23	23
30	0.6	17.4	17.0	17	17
50	0.3	10.8	10.5	11	9
100	0.15	7.1	6.9	7	7
200	0.075	5.0	4.9	4.9	4.4

Table 2-3 Gradation analysis for SP 19-mm gradation

Sieve size (U.S. Designation)	Sieve size mm	Sample 1 % passing	Sample 2 % passing	Average % passing	Target % passing
1"	25	100	100	100	100
3/4"	19	98.1	98.8	98	99
1/2"	12.5	78.6	78.6	79	80
3/8"	9.5	59.5	58.4	59	62
4	4.75	36.8	37.6	37	35
8	2.36	27.4	28.0	28	27
16	1.18	22.2	22.5	22	22
30	0.6	16.4	16.5	16	16
50	0.3	9.9	10.0	10	9
100	0.15	6.6	6.6	7	6
200	0.075	4.6	4.6	4.6	4.2

Table 2-4 Superpave Hot Mix Asphalt Job Mix Formulas

Mix Type	Max. Sp. Gr. G_{mm}	Gyratory Sp. Gr. G_{mb} @ N_d	Voids in total mix(%)	Voids in Min. Aggregate (%)	Voids Filled w/asph (%)
SP 12.5	2.464	2.356	4	14.8	73
SP 19.0	2.483	2.384	4	14	70

Table 2-5 Laboratory evaluated Rice specific gravity

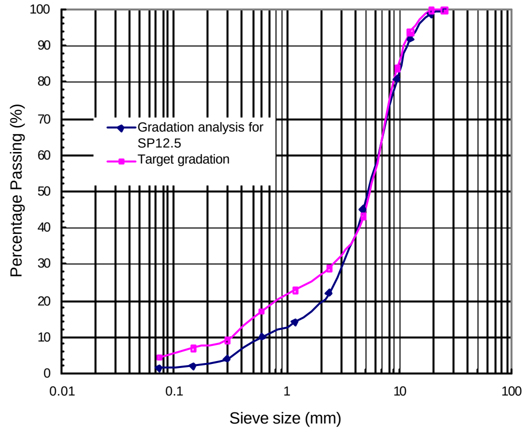
Gradation	Asphalt Content	Average G_{mm}
SP 12.5-mm	Optimum	2.471
	Optimum-0.5%	2.489
SP 19-mm	Optimum	2.487
	Optimum-0.5%	2.502

Table 2-6 Volumetrics for mix types SP 12.5-mm and SP 19-mm

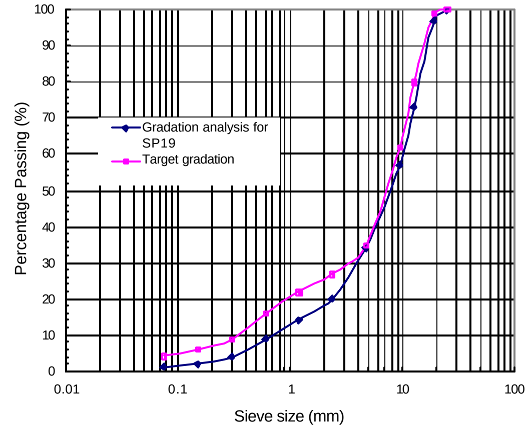
Asphalt Content %	G_{mm}	# Of Gyrations	Height mm	Mass W_m (g)	G_{mb} Estimated	Corr. Factor	G_{mb} Corrected	% G_{mm}
4.7	2.493	N_{ini}	128.4		1.962		2.155	86.4%
		N_{des}	114.6	4452.1	2.198	1.098	2.415	96.8%
		N_{max}	113.0		2.230		2.449	98.2%
5.2	2.471	N_{ini}	125.9		2.117		2.125	86.0%
		N_{des}	112.4	4709.7	2.371	1.004	2.380	96.3%
		N_{max}	110.8		2.405		2.415	97.7%

Table 2-7 Laboratory evaluated volumetrics for SP 12.5-mm and SP 19-mm

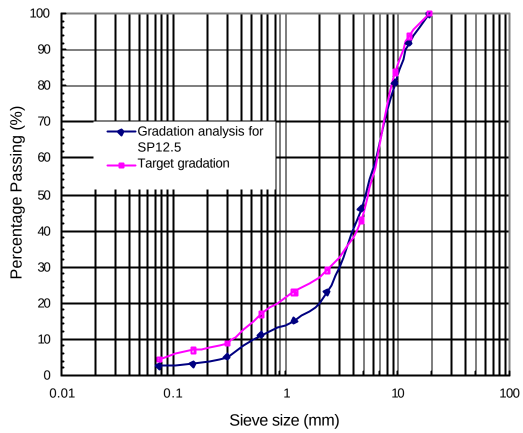
Asphalt Content %	Agg. G_{sb}	Agg. G_{se}	% G_{mm} @ N_{des}	Voids %	VMA %	VFA %
4.7	2.639	2.681	96.8%	3.2%	12.8	75.3
5.2	2.631	2.687	96.3%	3.7%	14.2	74.3



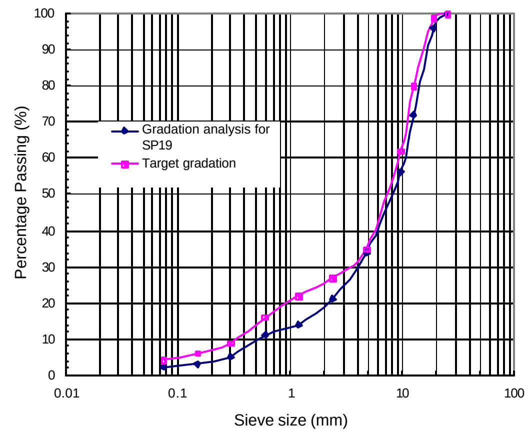
(a) SP12.5 without bagfines



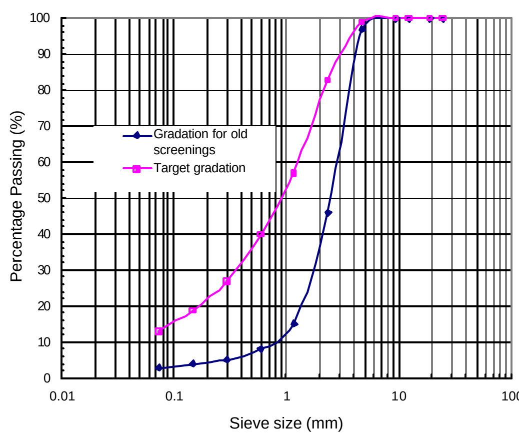
(b) SP19 without bagfines



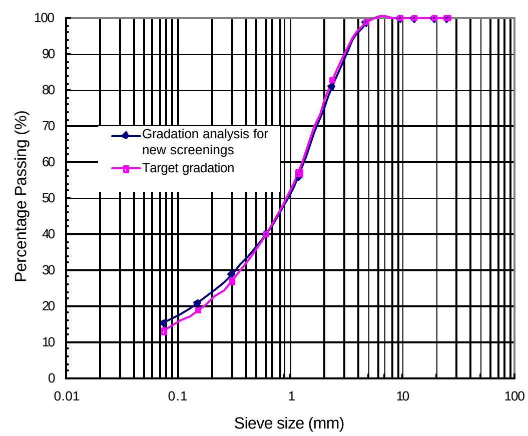
(c) SP12.5 with 1% bagfines



(d) SP19 with 1% bagfines



(e) Gradation using old screenings



(f) Gradation using new screenings

Figure 2-1 (a)-(f) Gradation analysis

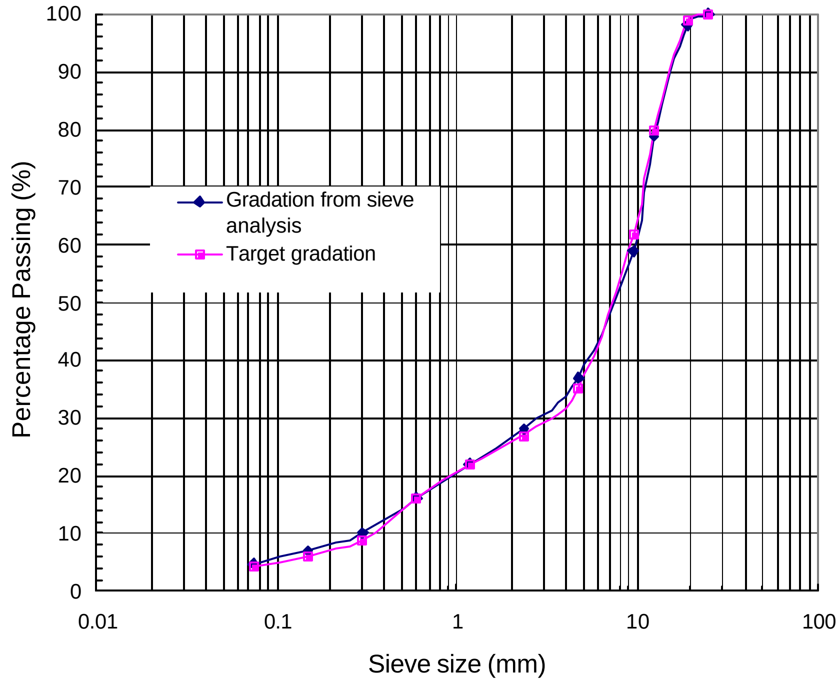


Figure 2-2 Final gradation for SP 12.5-mm gradation

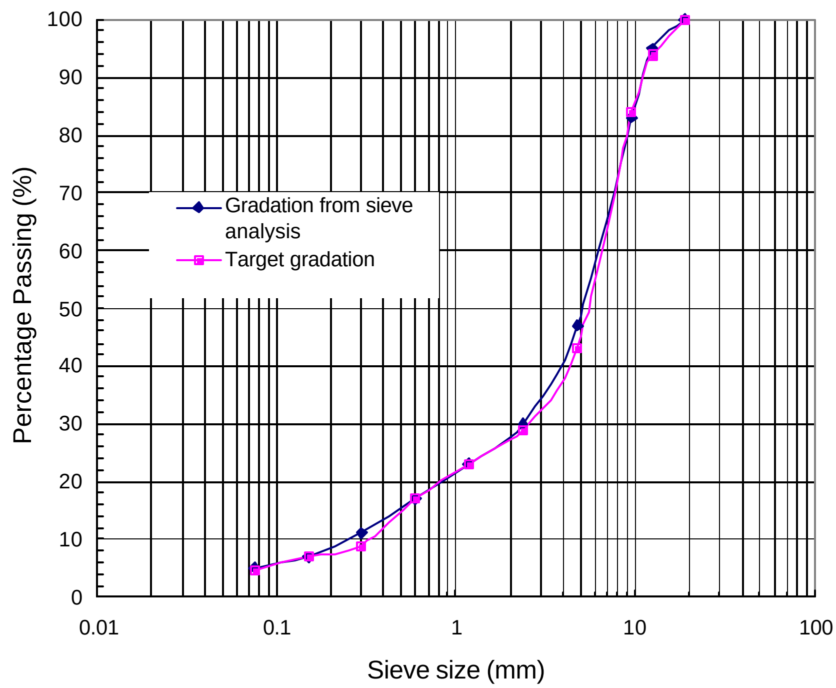


Figure 2-3 Final gradation for SP 19-mm gradation

3. Fatigue Testing

3.1 Objective

The primary purpose of this study was to evaluate the fatigue response of NCDOT Superpave 12.5-mm and 19-mm mixes. Variables that affect the fatigue response of asphalt mixes are asphalt type (temperature susceptibility) and grade, aggregate type (stripping potential) and gradation, asphalt content, air void content, temperature, and stress/strain level, aging , and moisture conditioning, etc. The significant variables considered in this study are asphalt content (AC), air void content (V_a), temperature (Temp), and gradation (GR) as well as strain level. The other variables such as asphalt type and grade, aggregate type, aging as well as moisture conditioning, were not included in this study. The specific objectives of this experiment program were as follows:

1) Evaluating the effect of two levels of asphalt content (optimum and optimum minus 0.5-percent) on the fatigue response;
2) Assessing the effect of two gradations (SP 12.5-mm and SP 19-mm) on the fatigue response;
3) Investigating the effect of temperature on the fatigue response;
4) Estimating the effect of change in air void on the fatigue response; and
5) Based upon the effects of the above four factors and strain amplitude, developing a fatigue response model, initial flexural stiffness model and initial flexural loss stiffness model.

3.2 Mix and Test Variables

The mix and testing variables included in this testing program are summarized in Table 3-1 and are as follows:

- **Asphalt Cement:** PG64-22, Citgo Wilmington, NC.
- **Asphalt Content:** Two asphalt contents were used. One is optimum asphalt content, the other is optimum minus 0.5% by wt. of mix.
- **Aggregate Gradation:** Two types of aggregate gradation were used. The nominal aggregate size is 19-mmand 12.5-mm, respectively.
- **Air-Void Content:** Three levels of air void content were targeted to 4, 6 and 8-percent, with a tolerance of ±1-percent.
- **Strain Levels:** Three levels of strain, 200, 400, and 600 microns, were selected as targets. During testing, the actual strain levels may be slightly different from the target strains.
- **Replicates:** Two replicate specimens were planned to be used at each strain level. However, as will be shown later, replicates could not be tested at exactly the same strain level.
- **Test Frequency:** All the tests were performed in the controlled-strain mode-of-loading at a frequency of 10 Hz, sinusoidal loading with no rest periods.
- **Test temperature.** Three levels of temperature, 15°, 20° and 25° Celsius, were used.

The total number of compacted asphalt mixes used was 12, with total number of specimens that were planned to be tested being equal to 216 as shown in Table 3-1. However, some tests had to be repeated due to high variability in fatigue life for total number of tested specimens being 241.

As mentioned earlier, the fatigue tests conducted in this study were in controlled-strain mode-of-loading. The response variables measured was the stress (s) and fatigue life. Based on the stress response, the stiffness was computed as the ratio of peak stress and peak strain, and the phase angle was computed as the phase lag between peak stress and peak strain. Initial stiffness was defined to correspond to 50th load cycle; and fatigue life was defined to correspond to 50-percent reduction in initial stiffness.

Figure 3-1 and Figure 3-2 show typical evolution of stiffness as function of the number of loading cycles at 15 and 25°C.

3.3 Fatigue test results and discussion

3.3.1 Fatigue test results

The fatigue test results are presented in Appendix B, which shows the test strain level used, the initial stiffness, initial phase angle, initial loss stiffness, and the fatigue life for each specimen and test condition.

It should be noted that the mix type and test condition is coded in Appendix B for simplicity in presenting the data. Following is the code number system used in presenting the data:

Asphalt content (AC): -1--optimum minus 0.5%, and +1--optimum

Aggregate gradation (GR): -1--12.5-mm, and +1--19.0-mm

Temperature (Temp): -1--15°C, 0---20°C, and +1--25°C

Repeat (RT): -1--First repeat, and +1--Second repeat

The air void content and strain levels used are actual numbers, in percent and in./in., respectively.

3.3.2 Discussion of test results

For a large data set such as the one presented in this study, it is always difficult to describe the trend in data for each individual variable. Therefore, for simplicity in presentation, the discussion below is subdivided based on grouping of data. It should be noted that the comparison presented herein may not be a true reflection of the trends due to variations in air void content as well as the strain levels from specimen to specimen. Therefore, the following section presents the general trend in data. More rigorous statistical analysis of the data is presented in chapter 4 of this report.

3.3.2.1 Effect of asphalt content

The effect of asphalt content on fatigue life is presented in Figure 3-3 to Figure 3-6. Figure 3-3 to Figure 3-5 pertains to 12.5-mm gradation. It can be seen from these figures that in general, there is distinct difference in fatigue life due to different asphalt content. Lower asphalt content results in lower fatigue life for the three temperatures as well as air void levels considered in this study. The same is also true for the SP 19-mm gradation mixes presented in Figure 3-6. It should be noted that there is some variability in the data, especially with regard to air voids. The design implication due to change in asphalt content will be enumerated in a later chapter.

3.3.2.2 Effect of gradation on fatigue life

Figure 3-7 to Figure 3-12 show the effect of aggregate gradation on fatigue life of mixes. In general, there seems to be a difference in the performance with SP 19-mm gradation mixes showing lower fatigue life in comparison with SP 12.5-mm gradation mixes. However, it should be noted that the SP 19-mm mixes have an optimum asphalt content of 4.7-percent compared to 12.5-mm mixes that have an optimum asphalt content of 5.2-percent.

3.3.2.3 Effect of air void content

The effect of air void content is shown in Figure 3-13 and Figure 3-14 for SP 12.5-mm and SP 19-mm mixes, respectively. The results show very large variability in test results, especially for the SP 12.5-mm mixes. For SP 19-mm mixes, there is some indication of longer fatigue life for mixes with lower air voids, especially at low strain levels.

3.3.2.4 Effect of temperature on fatigue life

Figure 3-15 and Figure 3-16 show the effect of temperature on fatigue life. Although, there is some variability, in general, the fatigue life is lower at lower temperature. This is expected as fatigue testing was conducted in strain-controlled mode-of-loading.

Table 3-1 Features of the experimental study

Number of asphalts	1-PG64-22
Number of aggregate gradations	2-12.5-mm and 19-mm intermediate
Asphalt Contents	2-Superpave optimum 5.2-percent. and optimum minus 0.5-percent for SP12.5; Superpave optimum 4.7-percent and optimum minus 0.5-percent for Sp19
Air Void Levels	3- About 4, 6, and 8-percent
Temperatures	3- 15°C, 20°C, and 25°C
Test Frequency	10 Hz sinusoidal loading without rest period
Strain Levels	3-About 200, 400 and 600 micro in./in.
Specimen Size	2 in. height, 2.5 in. width, 15 in. length
Replicates	2- at each strain level
Total Number of Mixes	12- 2 gradations, 2 asphalt contents, 3 air void contents
Total Number of Fatigue Tests	2 replicates x 12 mixes x 3 x 3 = 216

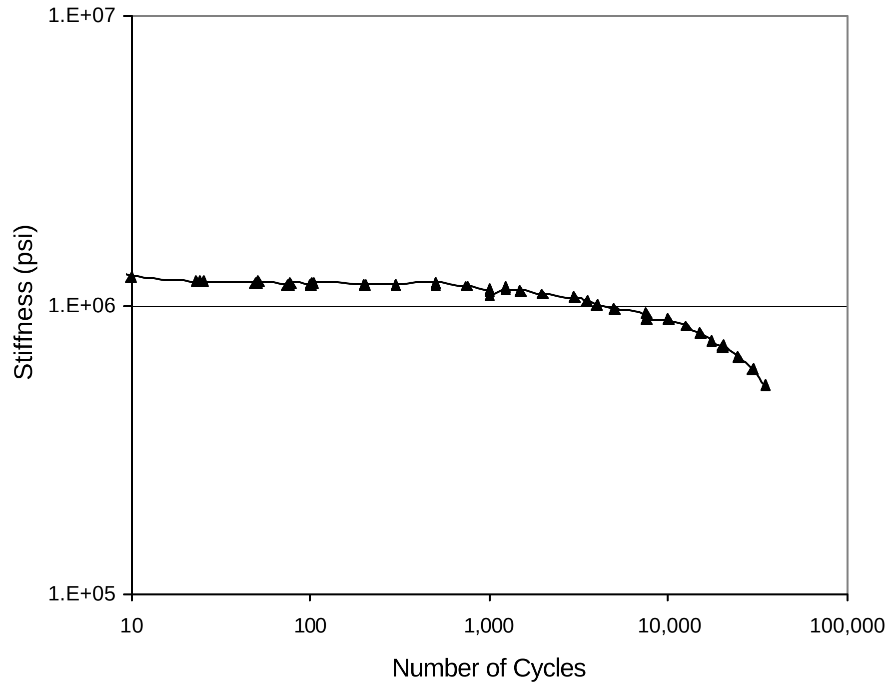


Figure 3-1 Stiffness vs. number of cycles at 15° C

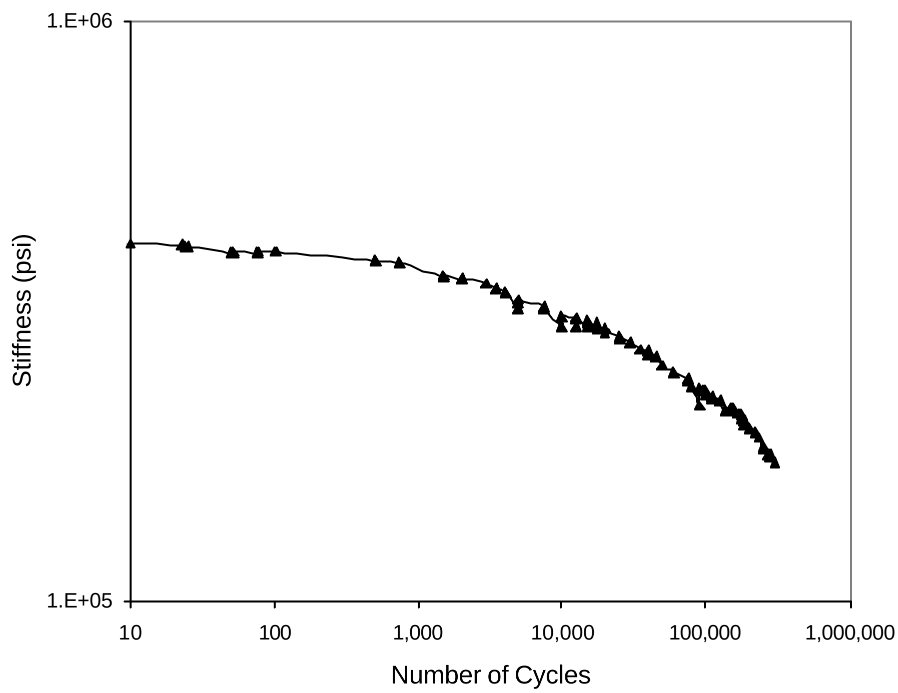
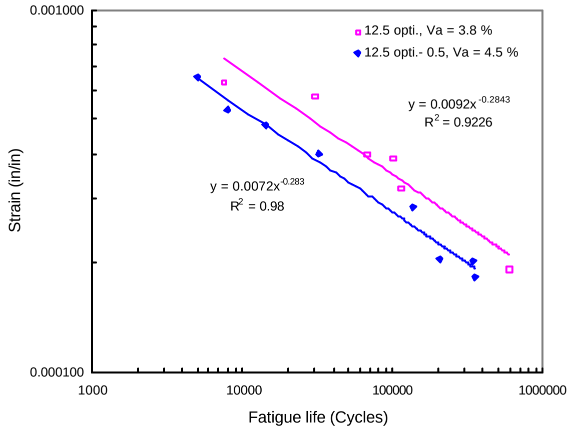
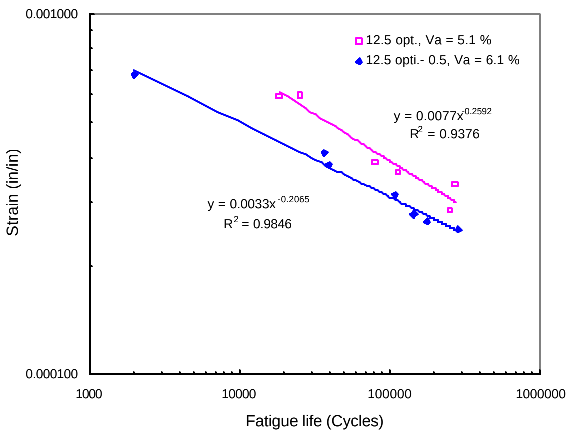


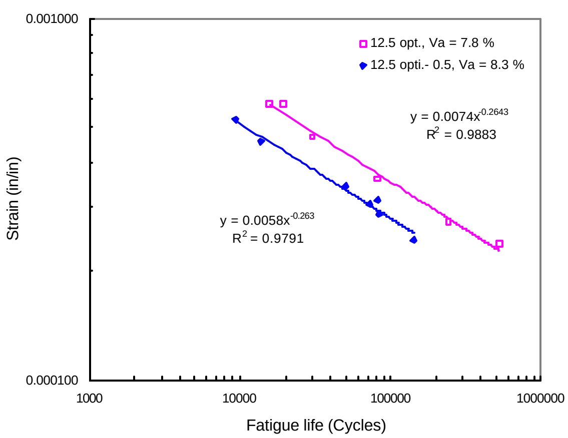
Figure 3-2 Stiffness vs. number of cycles at 25° C



(a) T=15°C, Air void is about 4%

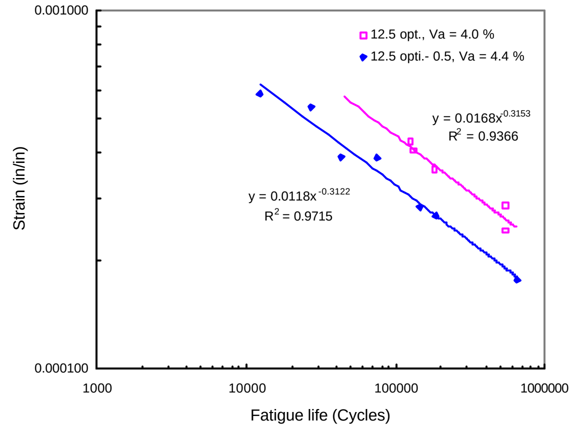


(b) T=15°C, Air void is about 5.5%

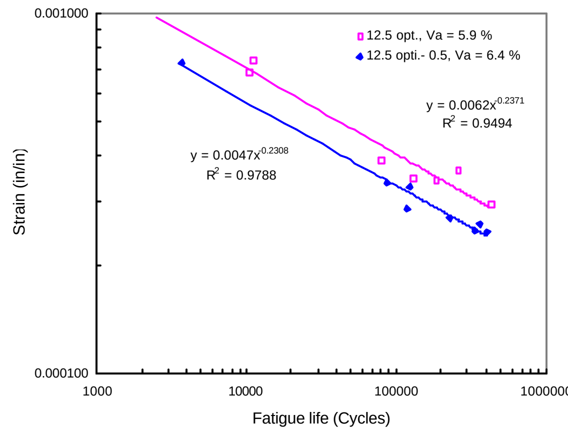


(c) T=15°C, Air void is about 8%

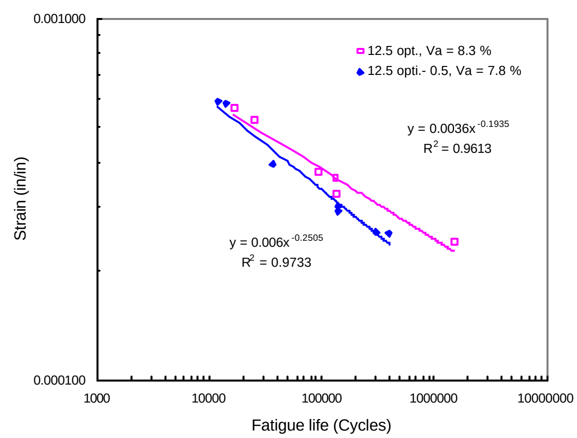
Figure 3-3 (a)-(c) Effect of asphalt content on fatigue life for SP 12.5-mm mixes, T=15°C



(a) T=20°C, Air void is about 4%

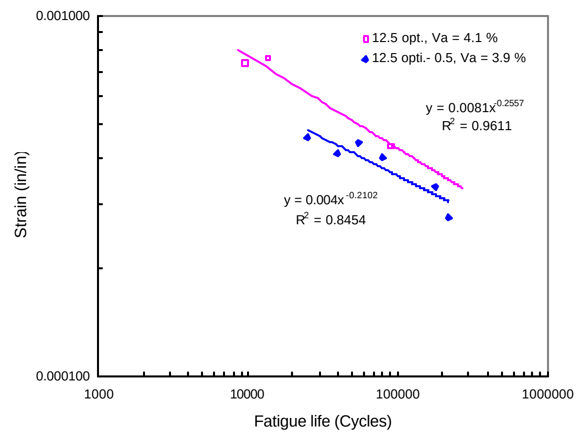


(b) T=20°C, Air void is about 6%

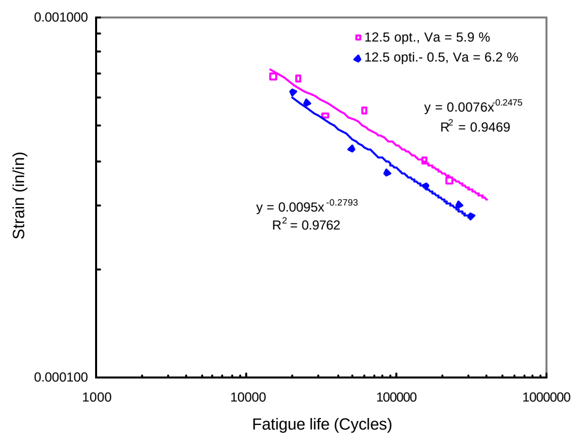


(c) T=20°C, Air void is about 8%

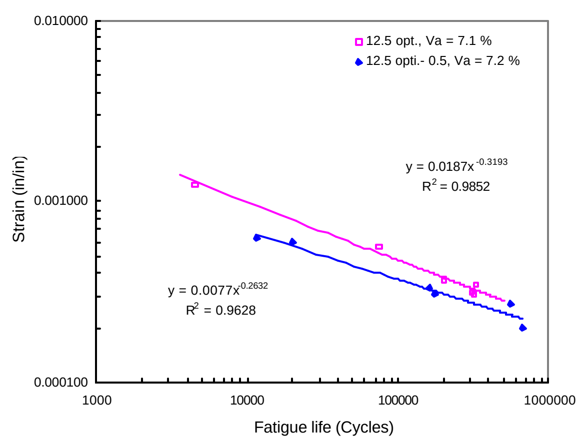
Figure 3-4 (a)-(c) Effect of asphalt content on fatigue life for SP 12.5-mm mixes, T=20°C



(a) T=25°C, Air void is about 4%

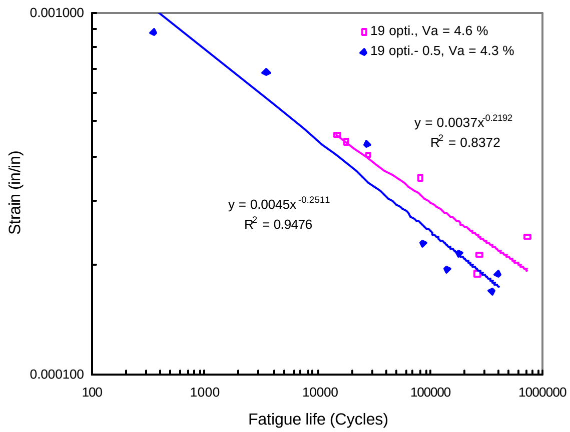


(b) T=25°C, Air void is about 6%

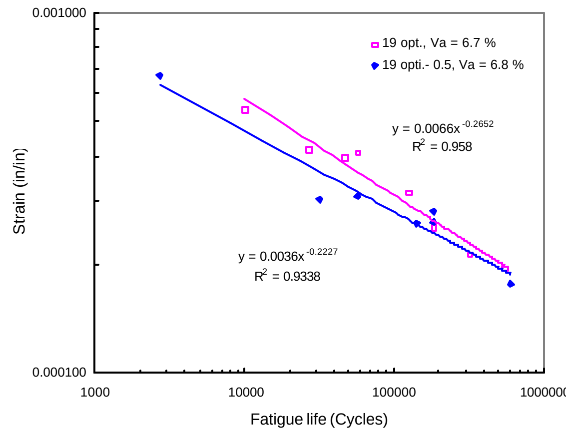


(c) T=25°C, Air void is about 7%

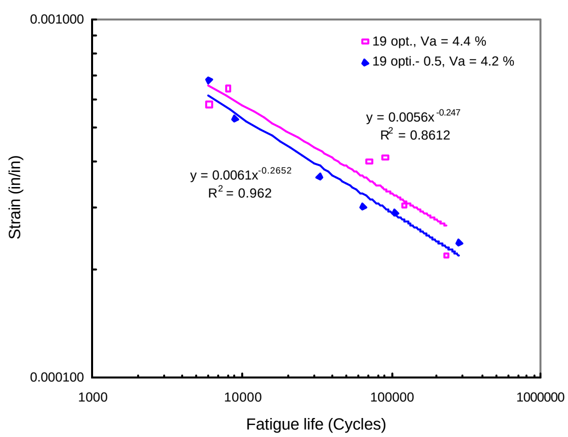
Figure 3-5 (a)-(c) Effect of asphalt content on fatigue life for SP 12.5-mm mixes, T=25° C



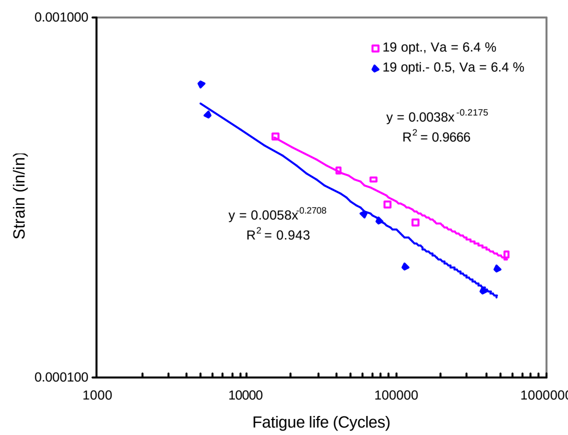
(a) T=15°C, Air void is about 4.5%



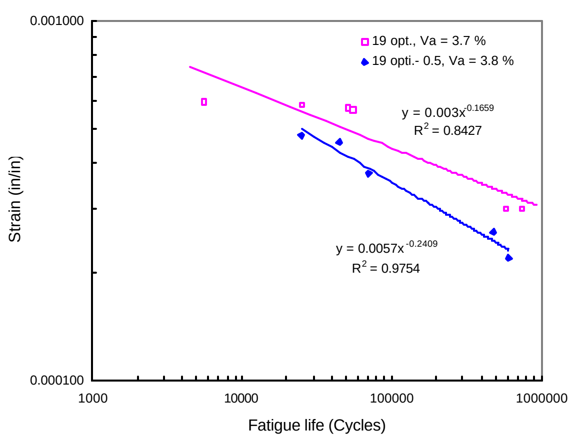
(b) T=15°C, Air void is about 7%



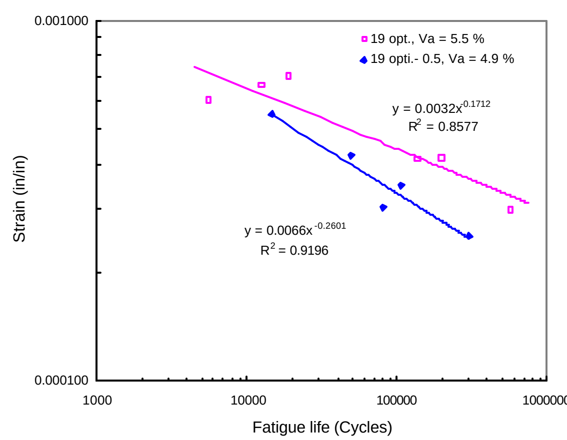
(c) T=20°C, Air void is about 4%



(d) T=20°C, Air void is about 6.4%

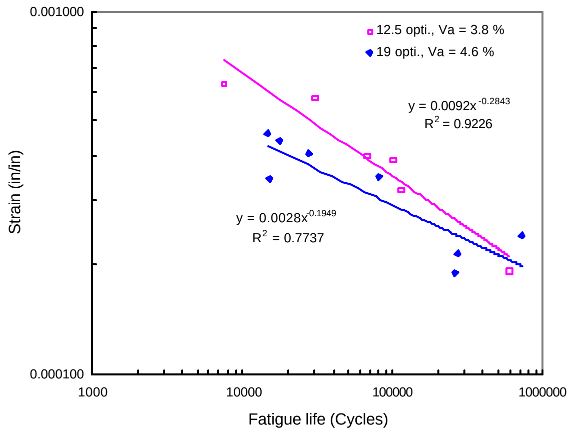


(e) T=25°C, Air void is about 4%

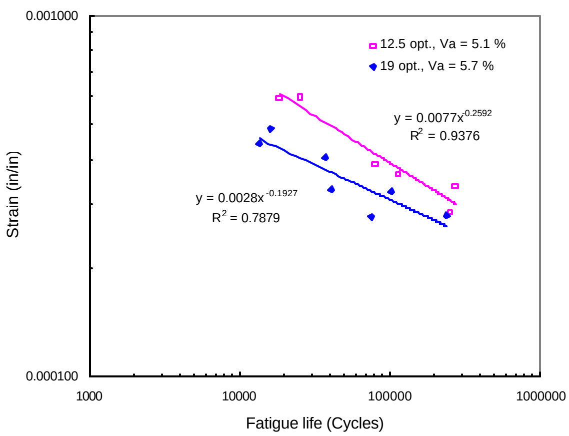


(f) T=25°C, Air void is about 5%

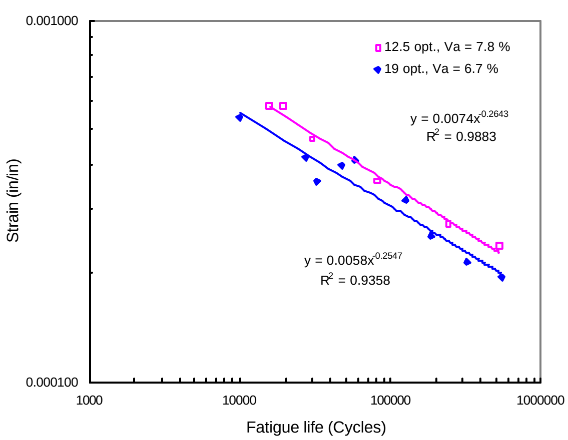
Figure 3-6 (a)-(f) Effect of asphalt content on fatigue life for SP 19-mm mixes



(a).T=15°C, V_a≈4.2%, Optimum AC

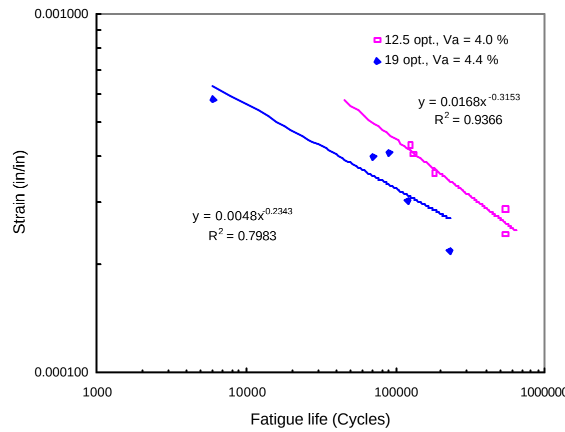


(b).T=15°C, V_a≈5.4%, Optimum AC

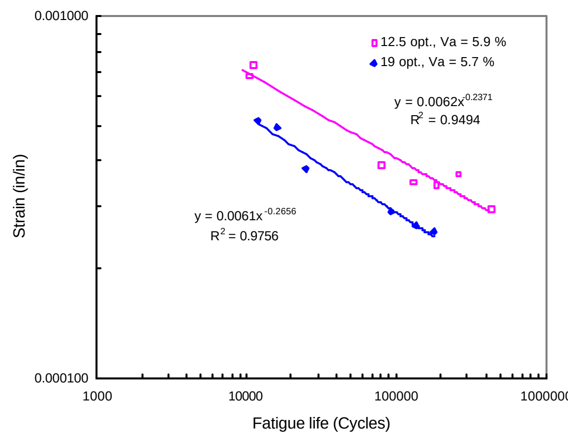


(c).T=15°C, V_a≈7.2%, Optimum AC

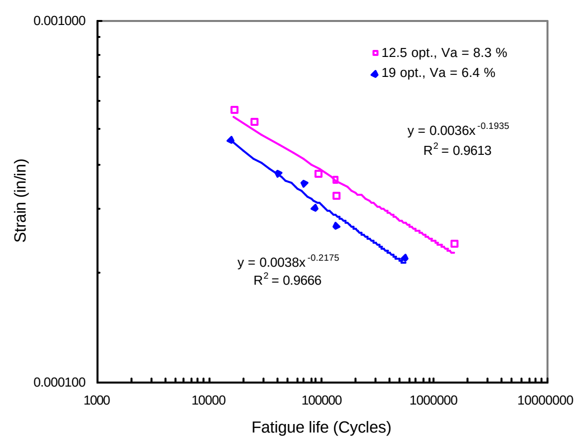
Figure 3-7 (a)-(c) Effect of gradation on fatigue life for optimum asphalt content, T=15°C



(a).T=20°C, V_a≈4.2%, Optimum AC

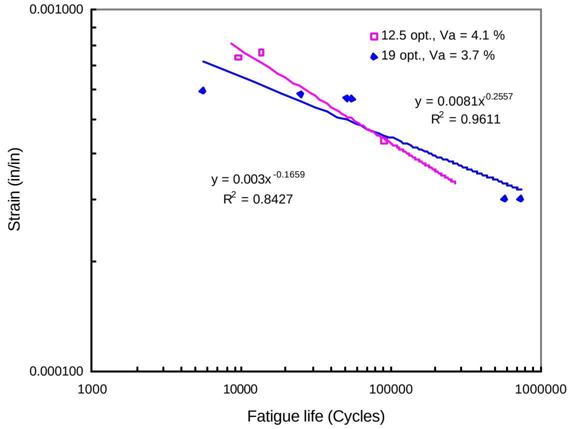


(b).T=20°C, V_a≈5.8%, Optimum AC

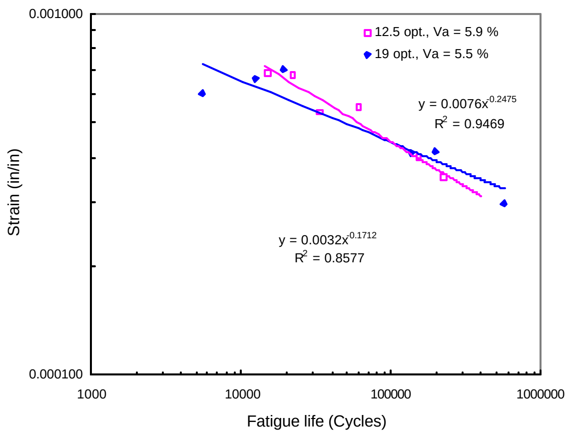


(c).T=20°C, V_a≈7.4%, Optimum AC

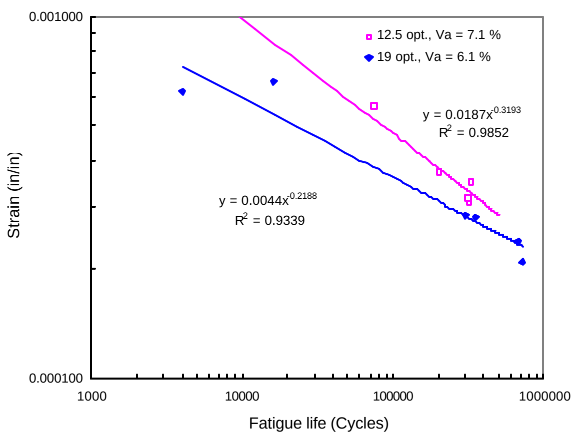
Figure 3-8 (a)-(c) Effect of gradation on fatigue life for optimum asphalt content, T=20°C



(a).T=25°C, V_a≈3.9%, Optimum AC

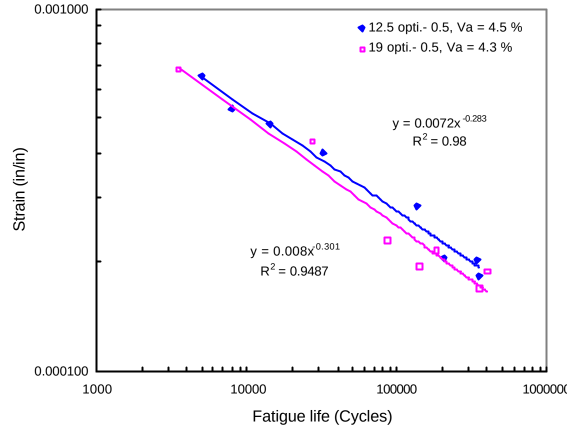


(b).T=25°C, V_a≈5.7%, Optimum AC

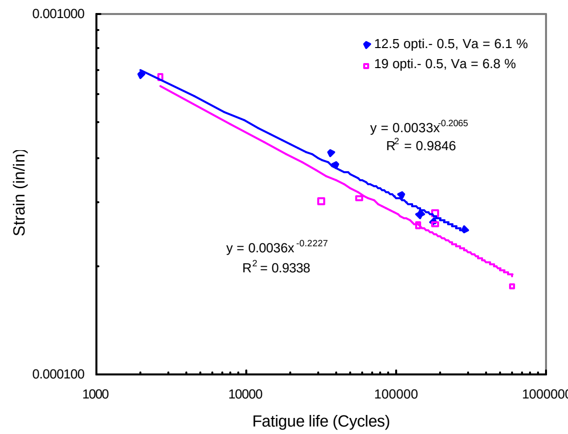


(c).T=25°C, V_a≈6.6%, Optimum AC

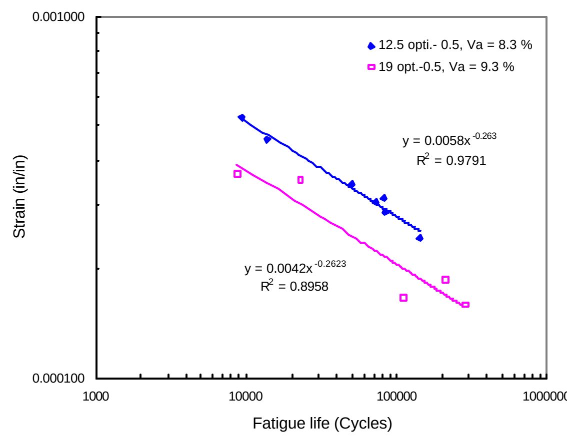
Figure 3-9 (a)-(c) Effect of gradation on fatigue life for optimum asphalt content, T=25°C



(a).T=15°C, V_a≈4.4%, Optimum-0.5% AC

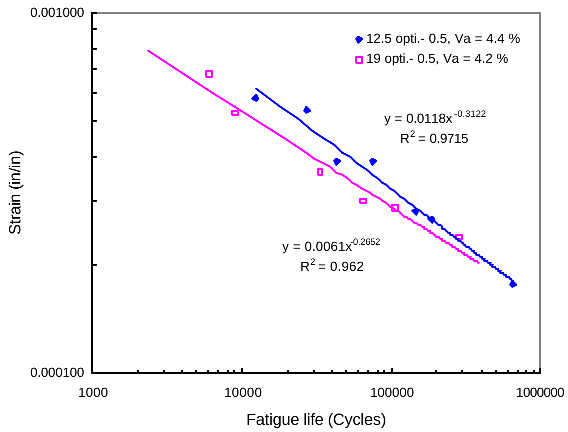


(b).T=15°C, V_a≈6.5%, Optimum-0.5% AC

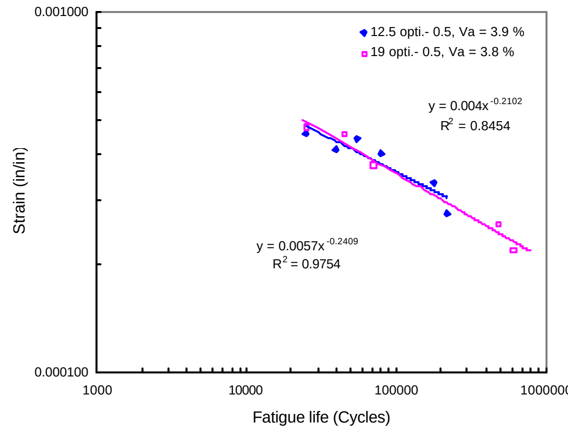


(c).T=15°C, V_a≈8.8%, Optimum-0.5% AC

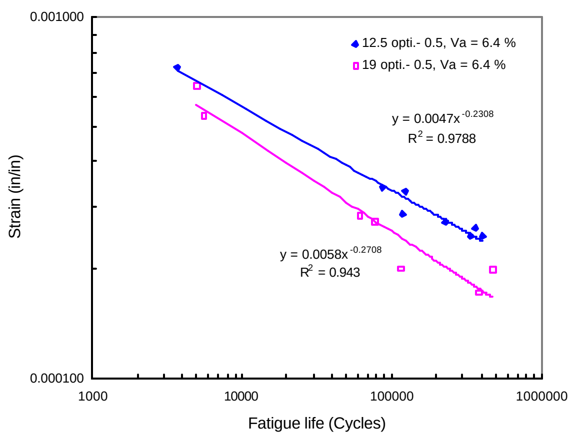
Figure 3-10 (a)-(c) Effect of gradation on fatigue life for optimum-0.5% asphalt content, T=15°C



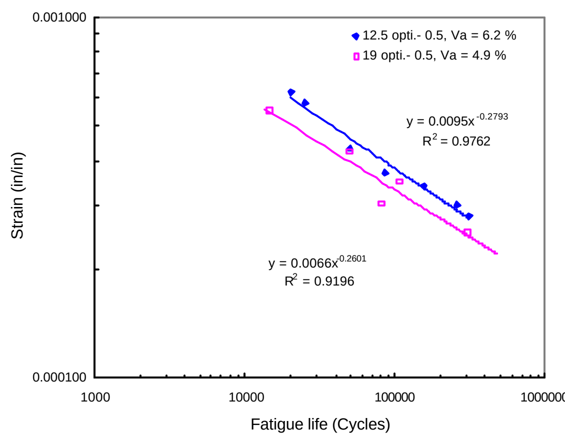
(a).T=20°C, V_a≈4.3%, Optimum-0.5% AC



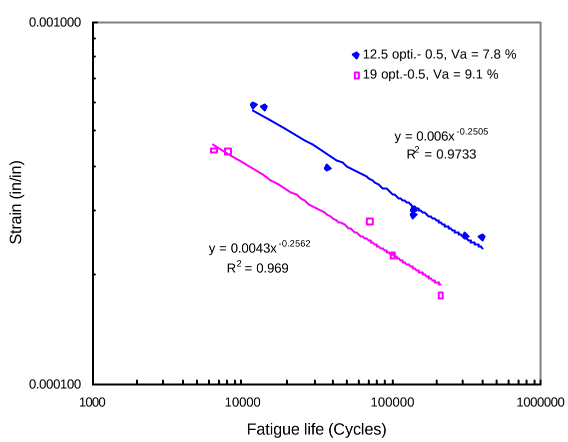
(a).T=25°C, V_a≈3.85%, Optimum-0.5% AC



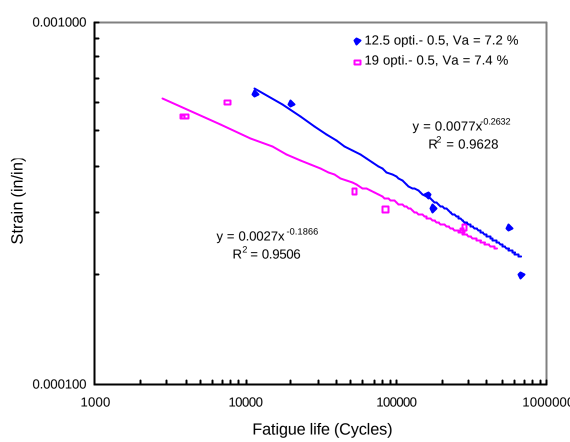
(b).T=20°C, V_a≈6.4%, Optimum-0.5% AC



(b).T=25°C, V_a≈6.2, 4.9%, Optimum-0.5% AC



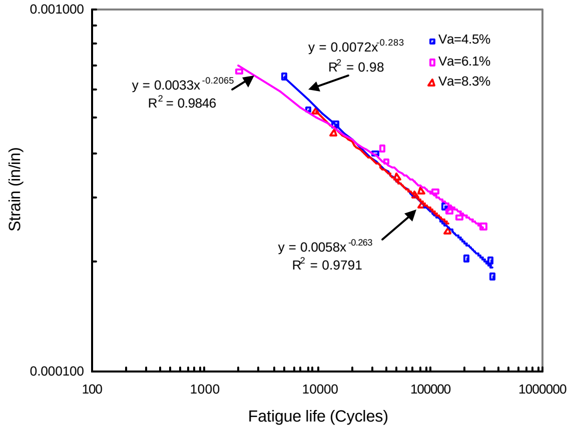
(c).T=20°C, V_a≈7.8, 9.1%, Optimum-0.5% AC



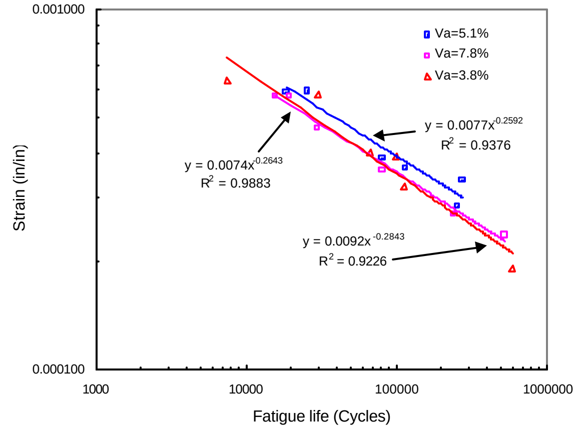
(c).T=25°C, V_a≈7.3%, Optimum-0.5% AC

Figure 3-11 (a)-(c) Effect of gradation on fatigue life for optimum-0.5% asphalt content, T=20° C

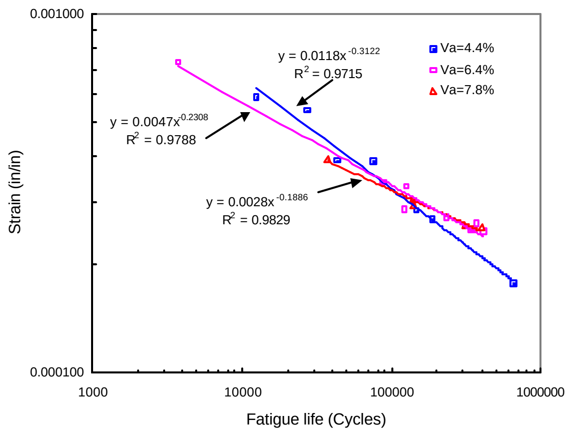
Figure 3-12 (a)-(c) Effect of gradation on fatigue life for optimum-0.5% asphalt content, T=25° C



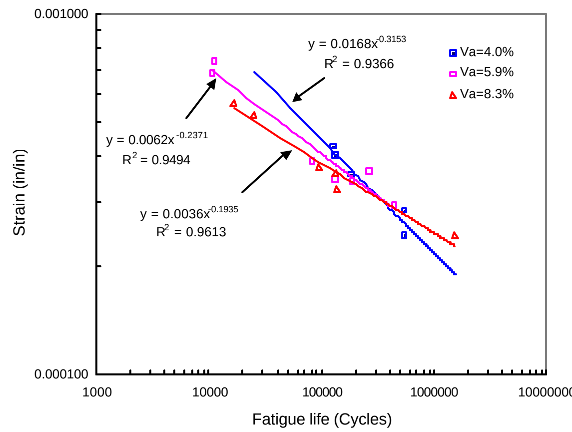
SP 12.5-mm, T=15°C, Optimum-0.5



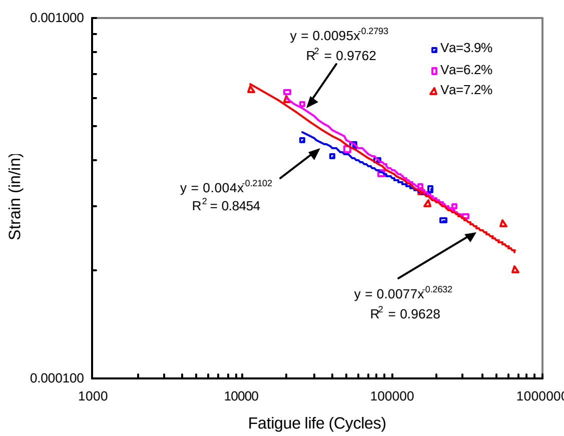
SP 12.5-mm, T=15°C, Optimum



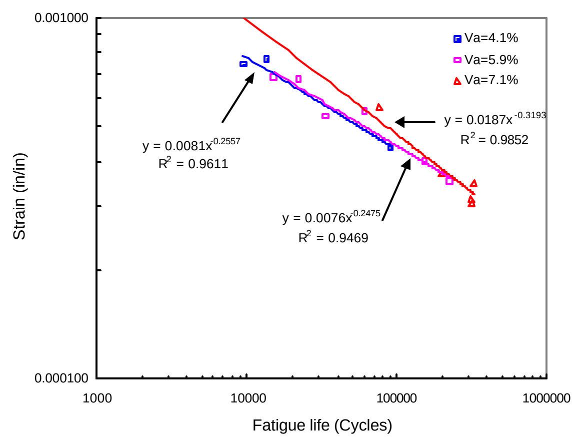
SP 12.5-mm, T=20°C, Optimum-0.5



SP 12.5-mm, T=20°C, Optimum

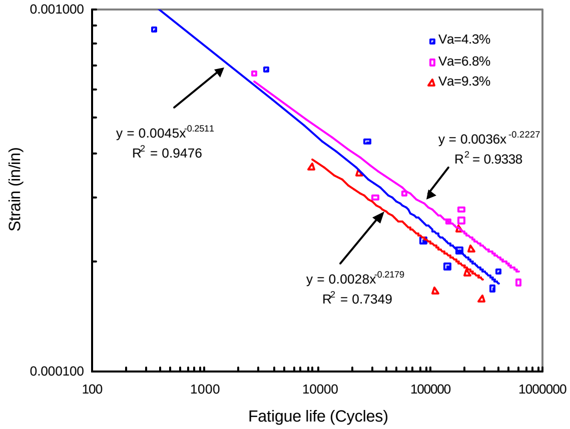


SP 12.5-mm, T=25°C, Optimum-0.5

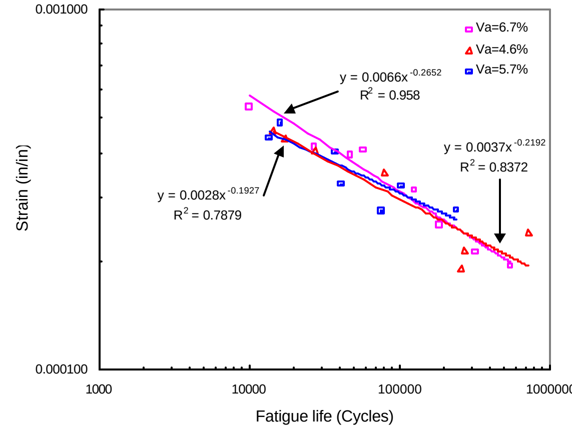


SP 12.5-mm, T=25°C, Optimum

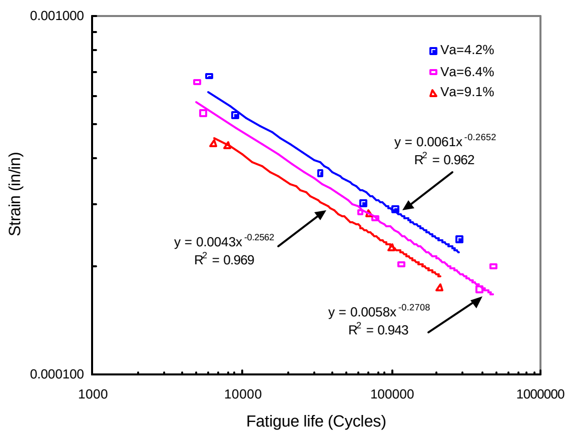
Figure 3-13 Effect of air voids on fatigue life for SP 12.5-mm mixes



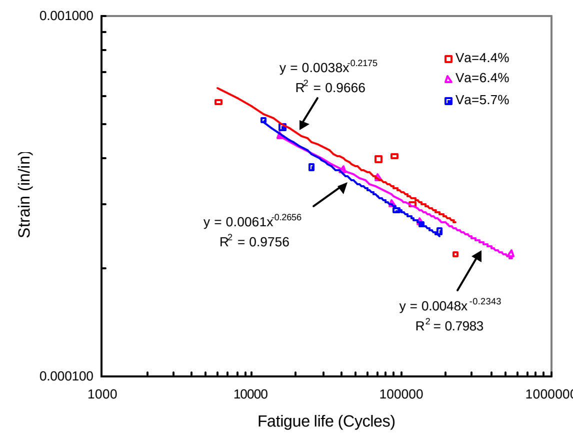
SP 19-mm, T=15°C, Optimum-0.5



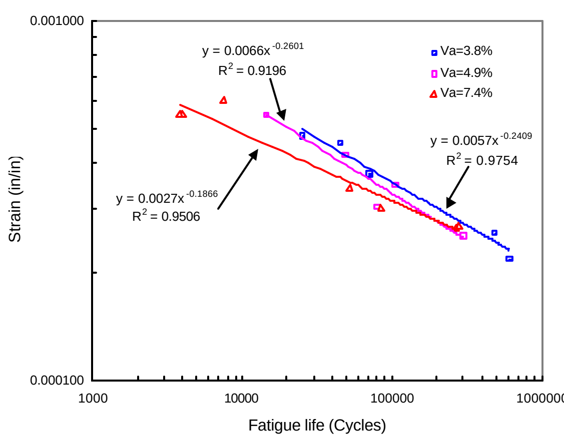
SP 19-mm, T=15°C, Optimum



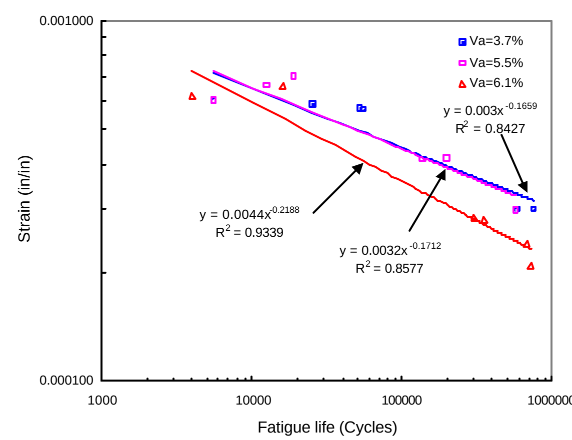
SP 19-mm, T=20°C, Optimum-0.5



SP 19-mm, T=20°C, Optimum

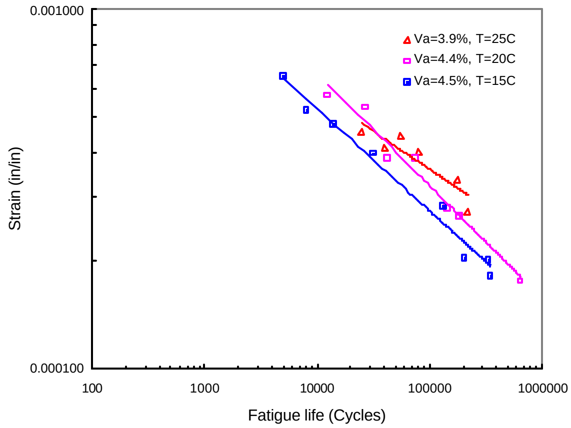


SP 19-mm, T=25°C, Optimum-0.5

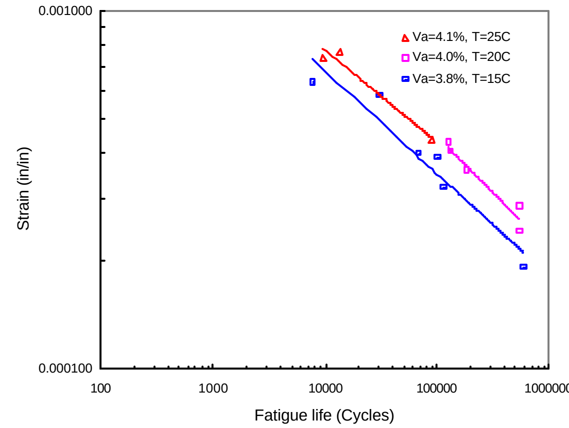


SP 19-mm, T=25°C, Optimum

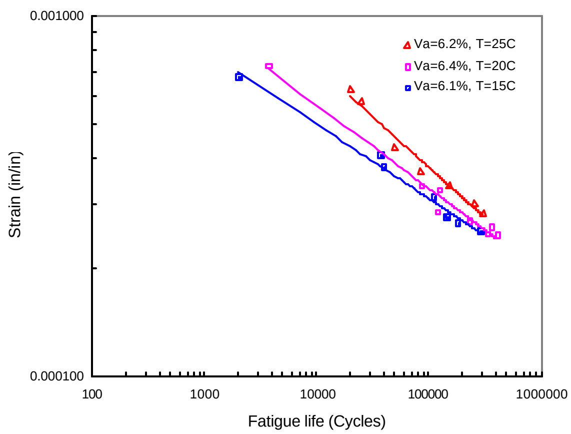
Figure 3-14 Effect of air voids on fatigue life for SP 19-mm mixes



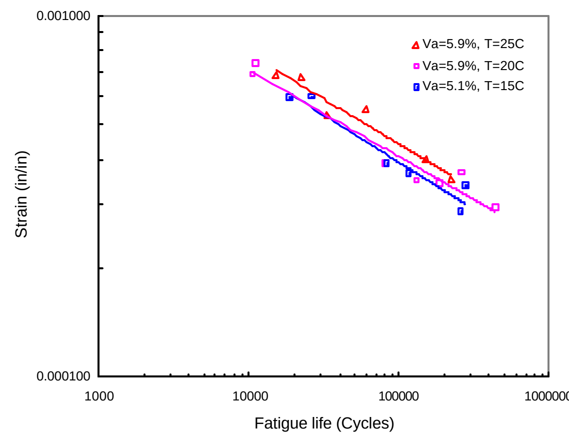
SP 12.5-mm, V_a≈4.3%, Optimum-0.5%



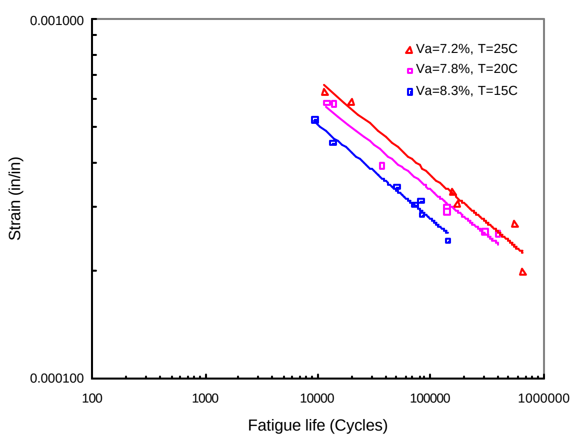
SP 12.5-mm, V_a≈4.0%, Optimum



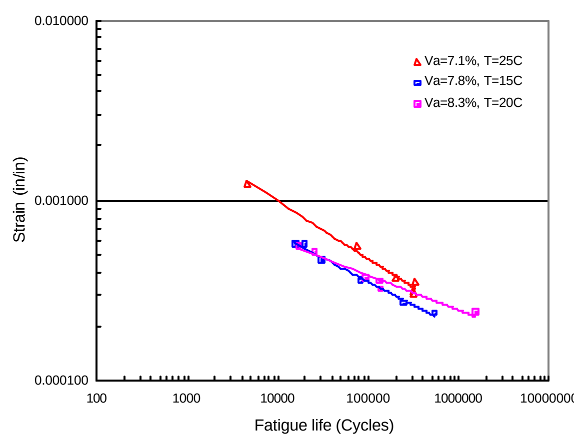
SP 12.5-mm, V_a≈6.2%, Optimum-0.5%



SP 12.5-mm, V_a≈5.6%, Optimum

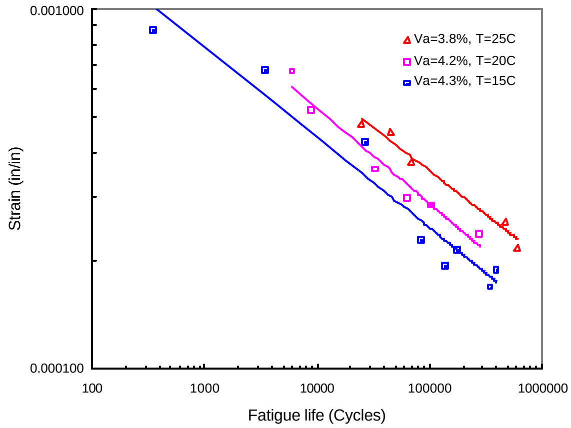


SP 12.5-mm, V_a≈7.7%, Optimum-0.5%

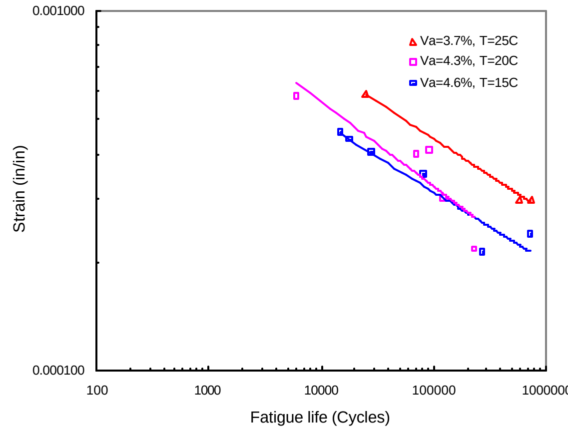


SP 12.5-mm, V_a≈7.7%, Optimum

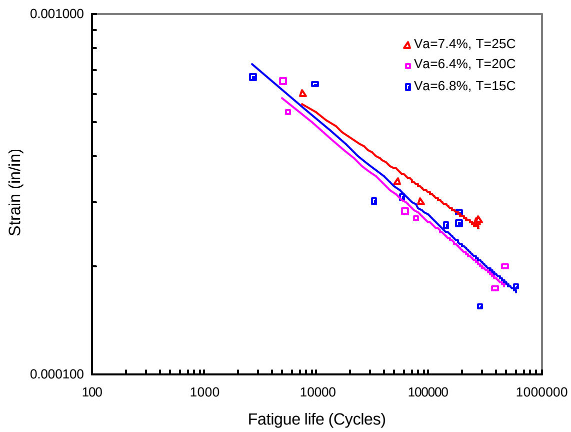
Figure 3-15 Effect of temperature on fatigue life for SP 12.5-mm mixes



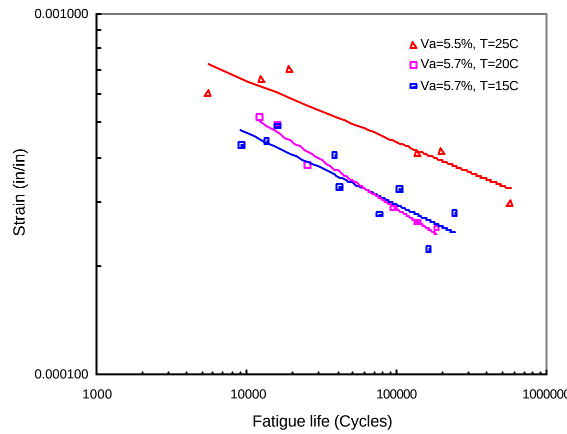
SP 19-mm, V_a≈4.1%, Optimum-0.5%



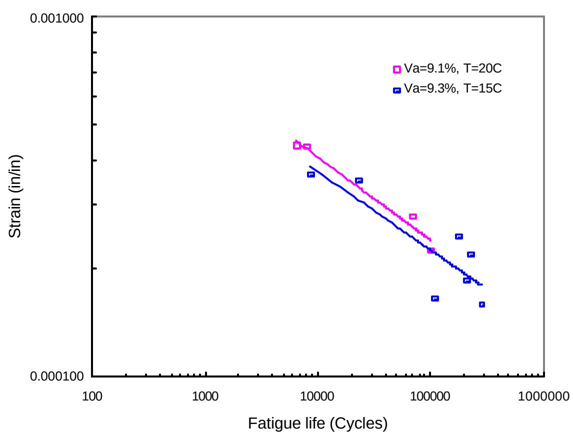
SP 19-mm, V_a≈4.2%, Optimum



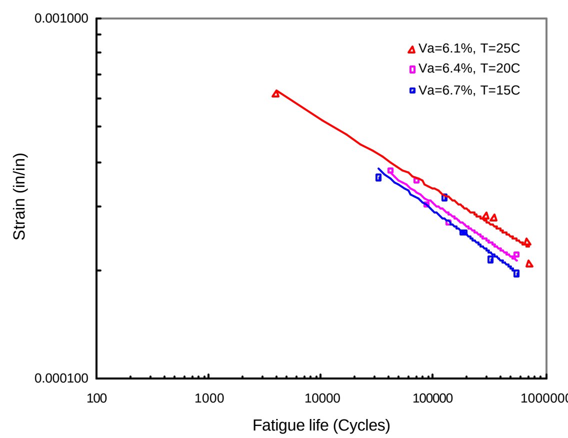
SP 19-mm, V_a≈6.8%, Optimum-0.5%



SP 19-mm, V_a≈5.6%, Optimum



SP 19-mm, V_a≈9.2%, Optimum-0.5%



SP 19-mm, V_a≈6.4%, Optimum

Figure 3-16 Effect of temperature on fatigue life for SP 19-mm mixes

4. Statistical Analysis of Fatigue Test Results

4.1 Introduction

In this section, general linear model (GLM) and regression analysis procedure were used to investigate the individual effect of each independent factor (such as temperature, air void content, gradation, and strain level as well as asphalt content) on the response variables (initial flexural stiffness S_0, and fatigue life N_f). One of the assumptions necessary for GLM is that the dependent and independent variables are normally distributed. From past research, Tayebali et al, [3], distribution for stiffness and cycles to failure have been reported to be log-normally distributed. In this study, log transformed data were used for GLM. The analysis was conducted with full model. It included all the effects and two-factor interactions in the following general form:

$$\begin{aligned}\ln(Y) &= m + a_1 \cdot AC + a_2 \cdot GR + a_3 \cdot Temp + a_4 \cdot V_a + a_5 \cdot \ln(e_0) \\ &+ a_6 \cdot AC \cdot GR + a_7 \cdot AC \cdot Temp + a_8 \cdot AC \cdot V_a + a_9 \cdot AC \cdot \ln(e_0) \\ &+ a_{10} \cdot GR \cdot Temp + a_{11} \cdot GR \cdot V_a + a_{12} \cdot GR \cdot \ln(e_0) + a_{13} \cdot Temp \cdot Va \\ &+ a_{14} \cdot Temp \cdot \ln(e_0) + a_{15} \cdot Va \cdot \ln(e_0) + error\end{aligned} \tag{4.1}$$

where, Y = response variable N_f, S_0,

m = constant,

a_i = regression coefficients,

AC = asphalt content,

GR = gradation,

Temp = temperature,

V_a = Air void content,

e_0 = strain level,

error = higher order interactions plus experiment error.

The GLM analysis was conducted using three typical regression methods---forward selection, backward elimination and stepwise selection. The forward selection procedure is as follows: consider the individual t-test for each parameter and choose the single best one-variable model. For the other parameters, choose the one that when added to the model gives a greatest decrease in SSE (sum square of error) based on SLE (significant level entry) criteria. The process continues until no remaining variables significantly give rise to reduction in SSE. Once a variable has entered the model, it must remain in the model.

Backward elimination is a contrast to forward selection method. It follows the procedure that starts with full model and drops the parameter that has the largest p value. The process continues based upon SLS (significant level stay) criteria. The elimination process stops when no parameter in the model has p value greater than the SLS.

Stepwise selection method works as follows: begin with selection of variable similar to forward selection method, and add the variable that gives the greatest decrease in SSE. Then go back and consider all variables again. Drop variable that is not significant at the current time. Continue the process until no more addition and/or elimination in variables occur by using SLE and SLS criteria.

As compared to forward selection and backward elimination methods, stepwise selection method is more flexible. The variable that has entered into the model earlier may be eliminated later on. The opposite is also true, i.e., the variable that was eliminated from the model earlier may re-enter the model in the later stage of regression process.

Before starting the analysis, the correlation coefficient among variables was examined to guard against multicollinearity. Pearson correlation matrix for the dependent and independent variables is shown in Table 4-1.

Table 4-1 shows that there are two interactions with high correlation coefficients: fatigue life (N_f) versus strain (ε_0); and stiffness (S_0) versus temperature. The first correlation is expected and is of no great concern as N_f is the dependent variable, whereas ε_0 is an independent variable. The second one is of concern as both independent variables temperature and S_0 can't simultaneously be included in the regression equation. As the stiffness (S_0) depends on both temperature and air void content, for the GLM analysis, both temperature and air void contents were included in the analysis.

4.2 GLM analysis for fatigue life (N_f)

In this section, the effects of main factors (AC, GR, Temp, V_a, and strain level) and their interactions, on fatigue life were investigated. The analysis of N_f was conducted using full model as shown in equation (4.1) that includes all the main effects and their two-factor interactions. As many of the parameters and their interactions were not significant under 5-percent significance level in the full model regression analysis, the forward selection, backward elimination and stepwise selection methods were all used for the regression analysis.

Table 4-2 shows the results of the regression analysis using forward and stepwise selection methods. Table 4-3 shows the results of regression analysis using backward elimination method. R^2 value for both models is greater than 0.85. Variance inflation factors for all the parameters in each model are much less than 10. Therefore, both models are acceptable.

The two models presented in Table 4-2 and Table 4-3 are almost identical except that the last term is different. Note that the R^2 values are identical also. By using either of the two models, the mean value of fatigue life (N_f) can be determined for given values of the independent variables: AC, GR, Temp, V_a and ε_0. In the following section, the effect of each individual variable is further explored.

4.2.1 Effect of asphalt content and aggregate gradation

Figure 4-1 to Figure 4-9 show the effect of both asphalt content and gradation on fatigue life for different combinations of air void contents and temperatures. These figures indicate that fatigue life at optimum asphalt content is significantly higher than that at optimum minus 0.5-percent, for both SP 12.5-mm and SP 19-mm mixes. It is also clear that the aggregate gradation has a pronounced effect on fatigue life for each of air void content and temperature. In general, SP 12.5-mm mixes appear to be more resistant to fatigue as compared to SP 19-mm mixes. This is expected as the SP 12.5-mm mixes have a 0.5% more asphalt content compared to the SP 19-mm mixes. When air void content is at 6-percent (as shown in Figure 4-2, Figure 4-5, and Figure 4-8), the fatigue resistance of SP 12.5-mm mix with optimum minus 0.5-percent asphalt content is almost equal to the fatigue resistance of SP 19-mm mix with optimum asphalt content.

Assuming other factors such as strain amplitude, temperature, and gradation as well as air void content remain the same it is possible to quantitatively compute the difference in fatigue life due to the change in asphalt content from optimum to optimum minus 0.5-percent. As shown in Table 4-2, since there is no interaction term for AC, one can obtain:

$$\ln(N_{f\_opti}) - \ln(N_{f\_opti-0.5}) = 0.30902 \cdot (1-(-1)) = 0.61804 \quad (4.2)$$

$$N_{f\_opti} / N_{f\_opti-0.5} = \exp(0.61804) = 1.855 \quad (4.3)$$

That is, with all other factors remaining the constant, the fatigue life of specimens with optimum asphalt content is 1.855 times that of specimens with optimum minus 0.5-percent asphalt content.

Because GR interacts with V_a, the effect of GR on fatigue life is different under different air void contents. Table 4-4 shows the effect of GR on fatigue life. Based on the results it appears that the effect of gradation increases with increase in air void content.

4.2.2 Effect of temperature on fatigue life

Figure 4-10 through Figure 4-12 show the effect of temperature on fatigue life at 4, 6 and 8-percent air void contents, respectively. The straight lines presented in the figures represent the average fatigue life across gradation and asphalt contents at given temperature and air void content. That is, the value of a point on a line represents the average fatigue life of specimens with SP 12.5-mm and SP 19-mm mixes with optimum and optimum minus 0.5-percent asphalt contents. These figures indicate that for the same mix and same strain level, the higher the temperature, the longer the fatigue life. This behavior is expected in controlled-strain mode-of-loading.

4.2.3 Effect of air void on fatigue life

Figure 4-13 and 4-14 show the effect of air void content on fatigue life for SP 12.5-mm and SP 19-mm mixes, respectively. The numbers plotted in the figures are the average fatigue life across all temperatures and asphalt contents. The results presented in Figure 4-13 are indeed surprising. It shows that for SP 12.5-mm mix, air voids do not have any effect on fatigue life. This result is contrary to the general accepted norm based on past studies. One of the reasons for this contrary behavior could be high dispersion (variability) in the data as noted in Chapter 3. However, what is truly puzzling is the fact that this mix shows significant changes in fatigue life with respect to all other variables such as asphalt content, gradation, and temperature. The fatigue behavior of the SP 19-mm mix shown in Figure 4-14, however, seems to be generally in line with the expectations – increase in air void content leads to reduction in fatigue life with all the other variables being constant.

With regard to air voids, there are two terms in the model shown in Table 4-2. One represents the main effect of the air void content and the other stands for interaction term of air void content with gradation. Since GR only takes on two numeric values, -1 and +1, the final coefficient of air void content is definitely negative. It implies that with the other factors being the same, fatigue life is inversely proportional to the air void content. However, to what extent air void content affects fatigue life depends on the gradation. Table 4-5 shows fatigue life ratios between different air void contents for two different gradations. For the SP 12.5-mm mix, there is very little difference in fatigue life with increase in air voids. For the SP 19-mm mix, there is an average of 20-percent reduction in life for 2-percent increase in void content.

4.2.4 Effect of strain level

Strain level is the most important factor to affect the fatigue life of a given mix. In general, greater the strain level, shorter the fatigue life. The coefficient k_2 for strain level in this study corresponds to values of 3.635, 3.691, and 3.747 at 15, 20 and 25°C temperatures, respectively. This compares well with the value of k_2 of 3.291 reported for the Asphalt Institute (AI) equation, and a value of 3.624 reported for the SHRP equation [3]. It may be noted that the SHRP equation was developed mostly based on fatigue data obtained at 20°C.

4.3 Analysis of Initial Flexural Stiffness S_0

In the last section, the effects of various factors on fatigue life were investigated and fatigue life models in terms of those factors were established. In this section, the goal is to investigate the effect of those factors on initial flexural stiffness.

Regression analysis was carried out with the full model (as shown in equation (4.1)). The result of an analysis of variance (ANOVA) on the full model is given in Table 4-6. Although adjusted R^2 is 0.85, estimated parameters such as asphalt content, gradation, air void content, strain and a lot of other interaction terms are not significant under 5-percent significance level. From statistical point of view, we are not able to reject the null hypothesis. This means that many of these parameters may not be necessary in the model.

The R^2 for forward stepwise selection, and backward elimination models is 0.82. The variance inflation factor for each parameter is around 1.0, which is much less than 10. Moreover, both models have the same number of parameters. The result of forward, stepwise selection and backward elimination of parameters are shown in Table 4-7 and Table 4-8.

The results presented in Tables 4-7 and 4-8 imply that temperature, air void content and strain level are the three main factors that affect the initial flexural stiffness. Asphalt content and gradation also play a minor role. The stiffness dependence on strain level is not a desirable effect. It indicates that stiffness is not being measured in linear elastic range and therefore is not a true measure of stiffness. The effects of the various factors are discussed briefly in the following section using the model presented in Table 4-7.

4.3.1 Effect of temperature, air void content, gradation, and asphalt content on S_0

Figure 4-15 to Figure 4-18 compare the initial flexural stiffness at different air void contents for both SP 12.5-mm and SP 19-mm mixes with optimum and optimum minus 0.5-percent asphalt content. First, these figures indicate that initial flexural stiffness decreases with increase in temperature. But, for different gradations the effect of temperature is slightly different. Secondly, the initial flexural stiffness is inversely proportional to air void content. Roughly, an increase of 2-percent air void content will result in a 20-percent decrease in initial flexural stiffness.

Figure 4-19 shows the overall comparison of S_0 for the four different mixes. The number presented in the figure is the average across air void contents and temperatures. At optimum asphalt content, the stiffness of SP 19-mm mix is 10-percent greater than that of SP 12.5-mm mix. However, at optimum minus 0.5-percent asphalt content, the stiffness of SP 12.5-mm mix is 10-percent greater than that of SP 19-mm mix.

For SP 19-mm mix, the initial flexural stiffness at optimum asphalt content is about 10-percent more than that at optimum minus 0.5-percent asphalt content. In contrast, for SP 12.5-mm mix, the initial stiffness at optimum asphalt content is about 10-percent less than that at optimum minus 0.5-percent asphalt content.

4.3.2 Effect of strain level on S_0

Fatigue test data indicates that strain amplitude has an impact on initial flexural stiffness. The larger the strain amplitude, the lower the initial flexural stiffness is. This indicates as mentioned earlier that the specimen being tested is undergoing damage in as little as the first 50 cycles during which the initial stiffness is measured. This is also probably the reason that stiffness is not directly dependent on asphalt content or gradation. The model described in Table 4-7 shows that the effect of strain amplitude on initial flexural stiffness can be computed as follows:

$$S_{0\_e_1} / S_{0\_e_2} = (e_1 / e_2)^{-0.1975} \quad (4.4)$$

For instance, for the same mix, the initial flexural stiffness at 100 μ-strain is about 1.5 times that at 600 μ-strain. For this reason the model development for fatigue life based on stiffness and strain level will be based on axial stiffness data (Chapter 5) rather than S_0 determined from fatigue testing.

4.4 Regeneration of data

Because of the variability associated with specimen preparation, it was not possible to exactly control the air void contents of each specimen. Moreover, it was also not possible to control strain amplitude to an exact number during fatigue testing. By using fatigue and stiffness models (shown in Table 4-2 and Table 4-7, respectively) developed, it is possible to adjust the response variables (fatigue life, stiffness and loss stiffness) of each specimen corresponding to its target air void content (4, 6, or 8-percent) and target strain amplitude. The adjusted data is presented in Appendix C.

Based on the adjusted data, the average effect of each test variable can be obtained as shown in Table 4-9. Note that percent difference is the difference expressed as a percentage of the higher value for two-level variables or of the highest value for three-level variables. Table 4-9 indicates that, although asphalt content and gradation do not have much impact on initial stiffness (S_0), they do have significant impact on fatigue life. The percent difference in fatigue life between optimum and optimum minus 0.5-percent asphalt content is 46-percent. And the percent difference in fatigue life between SP 12.5-mm mix and SP 19-mm mix is 48-percent. As for the temperature and air void content, they both not only have impact on fatigue life, but also affect initial stiffness (S_0).

4.5 Summary

Based on the analysis of fatigue data, the conclusions are as follows:

1. Both asphalt content and gradation have significant impact on laboratory fatigue life of Superpave SP 12.5-mm and SP 19-mm mixes. A change in asphalt content from optimum to optimum minus 0.5-percent will decrease fatigue life by about 50-percent. As for the gradation, SP 12.5-mm mix seems to be more resistant to fatigue distress.
2. In general, at the same strain level, increase in temperature will increase laboratory fatigue life. For instance, at 200 μ-strain the fatigue life at 20°C is about 1.7 times as that at 15°C.
3. Strain level has significant impact on initial stiffness. This result is expected but is very undesirable as the so-called initial stiffness is no longer a true measure of the mix property.
4. Asphalt content or gradation does not seem to have an effect on initial stiffness. This is again attributed to the damage caused by large strain levels that may mask any effect of asphalt content or gradation on initial stiffness.

Table 4-1 Pearson correlation coefficient (r) matrix

	AC	GR	Temp	V_a	$Ln(e_0)$	$Ln(S_0)$	$Ln(N_f)$
AC	1						
GR	0.06244	1					
Temp	0.00563	-0.03008	1				
V_a	-0.17459	-0.04526	-0.12202	1			
$Ln(e_0)$	0.19371	-0.12281	0.23924	-0.16347	1		
$Ln(S_0)$	0.08896	0.05009	-0.70659	-0.35586	-0.31371	1	
$Ln(N_f)$	0.02407	-0.10121	0.03124	0.03513	-0.84571	0.10691	1

Table 4-2 Results of forward and stepwise selection method on N_f

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F	
Model	5	447.408	89.48159	320.05	<.0001	
Error	235	65.70227	0.27958			
Corrected Total	240	513.1102				
Root MSE		0.52876	R-Square	0.872		
Dependent Mean		11.15383	Adj R-Sq	0.8692		
Coeff. Var.		4.74059				
Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|	Variance Inflation
Intercept	1	-17.7213	0.73428	-24.13	<.0001	0
Strain	1	-3.69093	0.09291	-39.73	<.0001	1.14763
Temp∗Strain	1	-0.05596	0.00548	-10.21	<.0001	1.07759
GR∗V_a	1	-5.6255	0.56183	-10.01	<.0001	1.02943
AC	1	0.30902	0.03524	8.77	<.0001	1.06909
V_a	1	-6.39159	2.27116	-2.81	0.0053	1.06321

Table 4-3 Results of backward elimination method on Nf

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F	
Model	5	447.363	89.4727	319.8	<.0001	
Error	235	65.747	0.2798			
Corrected Total	240	513.1102				
Root MSE		0.52894	R-Square	0.8719		
Dependent Mean		11.15383	Adj R-Sq	0.8691		
Coeff. Var.		4.74219				
Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|	Variance Inflation
Intercept	1	-18.0926	0.73735	-24.54	<.0001	0
AC	1	0.30889	0.03527	8.76	<.0001	1.07
Strain	1	-3.73687	0.09625	-38.82	<.0001	1.23083
Temp$*$Strain	1	-0.05596	0.00549	-10.2	<.0001	1.0778
GR$*V_a$	1	-5.61141	0.56178	-9.99	<.0001	1.02858
Strain$*V_a$	1	0.78946	0.28347	2.78	0.0058	1.1659

Table 4-4 Gradation effect on fatigue life

V_a	$N_{f\_GR=-1} / N_{f\_GR=1}$
4%	1.56
6%	1.96
8%	2.46

Table 4-5 The effect of air void content on fatigue life

GR	$\frac{N_{f\_6\%}}{N_{f\_4\%}}$	$\frac{N_{f\_8\%}}{N_{f\_4\%}}$
-1 (12.5-mm)	0.985	0.969
+1 (19-mm)	0.786	0.618

Table 4-6 Results of GLM for initial flexural stiffness S_0 in full model

Source	DF	Sum of Square	Mean Square	F Value	Pr > F
Model	15	23.36163	1.557442	76.75	<.0001
Error	208	4.220637	0.020292		
Corrected Total	223	27.58227	223		
R-Square	0.84698	Coeff. Var.	1.044389	Root MSE	0.142448
Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	1	12.96641	0.833195	15.56	<.0001
AC	1	-0.16679	0.219206	-0.76	0.4476
GR	1	-0.28864	0.209026	-1.38	0.1688
Temp	1	-0.49107	0.255743	-1.92	0.0562
V_a	1	-15.995	13.71894	-1.17	0.245
Strain	1	-0.15635	0.105278	-1.49	0.139
Temp∗AC	1	0.010341	0.012646	0.82	0.4145
Temp∗GR	1	-0.03515	0.012473	-2.82	0.0053
Temp∗Strain	1	-0.02086	0.032578	-0.64	0.5226
Temp∗V_a	1	0.137153	0.837429	0.16	0.8701
AC∗GR	1	0.055032	0.010251	5.37	<.0001
AC∗Strain	1	0.005614	0.027614	0.2	0.8391
AC∗V_a	1	3.89648	0.731896	5.32	<.0001
GR∗Strain	1	-0.02418	0.026625	-0.91	0.3648
GR∗V_a	1	1.68021	0.679602	2.47	0.0142
Strain∗V_a	1	-0.78139	1.72777	-0.45	0.6516

Table 4-7 Results of forward and stepwise selection method for S_0

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	22.6622	4.53244	200.83	<.0001
Error	218	4.92006	0.02257		
Corrected Total	223	27.58227			
R-Square	0.8175			C(p)	3.429
Variable	Parameter Estimate	Standard Error	F Value	Pr > F	Variance Inflation
Intercept	12.71624	0.20943	60.72	<.0001	0
Temp	-0.31859	0.01268	-25.12	<.0001	1.0561
V_a	-11.2828	0.6577	-17.16	<.0001	1.06192
Strain	-0.1975	0.02678	-7.37	<.0001	1.07856
Temp∗GR	-0.04708	0.01233	-3.82	0.0002	1.01006
AC∗GR	0.04373	0.01011	4.33	<.0001	1.01157

Table 4-8 Results of backward elimination method for S_0

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	22.67514	4.53503	201.47	<.0001
Error	218	4.90712	0.02251		
Corrected Total	223	27.58227			
R-Square	0.818			C(p)	2.8624
Variable	Parameter Estimate	Standard Error	F Value	Pr > F	Variance Inflation
Intercept	12.04275	0.212	56.81	<.0001	0
Temp	-0.31911	0.01267	-25.19	<.0001	1.05654
Strain	-0.28196	0.02797	-10.08	<.0001	1.17992
Temp∗GR	-0.04808	0.01232	-3.9	0.0001	1.01097
AC∗GR	0.0432	0.0101	4.28	<.0001	1.01217
Strain∗V_a	1.41172	0.0821	17.19	<.0001	1.17258

Table 4-9 Average effects of test variables

		N_f		S_0	
		Magnitude (cycle)	% diff	Magnitude (psi)	% diff
Asphalt content	Opt.	350,907		856,073	
	Opt.-0.5%	189,137	46%	855,333	0%
Gradation	12.5-mm	355,541		847,291	2%
	19-mm	184,502	48%	864,115	
Temperature	15°C	156,397	61%	1,138,332	
	20°C	250,946	38%	826,849	27%
	25°C	402,723		601,927	47%
Air void	4%	295,591		1,054,348	
	6%	268,255	9%	841,366	20%
	8%	246,220	17%	671,395	36%
Strain amplitude (micron)	200	740,743		958,948	
	400	56,705	92%	836,259	13%
	600	12,617	98%	771,902	19%

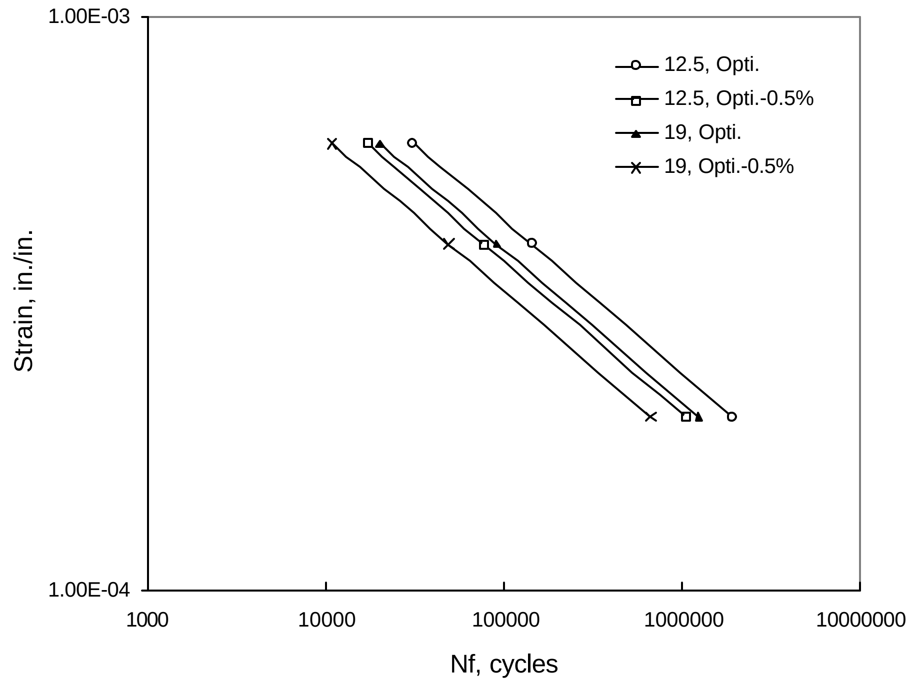


Figure 4-1 Effect of asphalt content and gradation on N_f, V_a=4%, T=25°C

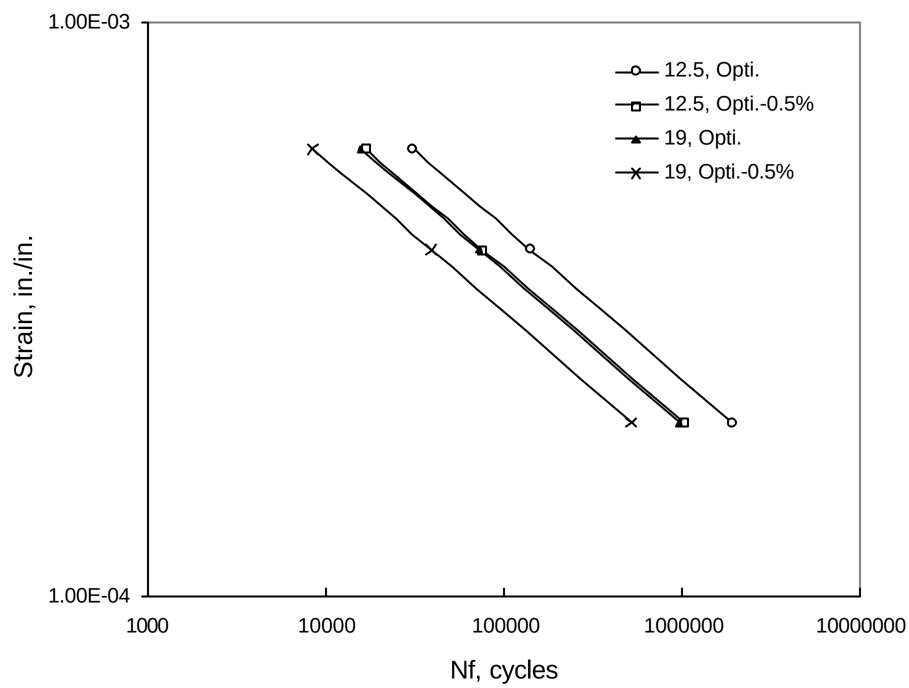


Figure 4-2 Effect of asphalt content and gradation on N_f, V_a =6%, T=25°C

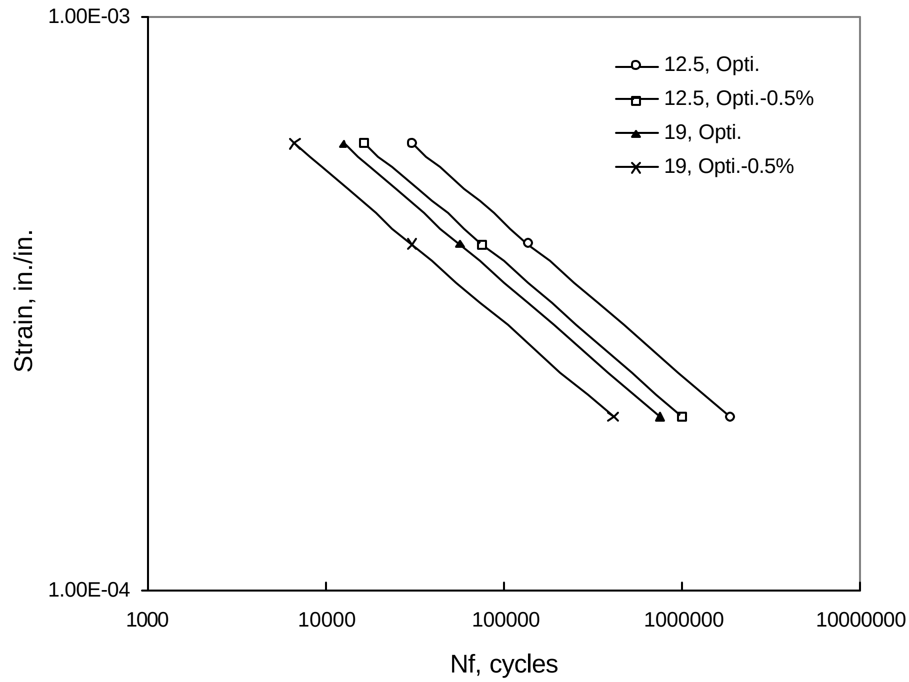


Figure 4-3 Effect of asphalt content and gradation on N_f, V_a =8%, T =25° C

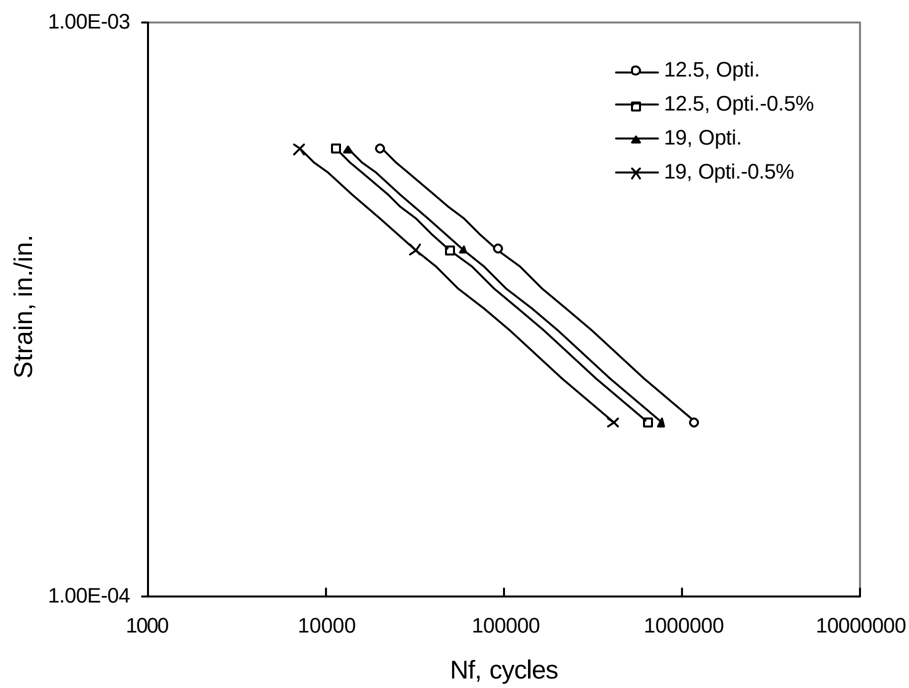


Figure 4-4 Effect of asphalt content and gradation on N_f, Va =4%, T=20° C

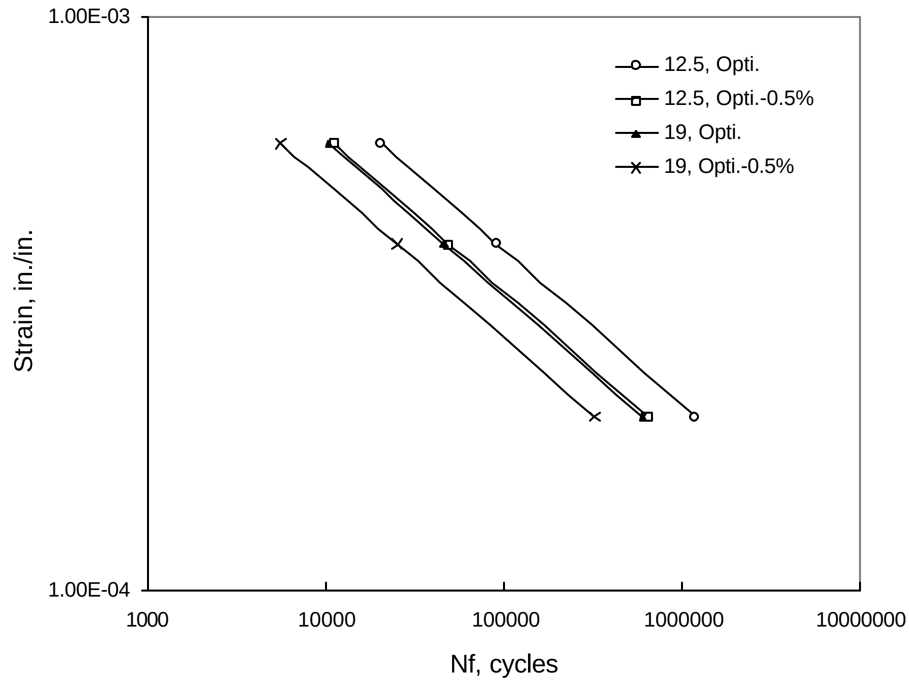


Figure 4-5 Effect of asphalt content and gradation on N_f, V_a =6%, T =20°C

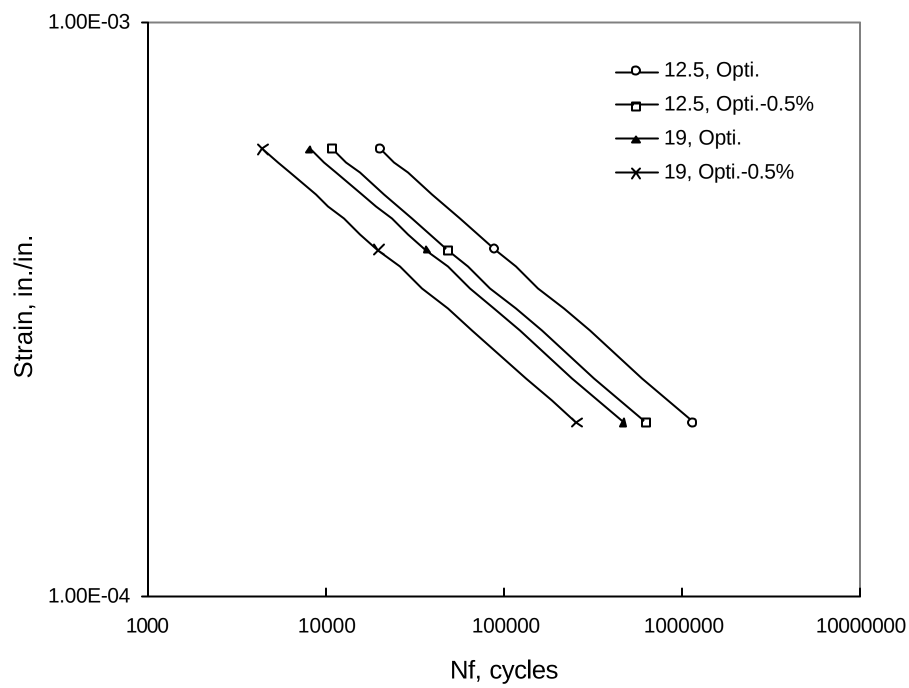


Figure 4-6 Effect of asphalt content and gradation on N_f, V_a =8%, T=20°C

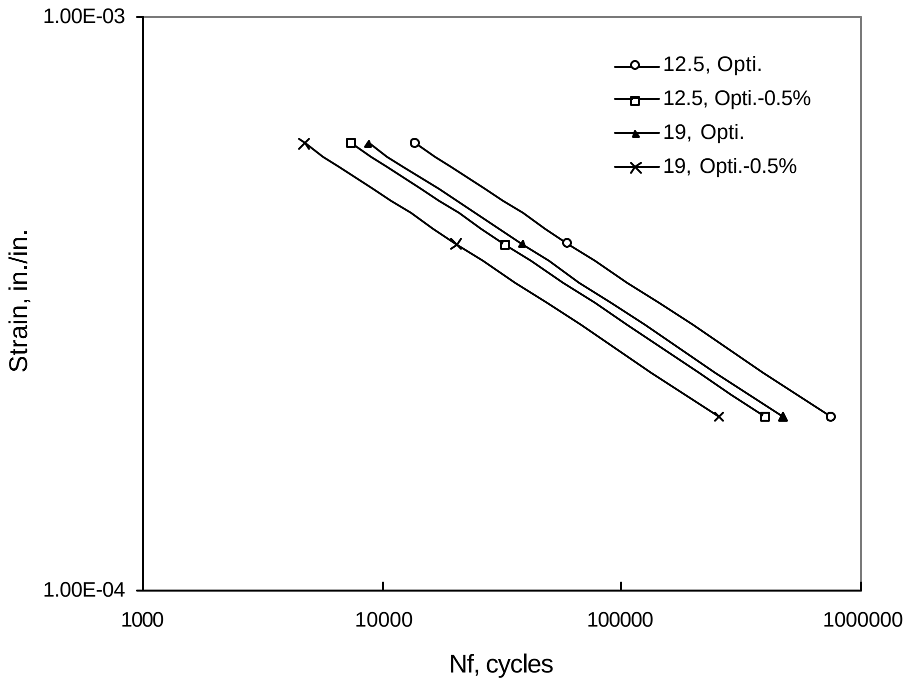


Figure 4-7 Effect of asphalt content and gradation on N_f, V_a =4%, T=15°C

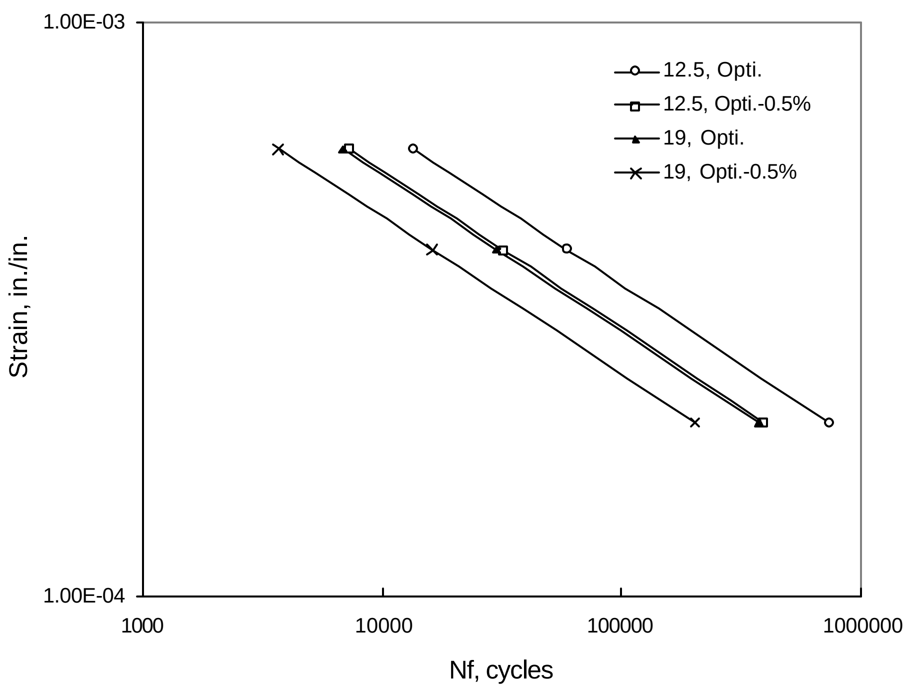


Figure 4-8 Effect of asphalt content and gradation on N_f, V_a =6%, T=15°C

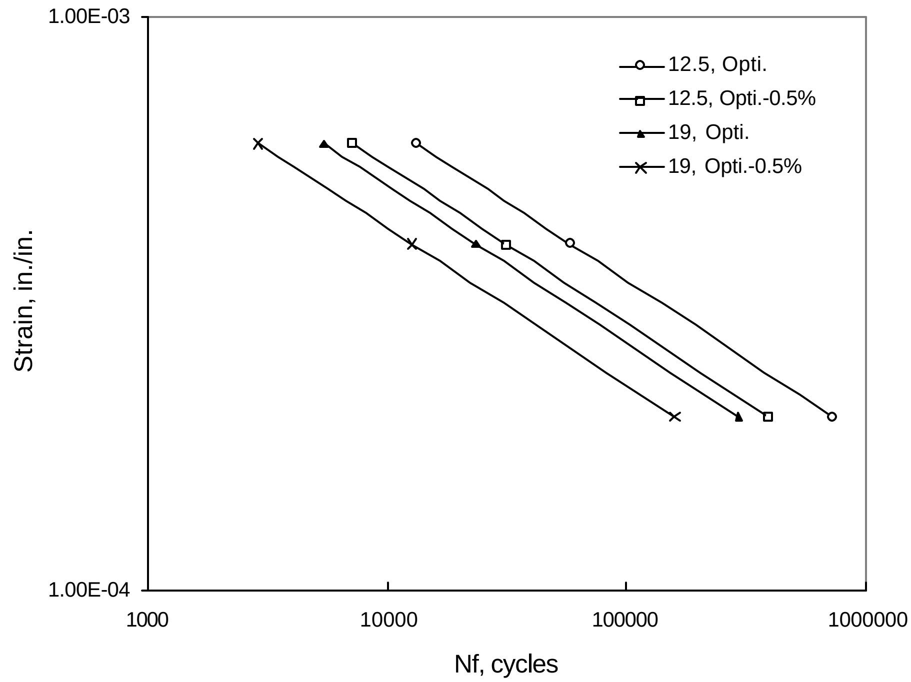


Figure 4-9 Effect of asphalt content and gradation on N_f, V_a =8%, T=15° C

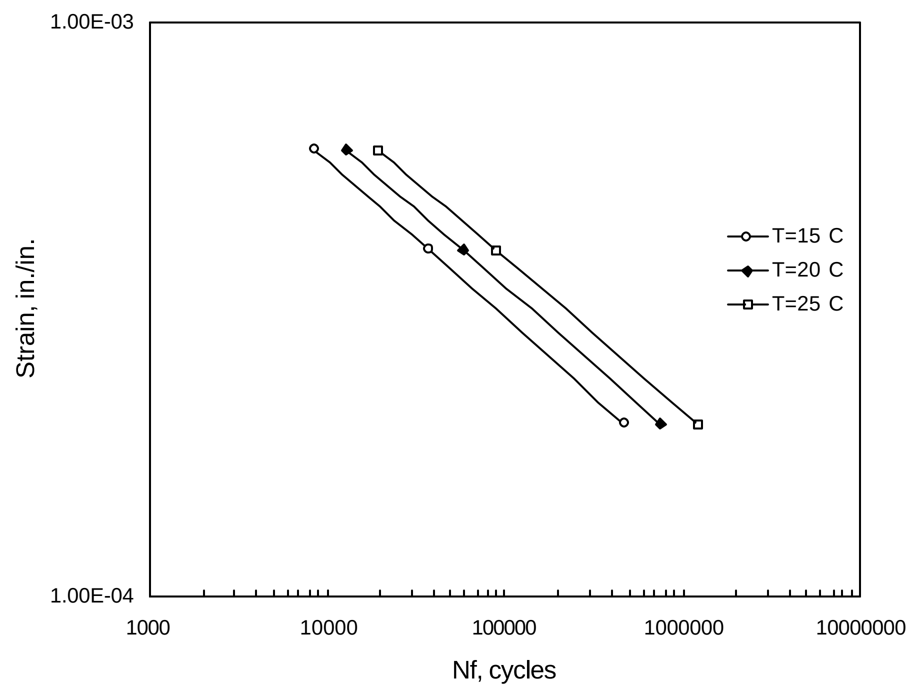


Figure 4-10 Effect of temperature on N_f, V_a = 4%

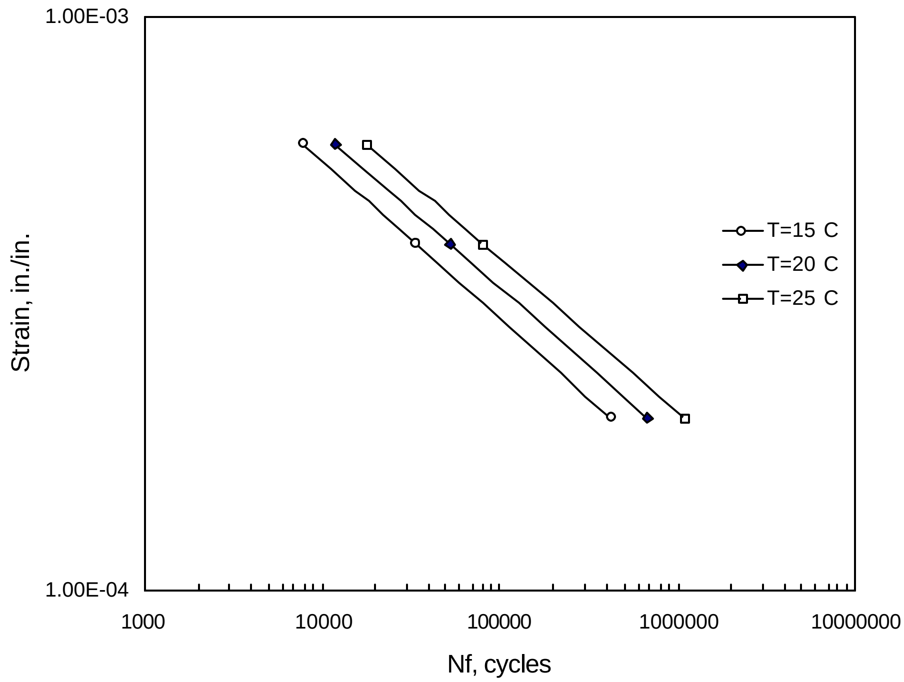


Figure 4-11 Effect of temperature on N_f, V_a = 6%

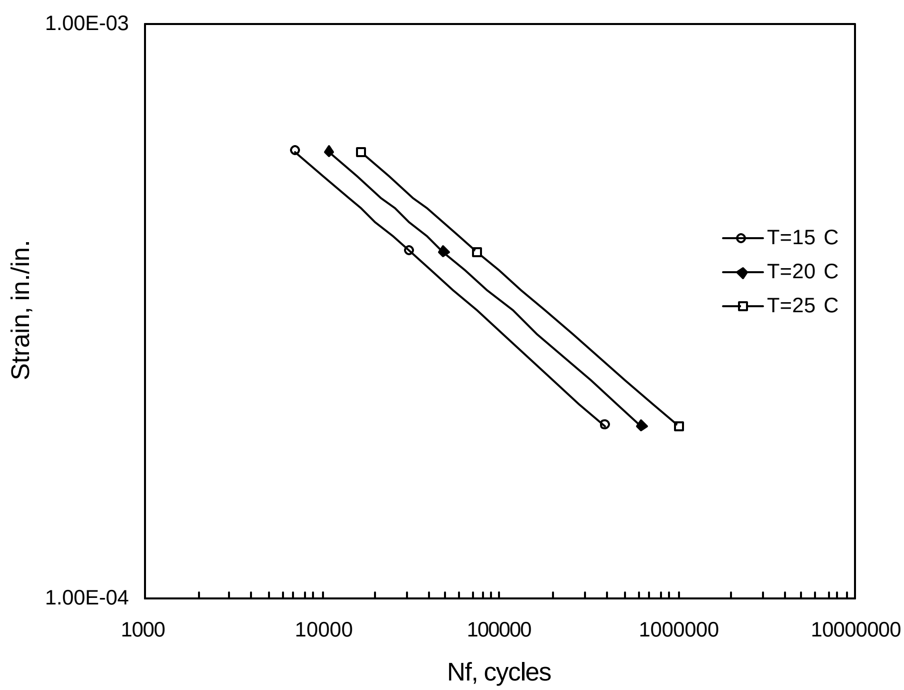


Figure 4-12 Effect of temperature on N_f, V_a = 8%

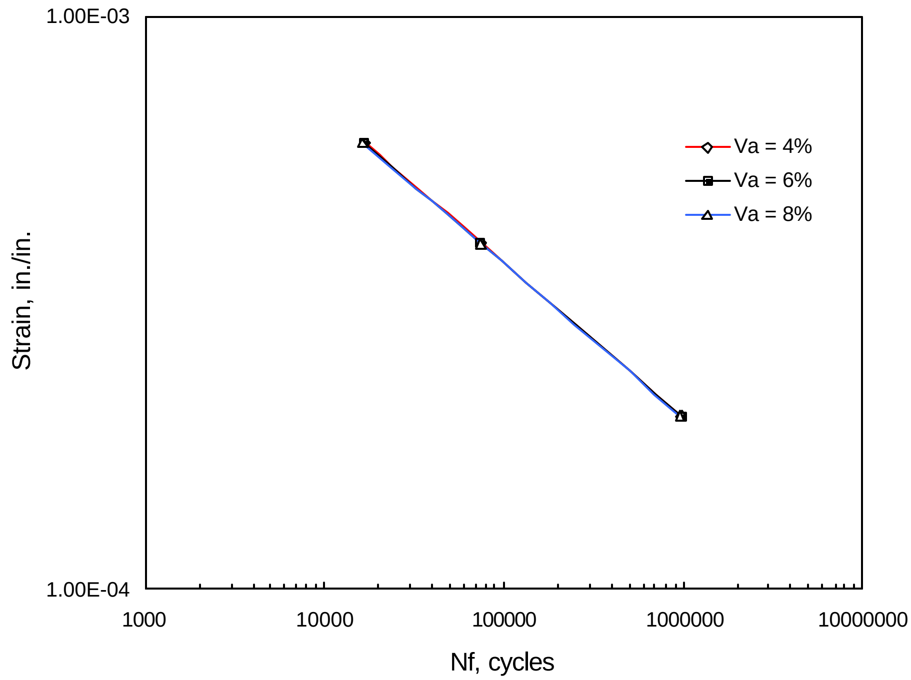


Figure 4-13 Effect of air void content on N_f for SP 12.5-mm mix

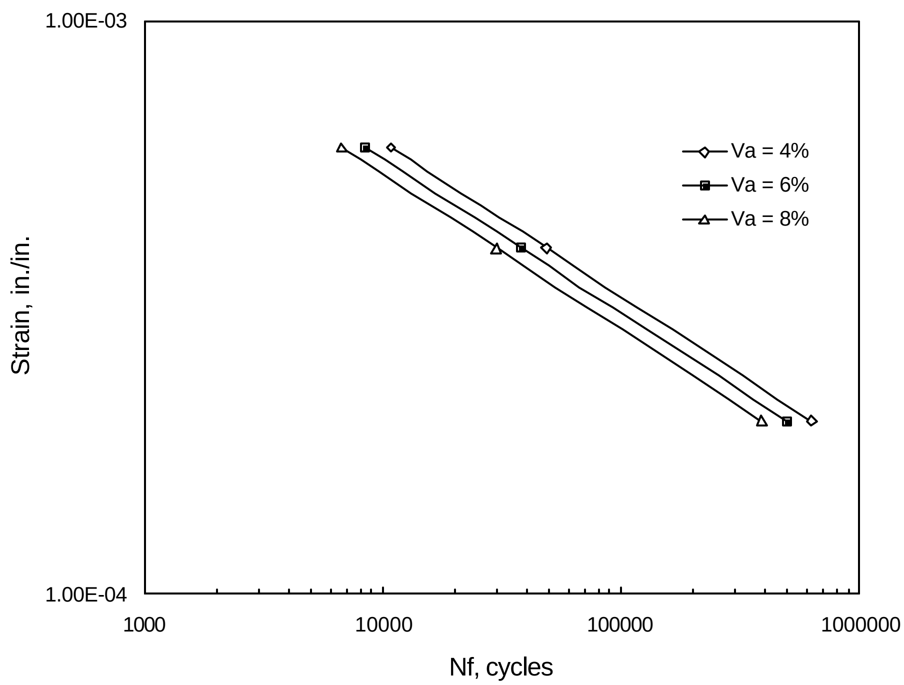


Figure 4-14 Effect of air void content on N_f for SP 19-mm mix

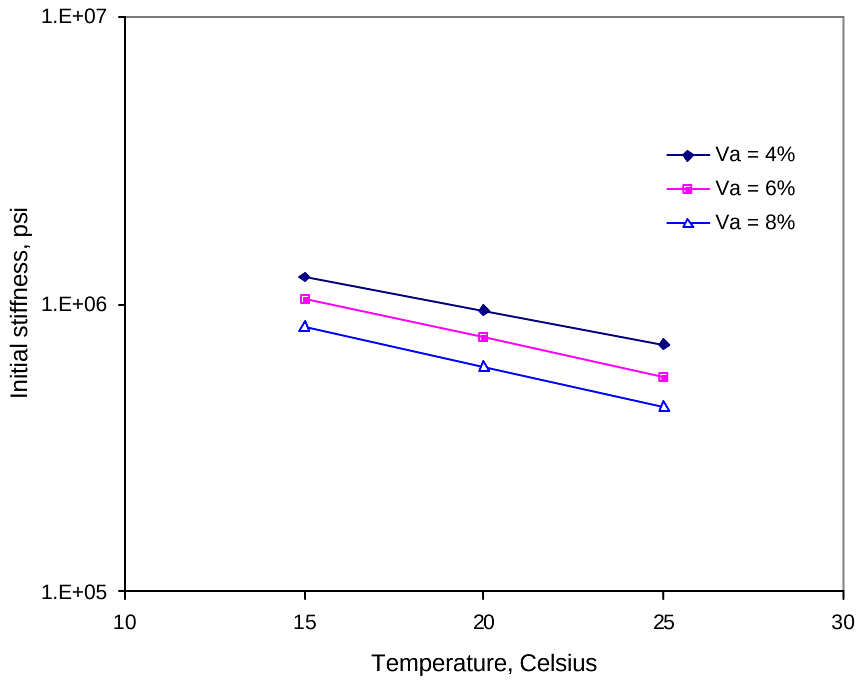


Figure 4-15 Effect of air void content and temperature on initial stiffness for SP 12.5-mm with optimum AC, 400 m-strain

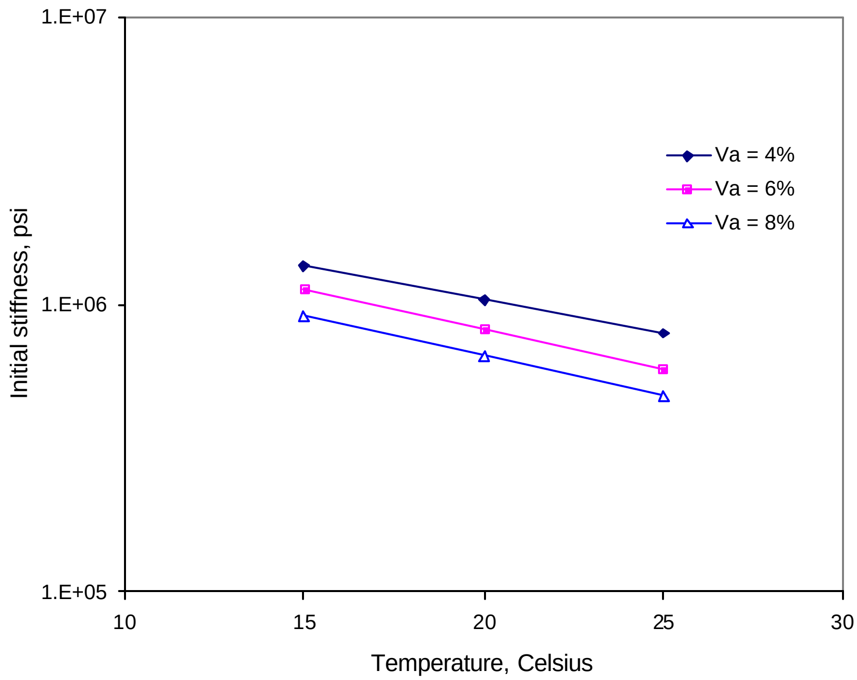


Figure 4-16 Effect of air void content and temperature on initial stiffness for SP 12.5-mm with optimum minus 0.5-percent AC, 400 m-strain

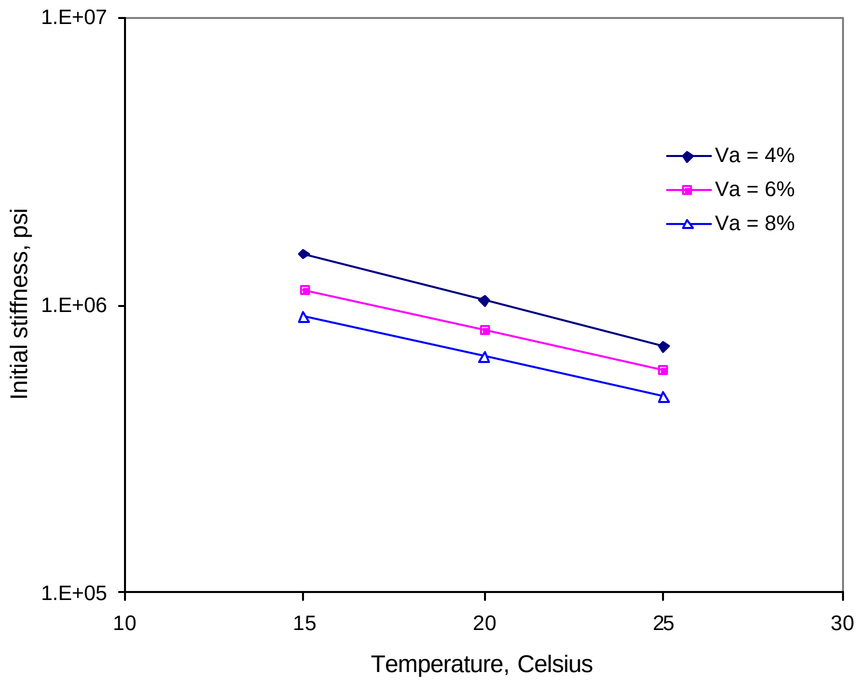


Figure 4-17 Effect of air void content and temperature on initial stiffness for SP 19-mm with optimum AC, 400 μ-strain

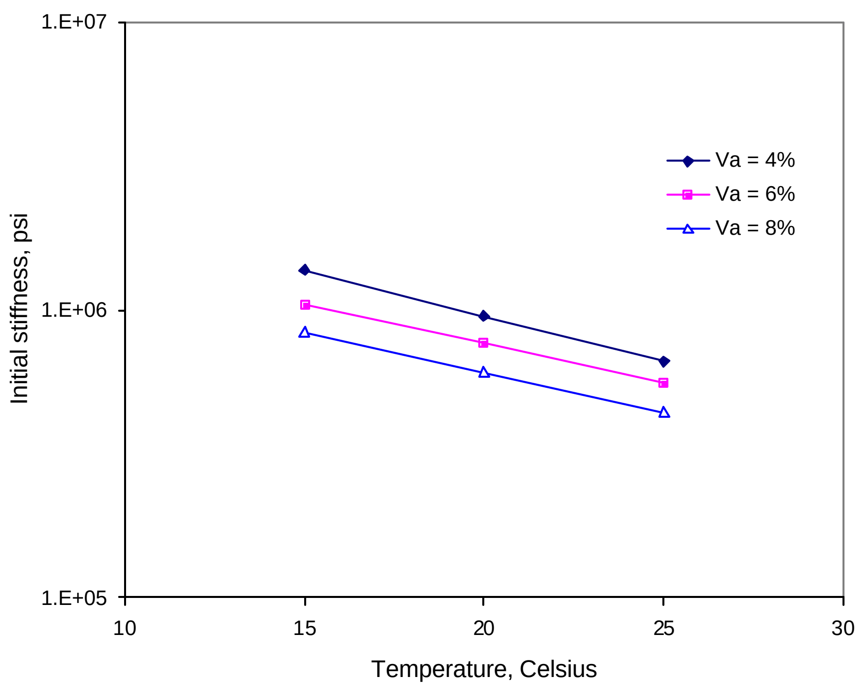


Figure 4-18 Effect of air void content and temperature on initial stiffness for SP 19-mm with optimum minus 0.5-percent AC, 400 μ-strain

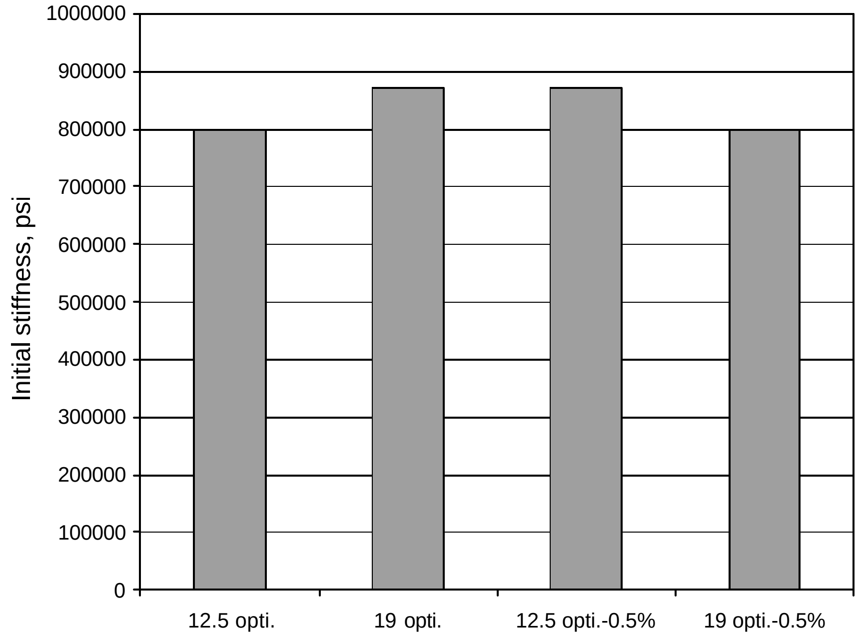


Figure 4-19 Comparison of average initial stiffness for different mixtures

5. Axial Frequency Sweep Testing

5.1 Introduction

For axial frequency sweep test (AFST), uniaxial loading is applied at different temperature and frequencies. A prismatic specimen with dimensions 6 inch by 2 inch by 2.5 inch was used in this study (as shown in Figure 5-1). This test measures the axial viscoelastic properties – dynamic axial modulus (|E*|), and the phase shift (ϕ) – over a range of testing frequencies and temperatures.

The axial frequency sweep test can be conducted in a controlled stress or strain mode-of-loading. In this study, testing was conducted in accordance with AASHTO TP7 Procedure E [5] in which a sinusoidal axial strain of amplitude ±0.005% (0.0001 mm/mm peak-to-peak strain) is applied at frequencies of 15, 10, 5, 2, 1, 0.5, 0.2, 0.1, 0.05, 0.02, and 0.01 Hz. At each frequency, the stress response is measured along with the phase shift between the stress and strain. The dynamic axial modulus (|E*|) is computed as the ratio of the stress over strain. Since this test is considered to be nondestructive, the same specimen was tested at different temperatures. By using time-temperature superposition technique, master curves for the mix were obtained. The |E*| and phase angle can be used as input to evaluate the response and performance of the mixes subjected to traffic loads. Complex modulus of the HMA can also be extracted from master curves by using nonlinear regression and optimization techniques.

Variables that may affect the axial stiffness of asphalt mixes are considered to be asphalt type and grade, aggregate type and gradation, air void content, temperature, loading frequency, aging and moisture conditioning. The significant variables included in this study were asphalt content, air void content, temperature and gradation. The specific objective of this task was to investigate how various factors influence the axial dynamic stiffness, and develop an axial dynamic stiffness predictive model based on these various factors for the mixes studied in this study.

5.2 Experiment design

Table 5-1 shows the experiment design for axial frequency testing. This design parallels the fatigue test design closely. Each of the 12 mixes were tested at 3 different temperatures. The total number of axial tests conducted was 72.

5.3 Axial frequency sweep test

Figure 5-2 and Figure 5-3 show the dynamic axial stiffness versus frequency for SP 19-mm and SP 12.5-mm mixes for different temperatures and air void contents, respectively. For some mixes, testing was conducted at higher than 25°C due to equipment problems.

The time-temperature superposition principle was applied to obtain master curves at 20°C. Assuming that the viscoelastic response of the material is controlled by a single function of temperature (i.e., a single rate controlling mechanism), time shift factor can be evaluated as:

$$\log(a_T) = \log\left(\frac{t_T}{t_{T_0}}\right) = \log\left(\frac{f_{T_0}}{f_T}\right) \tag{5-1}$$

where,

a_T = shift factor that is dependent on the difference between the reference temperature and datum temperatures;

f_T, f_{T_0} = frequency required to reach a specific |E*| at temperature T and T_0.

By using time-temperature superposition technique, master curves for each mix were obtained. Figure 5-4 to Figure 5-7 show master curves for SP 12.5-mm and SP 19-

mm mixes with optimum and optimum minus 0.5% AC, respectively. The figures show a fairly consistent trend, i.e., the lower the air void content, the higher the axial dynamic stiffness is.

5.4 Analysis of axial stiffness

This section deals with analysis of axial stiffness data. The sensitivity of axial stiffness to various mix and test parameters is investigated using statistical analysis, and surrogate models are developed for the prediction of axial stiffness and axial loss stiffness. The models presented herein, as well as in the following sections were utilized for the development of fatigue models and pavement analysis and design for the fatigue distress.

5.4.1 Surrogate models for axial stiffness

The axial stiffness model development procedure followed was similar to that used for fatigue characterization. The models presented in this section are the general models for axial stiffness |E*|, axial loss stiffness E", and axial stiffness $\left|E^*\right|_{10Hz}$ at 10 Hz frequency.

Table 5-2 through Table 5-4 provides summary of regression analysis results for the various models. The axial stiffness models based on GLM are as follows:

At 10 Hz frequency:

$$\left|E^*\right|_{10Hz} = 17.5153\times10^5 \exp(0.03956AC + 0.01256GR - 0.31472Temp - 0.11671V_a) \quad R^2 = 0.94 \tag{5.2}$$

For variable frequency:

$$\left|E^*\right| = 9.9535\times10^5 \exp(0.08946AC + 0.0368GR - 0.46242Temp - 0.15345V_a)\cdot(Freq)^{0.35152} \quad R^2 = 0.96 \tag{5.3}$$

$$\left|E''\right| = 5.7278\times10^5 \exp(0.09032AC + 0.20616GR - 0.41168Temp - 0.13566V_a)\cdot(Freq)^{0.35152} \quad R^2 = 0.91 \tag{5.4}$$

where,

$|E^*|$, E" = axial stiffness, and loss stiffness in psi;

AC = asphalt content: -1 and +1 for opt.-0.5% and opt.;

GR = aggregate gradation: -1 and +1 for SP 12.5-mm and SP 19-mm;

V_a = air void content in percent;

Temp = test temperature: -1,0, and +1 for 15, 20 and 25°C, respectively;

$Freq$ = frequency in Hz; and

exp = e: base of natural log.

It can be seen from these models that axial stiffness as well as loss stiffness is sensitive to all mix and test variables considered in this study.

5.4.2 Surrogate models for phase angle

The summary of regression analysis for axial phase angle is given in Table 5-5. It was found in this study that the phase angle is dependent on |E*| and the frequency. The model with variable frequency is:

$$f = -379.61 + 177.85 \cdot \log|E^*| - 18.5 \cdot (\log|E^*|)^2 + 1.942 \cdot \log(f) \qquad R^2 = 0.88 \qquad (5.5)$$

where,

f = phase angle in degree;

$|E^*|$ = axial dynamic modulus in psi;

f = frequency in Hz; and

log = logarithm to base 10.

For the phase angle at 10 Hz frequency, equation (5.5) reduces to:

$$f = -377.68 + 177.85 \cdot \log|E^*| - 18.5 \cdot (\log|E^*|)^2 \qquad R^2 = 0.88 \tag{5.6}$$

Figure 5-8 and Figure 5-9 compare the measured and predicted phase angle for SP 12.5-mm and SP 19-mm mixes, respectively. The equation, though not highly accurate in some cases, is useful for estimating phase angle for HMA. It should be kept in mind that the measurement of phase angle is particularly difficult, so the amount of scatter in Figure 5-8 and Figure 5-9 is not surprising. Nonetheless, the phase angle predictive model gives reasonable prediction in most cases.

5.5 Summary

In this chapter, the axial frequency testing data were analyzed and the following conclusion may be drawn based on the results.

1. Analysis shows that the axial stiffness data follow the time-temperature superposition principle.
2. Increase in temperature from 15°C to 20°C will decrease axial stiffness by 73-percent.
3. Regression models developed show that axial stiffness is sensitive to all mix and test variables considered in this study.

Table 5-1 Mix and test variables for AFST experiment design

Number of asphalts	1-PG64-22
Number of aggregate gradations	2-12.5-mm and 19-mm intermediate
Asphalt Contents	2-Superpave opt. and opt. minus 0.5-percent
Air Void Levels	3- About 4, 6, and 8-percent
Temperatures	3- 15°C, 20°C, and 25°C
Test Frequency	0.1 to 15 Hz for axial frequency sweep test
Specimen Size	6-in. by 2.5 by 2 in. prismatic specimen
Replicates	2- for axial tests
Total Number of Mixes	12- 2 gradations, 2 asphalt contents, 3 air void contents
Number of Axial Tests	2 replicates x 12 mixes x 3 = 72

Table 5-2 Summary of regression analysis for |E*| at 10 Hz

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	13.17039	3.2926	295.53	<.0001
Error	72	0.80219	0.01114		
Corrected Total	76	13.97257			
Root MSE	0.10555	Coeff. Var.	0.77628	R_Square	0.9426
Dependent Mean	13.59728			Adj R_Sq	0.9394
Variable	Parameter Estimate	Standard error	t Value	Pr > |t|	Variance Inflation
Intercept	14.37603	0.04448	323.21	<.0001	14.37603
AC	0.03956	0.01248	3.17	0.0022	0.03956
GR	0.01256	0.01239	1.01	0.3141	0.01256
V_a	-0.11671	0.00681	-17.13	<.0001	-0.11671
Temp	-0.31472	0.01072	-29.35	<.0001	-0.31472

Table 5-3 Summary of regression analysis for |E*| at variable frequency

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	995.1995	199.0399	4454.7	<.0001
Error	841	37.57662	0.04468		
Corrected Total	846	1032.776			
Root MSE	0.21138	Coeff. Var.	1.69491	R_Square	0.9636
Dependent Mean	12.47134			Adj R_Sq	0.9634
Variable	Parameter Estimate	Standard error	t Value	Pr > |t|	Variance Inflation
Intercept	13.81085	0.02697	512.15	<.0001	0
AC	0.08946	0.00753	11.87	<.0001	1.07137
GR	0.0368	0.00748	4.92	<.0001	1.04627
V_a	-0.15345	0.00411	-37.29	<.0001	1.09341
Temp	-0.46242	0.00648	-71.41	<.0001	1.01484
Log(f)	0.87459	0.00702	124.67	<.0001	1

Table 5-4 Summary of regression analysis for |E"| at variable frequency

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	840.1638	168.0328	1710.02	<.0001
Error	841	82.6395	0.09826		
Corrected Total	846	922.8033			
Root MSE	0.31347	Coeff. Var.	2.60357	R_Square	0.9104
Dependent Mean	12.04			Adj R_Sq	0.9099
Variable	Parameter Estimate	Standard error	t Value	Pr > |t|	Variance Inflation
Intercept	13.25825	0.03999	331.53	<.0001	0
AC	0.09032	0.01117	8.08	<.0001	1.07137
GR	0.20616	0.01109	18.58	<.0001	1.04627
V_a	-0.13566	0.0061	-22.23	<.0001	1.09341
Temp	-0.41168	0.0096	-42.87	<.0001	1.01484
Log(f)	0.80941	0.0104	77.8	<.0001	1

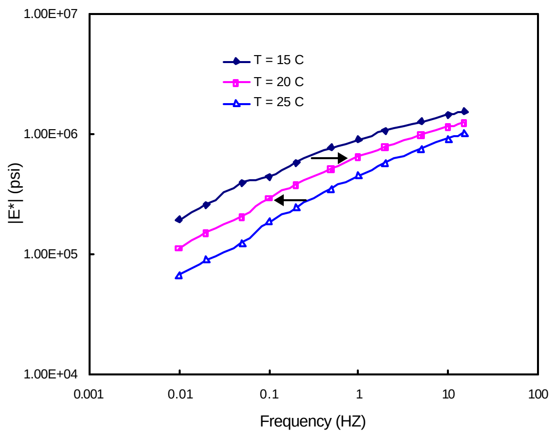
Table 5-5 Summary of regression analysis for axial phase angle

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	63162	21054	1968.92	<.0001
Error	843	9014.3	10.69132		
Corrected Total	846	72176			
Root MSE	3.27003	Coeff. Var.	9.16978	R_Square	0.8751
Dependent Mean	35.66099			Adj R_Sq	0.8747
Variable	Parameter Estimate	Standard error	t Value	Pr > |t|	Variance Inflation
Intercept	-379.612	13.25439	-28.64	<.0001	0
Log|E*|	177.8555	5.0517	35.21	<.0001	464.8846
Log|E*|*log|E*|	-18.5134	0.48026	-38.55	<.0001	476.152
Log(frequency)	1.94148	0.19392	10.01	<.0001	3.19285

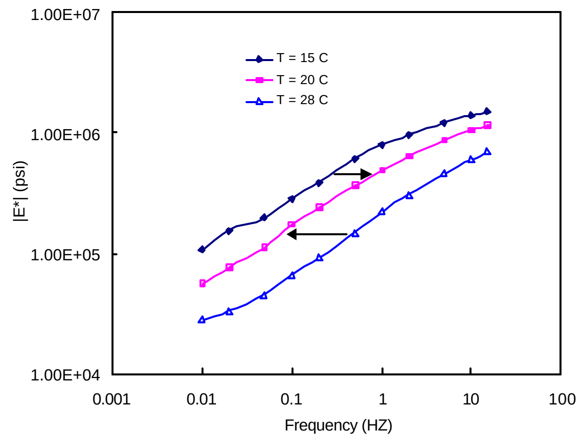
(a) After gluing

(b) Before gluing

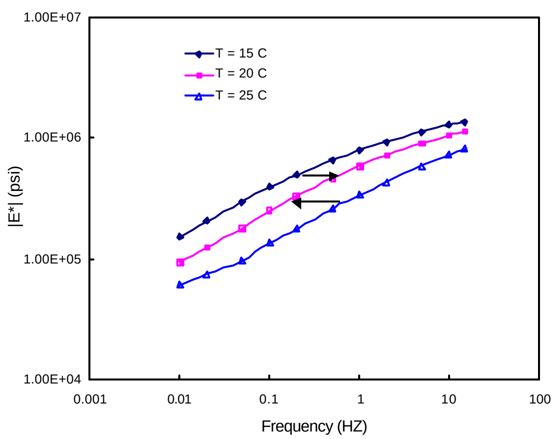
Figure 5-1 Typical specimens for axial frequency sweep test



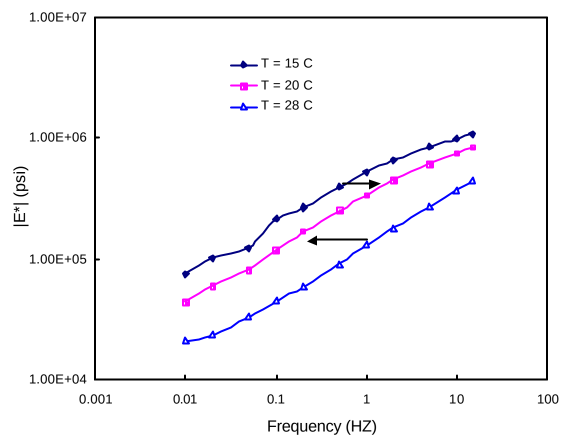
SP 19-mm mix with optimum asphalt content, V_a=3.4%



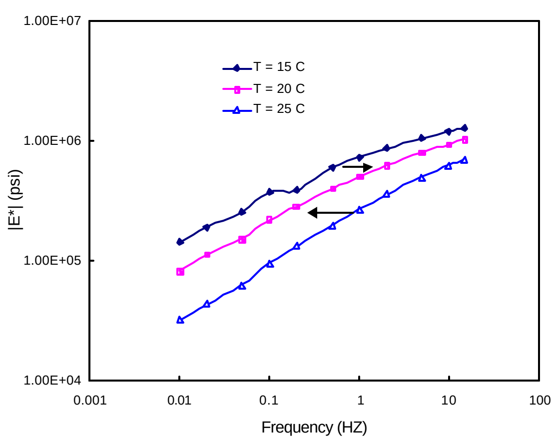
SP 19-mm mix with opti.-0.5% asphalt content, V_a=3.8%



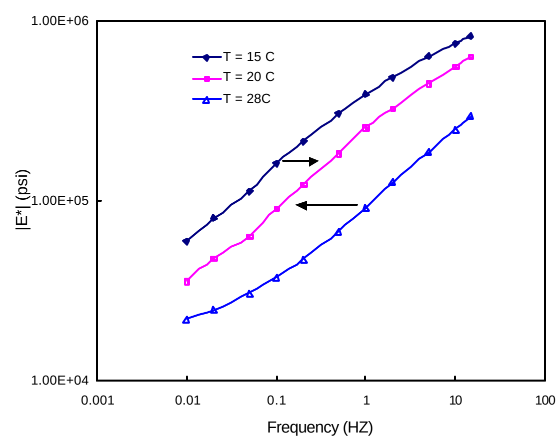
SP 19-mm mix with optimum asphalt content, V_a=6%



SP 19-mm mix with opti.-0.5% asphalt content, V_a=7.5%

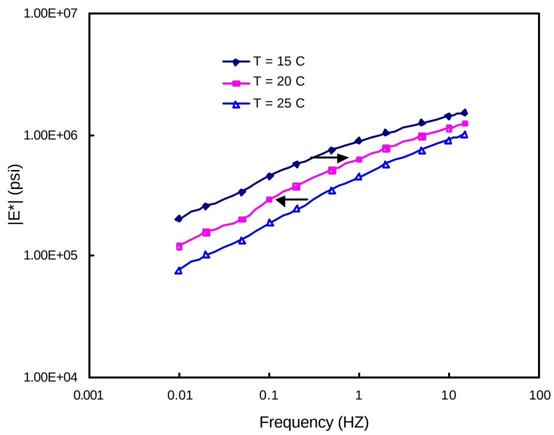


SP 19-mm mix with optimum asphalt content, V_a=7%

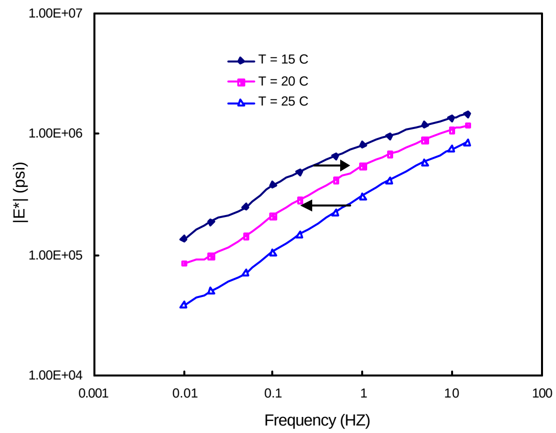


SP 19-mm mix with opti.-0.5% asphalt content, V_a=9.4%

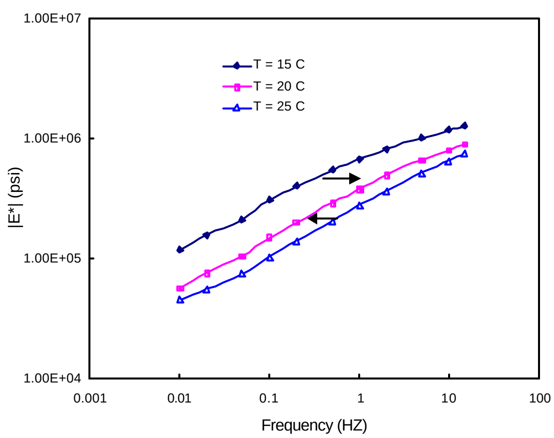
Figure 5-2 Axial stiffness versus frequency for SP 19-mm mixes



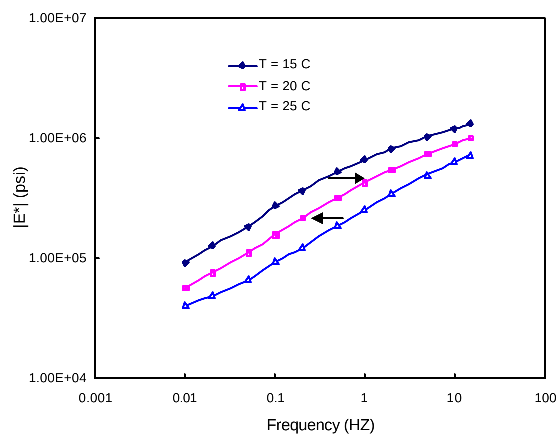
SP 12.5-mm mix with optimum AC, V_a=3.8%



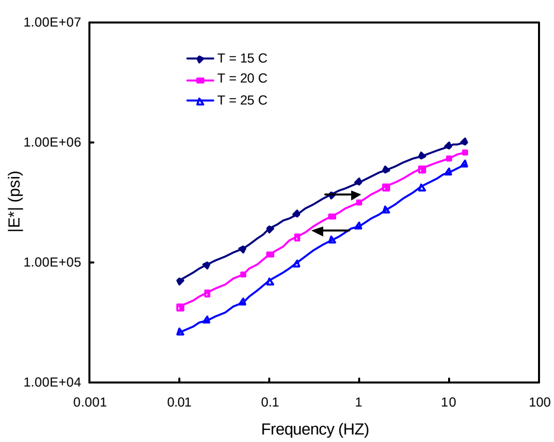
SP 12.5-mm mix with opti.-0.5% AC, V_a=4.5%



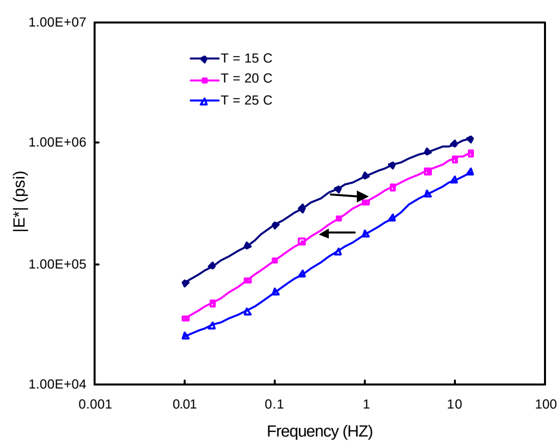
SP 12.5-mm mix with optimum AC, V_a=6%



SP 12.5-mm mix with opti.-0.5% AC, V_a=6.1%



SP 12.5-mm mix with optimum AC, V_a=7%



SP 12.5-mm mix with opti.-0.5% AC, V_a=7.8%

Figure 5-3 Axial stiffness versus frequency for SP 12.5-mm mixes

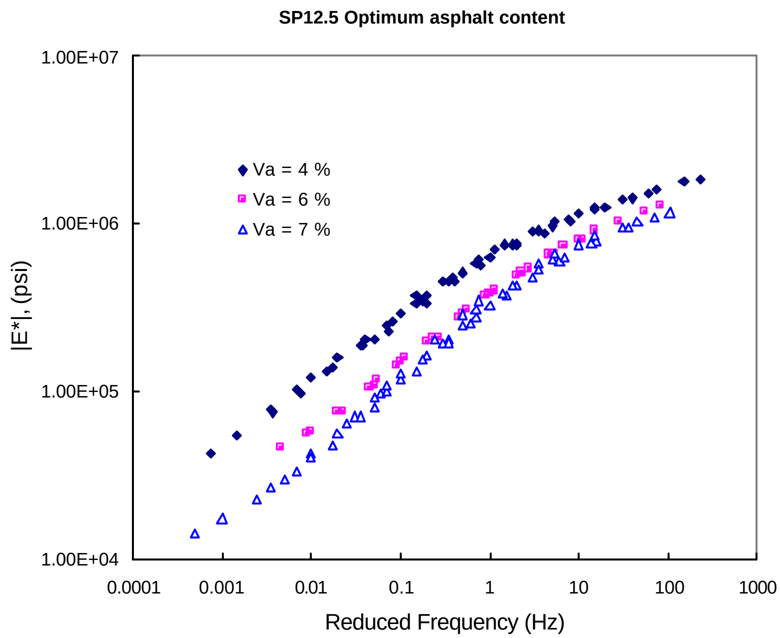


Figure 5-4 Master curves for SP 12.5-mm mix with optimum AC, 20°C

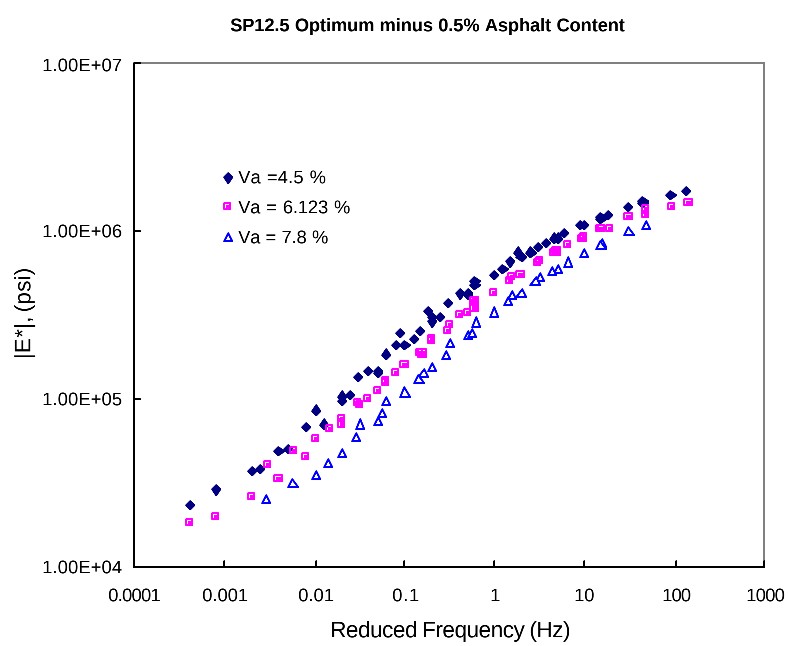


Figure 5-5 Master curves for SP 12.5-mm mix with optimum-0.5% AC, 20°C

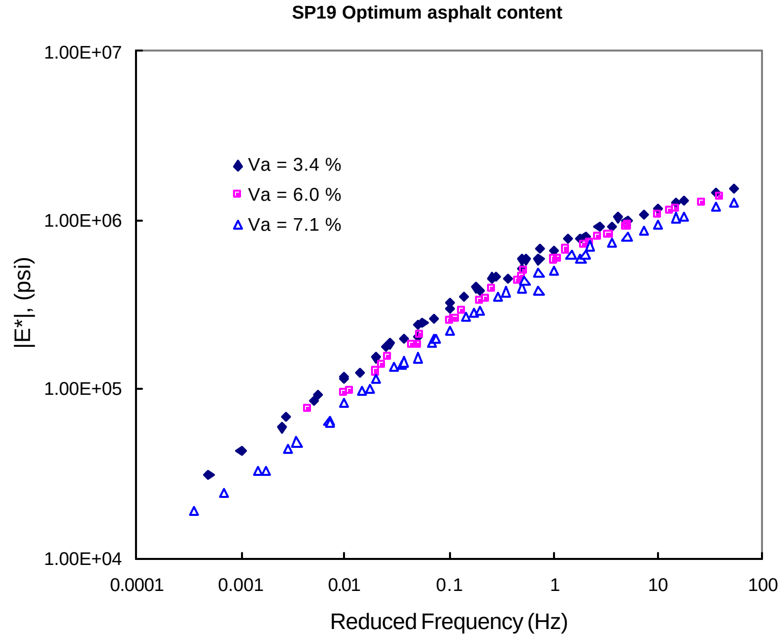


Figure 5-6 Master curves for SP 19-mm mix with optimum AC, 20°C

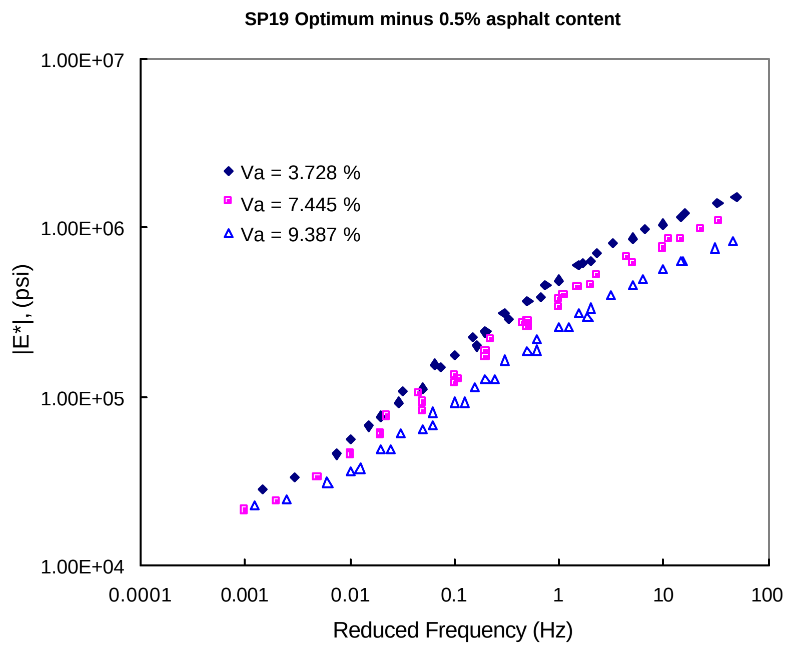
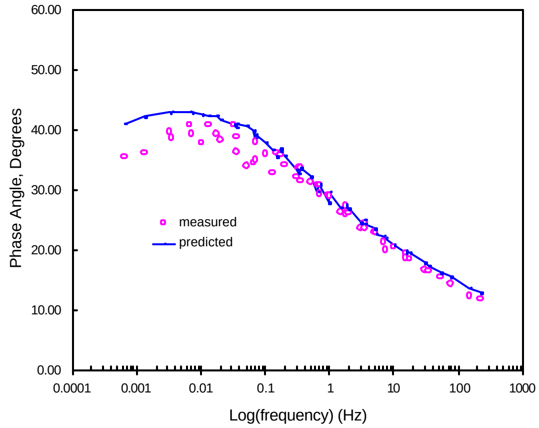
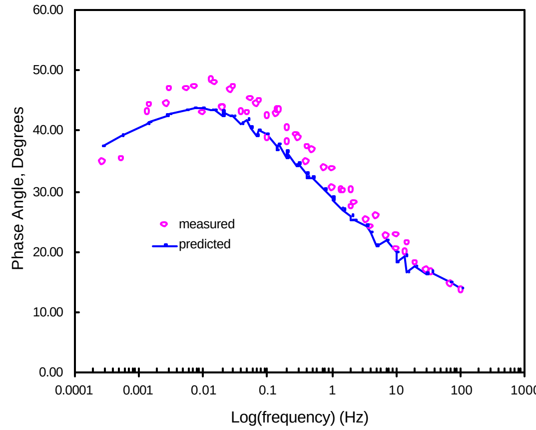


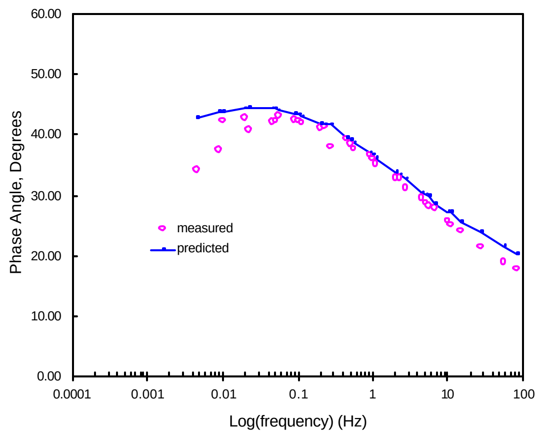
Figure 5-7 Master curves for SP 19-mm mix with optimum-0.5% AC, 20°C



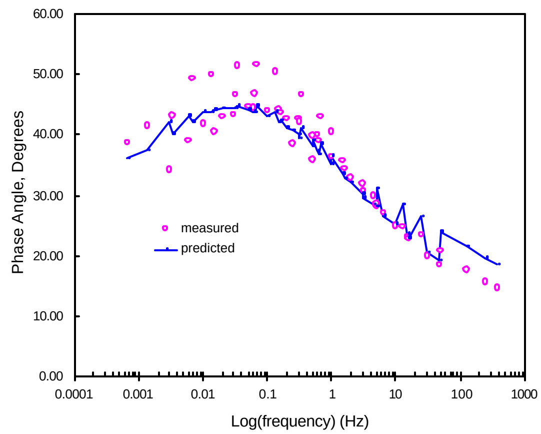
optimum AC, V_a=4%



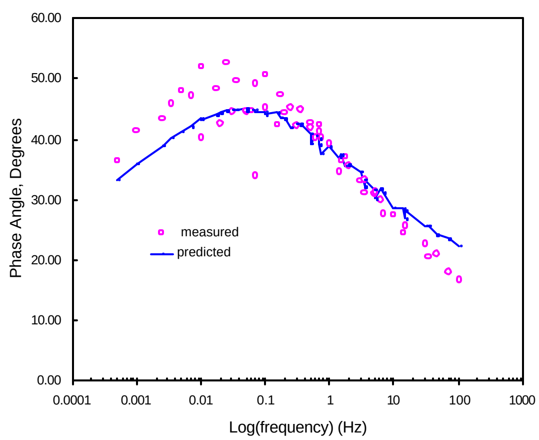
optimum-0.5% AC, V_a=4.5%



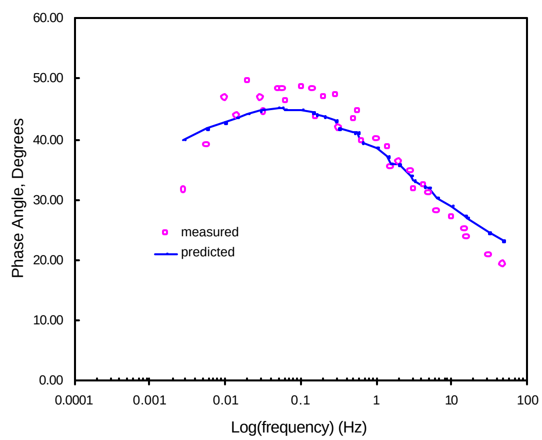
optimum AC, V_a=6%



optimum-0.5% AC, V_a=6%

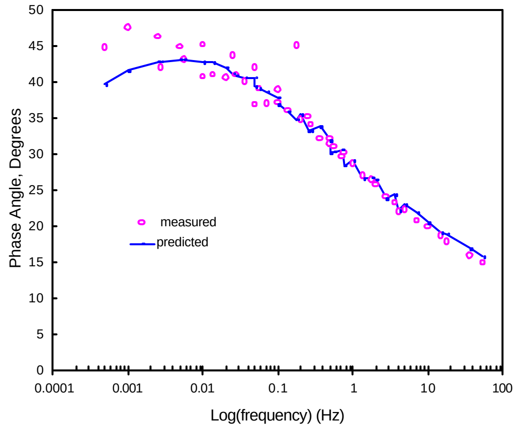


optimum AC, V_a=7%

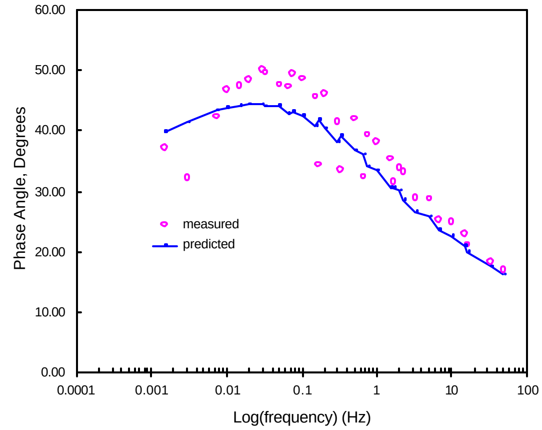


optimum-0.5% AC, V_a=7.8%

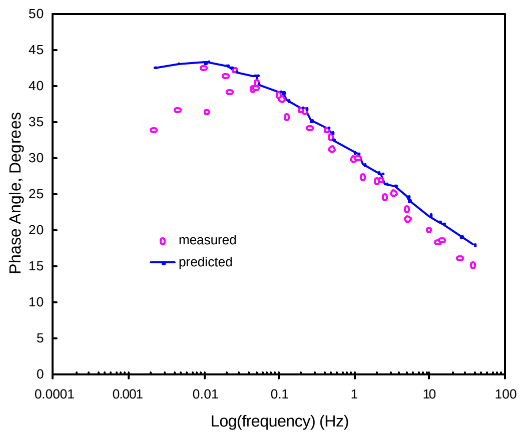
Figure 5-8 Comparison between calculated and measured phase angle for SP 12.5-mm mixes



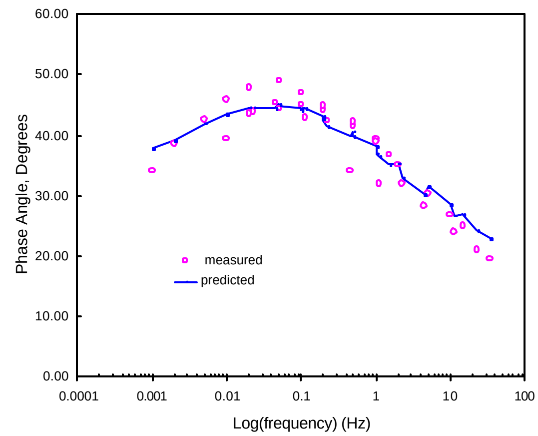
optimum AC, V_a=3.4%



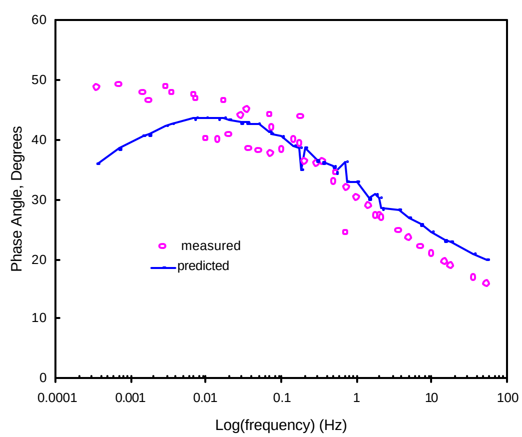
optimum-0.5% AC, V_a=3.7%



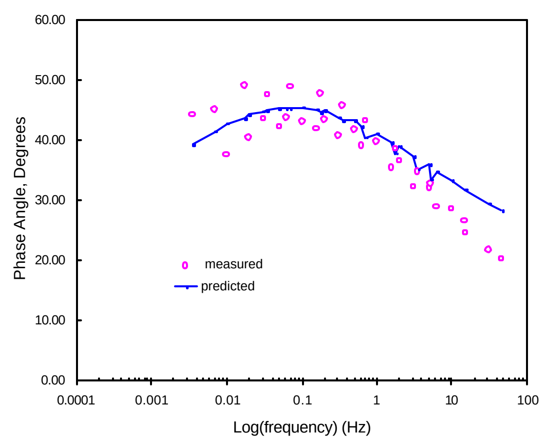
optimum AC, V_a=6%



optimum-0.5% AC, V_a=7.4%



optimum AC, V_a=7%



optimum-0.5% AC, V_a=9.4%

Figure 5-9 Comparison between calculated and measured phase angle for SP 19-mm mixes

6. Shear Frequency Sweep Testing

6.1 Introduction

For shear frequency sweep constant height test (FSCH), horizontal loading is applied at different temperature and frequencies. A cylinder specimen with dimensions of 6 in. diameter and 2 in. height was used in this study. This test measures the shear viscoelastic properties (dynamic shear stiffness |G*| and the phase shift (ϕ)) over a range of testing frequencies and at temperatures.

The shear frequency sweep constant height test can be conducted in a controlled stress or strain mode of loading. In this study, testing was conducted in accordance with AASHTO TP7 Procedure E [5] in which a sinusoidal shear strain of amplitude ±0.005% (0.0001 mm/mm peak-to-peak strain) is applied at frequencies of 15, 10, 5, 2, 1, 0.5, 0.2, 0.1, 0.05, 0.02, and 0.01 Hz. At each frequency, the stress response is measured along with the phase shift between the stress and strain. The dynamic shear stiffness (|G*|) is computed as the ratio of the stress over strain. Since this test is considered to be nondestructive, the same specimen was tested at different temperatures. By using time-temperature superposition technique, master curves for the mix were obtained. The |G*| and phase angle can be used as input to evaluate the response and performance of the mixes subjected to traffic loads. Complex shear stiffness of the HMA can also be extracted from master curves by using nonlinear regression and optimization techniques.

Variables that may affect the shear stiffness of asphalt mixes are considered to be asphalt type and grade, aggregate type and gradation, air void content, temperature, loading frequency, aging and moisture conditioning. The significant variables included in this study are asphalt content, air void content, temperature and gradation. The specific objective of this task was to investigate how various factors influence the dynamic shear stiffness, and develop a predictive model based on various factors included in this study.

6.2 Experiment design

Table 6-1 shows the experimental design for shear frequency sweep testing. This design parallels the fatigue and axial frequency test design. Each of 12 mixes were tested at 3 different temperatures. The total number of shear tests conducted was 72.

6.3 Shear frequency sweep test results

Figure 6-1 and Figure 6-2 show the dynamic shear stiffness versus frequency for SP 12.5-mm and SP 19-mm mixes for different temperatures and air void contents, respectively.

The time-temperature superposition principle was applied to the data to obtain master curves at 20°C. Assuming that the viscoelastic response of the material is controlled by a single function of temperature (i.e., a single rate controlling mechanism), time shift factor can be evaluated as:

$$\log(a_T) = \log(\frac{t_T}{t_{T_0}}) = \log(\frac{f_{T_0}}{f_T}) \qquad (6\text{-}1)$$

where,

a_T = shift factor that is dependent on the difference between the reference temperature and datum temperatures;

f_T, f_{T_0} = frequency required to reach a specific |G*|at temperature T and T_0.

By using the time-temperature superposition technique, master curves for each mix were obtained. Figure 6-3 to Figure 6-6 show master curves for SP 12.5-mm and SP 19-mm mix with optimum and optimum minus 0.5% AC, respectively. Each figure shows a fairly consistent trend, i.e., the lower the air void content, the higher the shear dynamic stiffness is.

6.4 Analysis of shear stiffness

This section deals with analysis of shear stiffness data. The sensitivity of shear stiffness to various mix and test parameters is investigated using statistical analysis, and surrogate models are developed for the prediction of dynamic shear stiffness and shear loss stiffness.

6.4.1 Surrogate models for shear stiffness

The shear stiffness model development procedure followed is similar to that used for axial stiffness characterization. The models presented in this section are the general model for shear stiffness (|G*|), shear loss stiffness (G"), and shear stiffness $\left|G^*\right|_{10Hz}$ at 10 Hz frequency.

Table 6-2 through Table 6-4 provides summary of regression analysis for the various models. The shear stiffness models based on GLM are as follows:

At 10 Hz frequency

$$\left|G^*\right|_{10Hz} = 10.7313\times10^5 \exp(-0.04504AC + 0.05947GR - 0.34265Temp - 0.1564V_a) \qquad R^2 = 0.71 \qquad (6.2)$$

For variable frequency

$$\left|G^*\right| = 4.297\times10^5 \exp(0.05805AC + 0.08957GR - 0.57338Temp - 0.1703V_a)\cdot(Freq)^{0.4775} \qquad R^2 = 0.91 \qquad (6.3)$$

$$G'' = 1.496\times10^5 \exp(-0.0195AC + 0.04779GR - 0.32727Temp - 0.13927V_a)\cdot(Freq)^{0.3091} \qquad R^2 = 0.71 \qquad (6.4)$$

where,

| G^* |, G"= shear stiffness, and shear loss stiffness in psi;

AC = asphalt content: -1 and +1 for opt.-0.5% and opt.;

GR = aggregate gradation: -1 and +1 for SP 12.5-mm and SP 19-mm;

V_a = air void content in percent;

Temp = test temperature: -1, 0 and 1 for 15, 20 and 25°C, respectively;

$Freq$ = frequency in Hz; and

exp = e: base of natural log.

It can be seen from these models that shear stiffness as well as shear loss stiffness is sensitive to all mix and test variables considered in this study.

6.4.2 Surrogate models for phase angle

Summary of the regression analysis for shear phase angle is presented in Table 6-5. It was found in this study that the phase angle is dependent on |G*| and the frequency. The model with variable frequency is:

$$f = -58.75 + 58.45 \cdot \log|G^*| - 7.87 \cdot (\log|G^*|)^2 - 1.41 \cdot \log(f) \qquad R^2 = 0.77 \qquad (6.5)$$

where,

f = phase angle in degree,

$|G^*|$ = shear dynamic stiffness, and

f = frequency in Hz, and

log = logarithm to base 10.

For the phase angle at 10 Hz frequency, equation 6.5 reduces to:

$$f = -59.86 + 58.45 \cdot \log|G^*| - 7.87 \cdot (\log|G^*|)^2 \qquad R^2 = 0.77 \qquad (6.6)$$

6.5 Relationships between axial and shear stiffness

Summary of the regression analysis between axial and shear stiffness is presented in Table 6-6 and Table 6-7. For mixes considered in this study, the axial stiffness can reliably be estimated from shear stiffness through the following regression equations:

$$\left|E^*\right|_{10Hz} = 37.6 \cdot \left|G^*\right|_{10Hz}^{0.78114} \qquad R^2 = 0.96 \tag{6.7}$$

$$E''_{10Hz} = 79.28 \cdot (G'')_{10Hz}^{0.71735} \qquad R^2 = 0.93 \tag{6.8}$$

where,

$|E^*|$, $|G^*|$ = axial and shear dynamic stiffness, respectively; and

E'', G'' = axial and shear loss-stiffness, respectively.

The use of equations 6.7 and 6.8 will be elaborated in the following section.

6.6 Shear frequency sweep test for field cores

In the previous section, a relationship between axial stiffness and shear stiffness was presented. This relationship presents a useful tool for forensic analysis of pavement sections.

For mechanistic analysis, it is required to evaluate the axial stiffness in laboratory, or to estimate it using models. However, laboratory evaluation of axial stiffness for field sample is often a difficult task, especially for pavement sections with thin layers. An alternate method is to obtain field cores that are tested in shear mode-of-loading to evaluate the shear stiffness $|G^*|$. Once the shear stiffness of a mix is known, the axial stiffness can be estimated using equations 6.7 and 6.8. Then, the procedure outlined in chapter 7 can be used for mechanistic analysis and for determining the fatigue resistance of pavement section under consideration.

In this study, 6 in. diameter field cores were obtained to conduct shear frequency sweep test. From each field core, a 2 inch high specimen was obtained for both SP 12.5-mm and SP 19-mm mixes. Tests were conducted at 15, 20 and 25°C. Four specimens were tested for each mix, and the data are presented in Appendix F. The average air void content for these mixes varied between 7.5 to 8.1-percent for both mixes.

Table 6-8 and Table 6-9 show the average test results for the SP 12.5-mm and SP 19-mm aggregate size cores, respectively, as function of temperature and frequency. Figure 6-7 and Figure 6-8 show the $|G^*|$ value as a function of reduced frequency at 20°C.

The comparison between the field $|G^*|$ and lab $|G^*|$ at 10 Hz frequency is presented in Table 6-9 and Table 6-10. It can be seen that there is a fair amount of scatter in the data for both field $|G^*|$ values and the corresponding phase angle. The field $|G^*|$ value at 10 Hz is less than the lab evaluated values.

6.7 Summary

In this chapter, the shear frequency sweep test data were analyzed and the following conclusion may be drawn based on the results.

1. Analysis shows that the shear stiffness data follow the time-temperature superposition principle.
2. Regression models developed show that shear stiffness is sensitive to all mix and test variables considered in this study.
3. There is a good correlation between axial and shear stiffness.
4. The shear stiffness of field cores was found to be lower as compared to the lab evaluated shear stiffness.

Table 6-1 Mix and test variables for FSCH experiment design

Number of asphalts	1-PG64-22
Number of aggregate gradations	2-12.5-mm and 19-mm intermediate
Asphalt Contents	2-Superpave opt. and opt. minus 0.5-percent
Air Void Levels	3- About 4, 6, and 8-percent
Temperatures	3- 15°C, 20°C, and 25°C
Test Frequency	0.1 to 15 Hz for shear frequency sweep test
Specimen Size	6-in. diameter x 2-in. high shear test specimen
Replicates	2- for shear tests
Total Number of Mixes	12- 2 gradations, 2 asphalt contents, 3 air void contents
Number of Shear Tests	2 replicates x 12 mixes x 3 = 72

Table 6-2 Summary of statistical analysis for $|G^*|$ at 10 Hz

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	13.40945	3.35236	57.25	<.0001
Error	88	5.15268	0.05855		
Corrected Total	92	18.56213			
Root MSE	0.24198	Coeff. Var.	1.86294	R_Square	0.7224
Dependent Mean	12.98899			Adj R_Sq	0.7098
Variable	Parameter Estimate	Standard Error	t Value	Pr > |t|	Variance Inflation
Intercept	13.88609	0.09095	152.68	<.0001	0
Temp	-0.34265	0.03089	-11.09	<.0001	1.0001
AC	-0.04504	0.02568	-1.75	0.0829	1.01234
GR	0.05947	0.02577	2.31	0.0234	1.01945
V_a	-0.1564	0.01568	-9.98	<.0001	1.00718

Table 6-3 Summary of statistical analysis for |G*| at variable frequency

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	1631.958	326.3915	2189.29	<.0001
Error	1022	152.3657	0.14909		
Corrected Total	1027	1784.323			
Root MSE	0.38612	Coeff. Var.	3.32337	R_Square	0.9146
Dependent Mean	11.61821			Adj R_Sq	0.9142
Variable	Parameter Estimate	Standard Error	t Value	Pr > |t|	Variance Inflation
Intercept	12.97083	0.04393	295.28	<.0001	0
Temp	-0.57338	0.0148	-38.73	<.0001	1.00017
AC	0.05805	0.01233	4.71	<.0001	1.0111
GR	0.08957	0.01235	7.25	<.0001	1.01824
V_a	-0.1703	0.00754	-22.58	<.0001	1.00702
Log(f)	1.09948	0.01163	94.55	<.0001	1.00009

Table 6-4 Summary of statistical analysis for |G"| at variable frequency

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	681.1776	136.2355	497.02	<.0001
Error	1022	280.1376	0.27411		
Corrected Total	1027	961.3152			
Root MSE	0.52355	Coeff. Var.	4.81559	R_Square	0.7086
Dependent Mean	10.87203			Adj R_Sq	0.7072
Variable	Parameter Estimate	Standard Error	t Value	Pr > |t|	Variance Inflation
Intercept	11.91586	0.05956	200.06	<.0001	0
Temp	-0.32727	0.02007	-16.3	<.0001	1.00017
AC	-0.0195	0.01671	-1.17	0.2435	1.0111
GR	0.04779	0.01674	2.85	0.0044	1.01824
V_a	-0.13927	0.01023	-13.62	<.0001	1.00702
Log(f)	0.71177	0.01577	45.14	<.0001	1.00009

Table 6-5 Summary of statistical analysis for phase angle

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F

Model	3	168128	56043	1160.49	<.0001
Error	1024	49451	48.29217		
Corrected Total	1027	217580			
Root MSE	6.94926	Coeff. Var.	20.71	R_Square	0.7727
Dependent Mean	33.55484			Adj R_Sq	0.7721
Variable	Parameter Estimate	Standard Error	t Value	Pr > |t|	Variance Inflation
Intercept	-58.7491	16.22962	-3.62	0.0003	
Log|G*|)	58.45281	6.56387	8.91	<.0001	
Log|G*|)$*$Log|G*|)	-7.87732	0.6645	-11.85	<.0001	
Log(f)	-1.41069	0.41435	-3.4	0.0007	

Table 6-6 Summary of statistical analysis for |E*| versus |G*|

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	3.21452	3.21452	780.3	<.0001
Error	34	0.14007	0.00412		
Corrected Total	35	3.35459			
Root MSE	0.06418	Coeff. Var.	0.4685	R_Square	0.9582
Dependent Mean	13.70003			Adj R_Sq	0.957
Variable	Parameter Estimate	Standard Error	t Value	Pr > |t|	Variance Inflation
Intercept	3.62685	0.36077	10.05	<.0001	0
Ln(G)	0.78114	0.02796	27.93	<.0001	1

Table 6-7 Summary of statistical analysis for |E"| versus |G"|

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	0.34649	0.34649	431.1	<.0001
Error	34	0.02733	0.000804		
Corrected Total	35	0.37382			
Root MSE	0.02835	Coeff. Var.	0.22112	R_Square	0.9269
Dependent Mean	12.82133			Adj R_Sq	0.9247
Variable	Parameter Estimate	Standard Error	t Value	Pr > |t|	Variance Inflation
Intercept	4.37294	0.40693	10.75	<.0001	0
Ln(G)	0.71735	0.03455	20.76	<.0001	1

Table 6-8 Average shear test data for field samples, SP 12.5-mm mix

Frequency (Hz)	T=15°C		T=20°C		T=25°C	
	|G*| (psi)	ϕ (Degree)	|G*| (psi)	ϕ (Degree)	|G*| (psi)	ϕ (Degree)

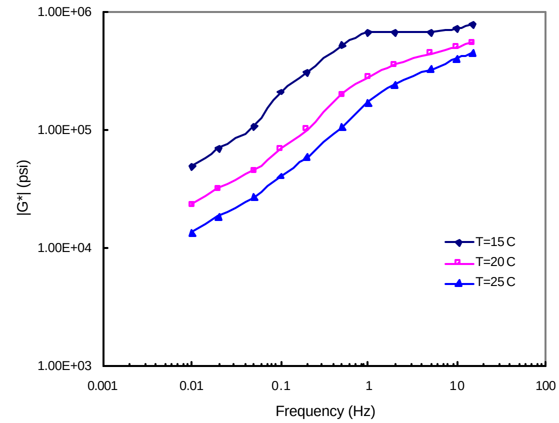
15	3.41E+05	17	1.89E+05	25	1.97E+05	26
10	3.14E+05	18	1.69E+05	26	1.72E+05	27
5	2.61E+05	21	1.35E+05	29	1.32E+05	31
2	2.06E+05	23	1.00E+05	33	9.09E+04	34
1	1.67E+05	28	7.65E+04	35	6.89E+04	38
0.5	1.30E+05	30	5.79E+04	38	4.93E+04	40
0.2	9.30E+04	33	3.94E+04	40	3.05E+04	43
0.1	7.21E+04	35	2.93E+04	41	2.12E+04	45
0.05	5.20E+04	36	2.07E+04	40	1.42E+04	45
0.02	3.75E+04	38	1.48E+04	42	9.97E+03	45
0.01	2.77E+04	39	1.13E+04	41	7.28E+03	43

Table 6-9 Average shear test data for field samples, SP 19-mm mix

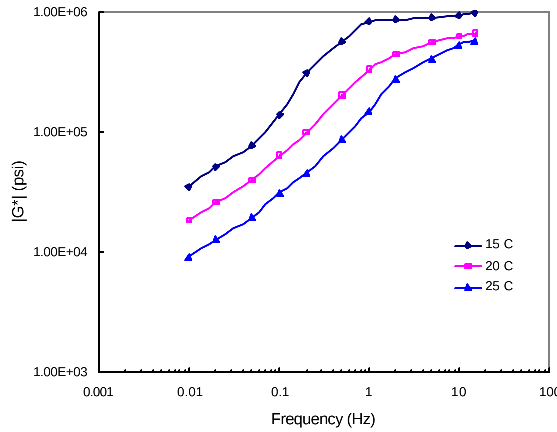
Frequency (Hz)	T=15°C		T=20°C		T=25°C	
	|G*| (psi)	ϕ (Degree)	|G*| (psi)	ϕ (Degree)	|G*| (psi)	ϕ (Degree)
15	4.86E+05	18	2.54E+05	21	2.84E+05	27
10	4.47E+05	19	2.31E+05	23	2.45E+05	29
5	3.89E+05	20	1.91E+05	26	1.84E+05	33
2	2.96E+05	25	1.42E+05	30	1.25E+05	38
1	2.85E+05	27	1.10E+05	35	8.93E+04	43
0.5	2.10E+05	31	8.21E+04	38	6.21E+04	46
0.2	1.27E+05	36	5.44E+04	42	3.74E+04	50
0.1	9.57E+04	39	3.94E+04	43	2.47E+04	51
0.05	6.65E+04	40	2.64E+04	45	1.55E+04	51
0.02	4.72E+04	43	1.83E+04	46	1.03E+04	50
0.01	3.28E+04	45	1.35E+04	46	7.53E+03	47

Table 6-10 Comparison of test data between lab and field samples

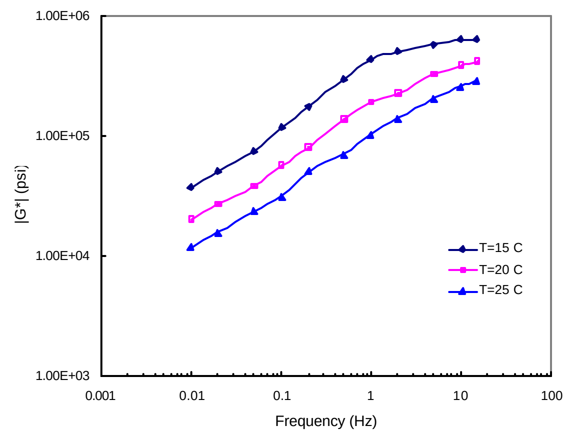
	GR	Temp	V_a	Frequency	Lab $\|G^*\|$	Lab ϕ	Field $\|G^*\|$	Field ϕ
			(%)	(Hz)	(psi)	(degree)	(psi)	(degree)
1	-1	-1	7.7	10	408378.68	20.03	280660.38	20.98
1	-1	-1	7.8	10	399534.01	20.31	316883.73	18.43
1	-1	-1	7.9	10	396421.84	20.41	320151.32	16.68
1	-1	-1	8.1	10	383613.25	20.83	337009.67	16.03
1	-1	0	7.7	10	289902.57	24.30	158321.01	25.51
1	-1	0	7.8	10	283623.85	24.56	165229.88	28.30
1	-1	0	7.9	10	281414.56	24.65	171670.78	25.57
1	-1	0	8.1	10	272321.92	25.04	179017.40	25.02
1	-1	1	7.7	10	205797.96	28.22	157229.88	29.66
1	-1	1	7.8	10	201340.78	28.46	140019.89	27.81
1	-1	1	7.9	10	199772.43	28.54	189186.85	27.65
1	-1	1	8.1	10	193317.69	28.90	202680.93	24.01
1	1	-1	7.9	10	444400.81	18.92	371397.39	18.06
1	1	-1	7.2	10	498148.83	17.39	578948.03	22.95
1	1	-1	7.3	10	491954.82	17.56	420409.23	18.62
1	1	-1	7.4	10	480547.89	17.88	459916.85	16.40
1	1	-1	7.5	10	473831.08	18.07	404731.93	16.68
1	1	0	7.9	10	315474.20	23.28	206634.28	26.23
1	1	0	7.3	10	349232.15	22.02	229184.92	22.78
1	1	0	7.4	10	341134.52	22.31	271434.61	23.62
1	1	0	7.5	10	336366.35	22.49	263734.83	20.88
1	1	1	7.9	10	223950.91	27.28	229282.09	30.39
1	1	1	7.20	10	251036.64	25.99	281716.46	34.53
1	1	1	7.3	10	247915.23	26.13	210263.96	27.48
1	1	1	7.4	10	242166.84	26.40	254903.31	25.88
1	1	1	7.5	10	238781.97	26.56	249171.38	25.70



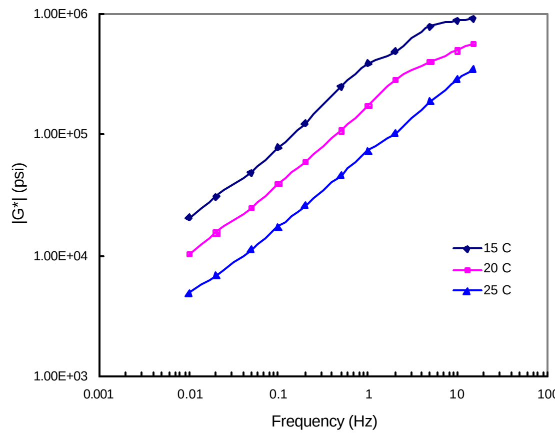
SP 12.5-mm mix with optimum AC, V_a=3.65%



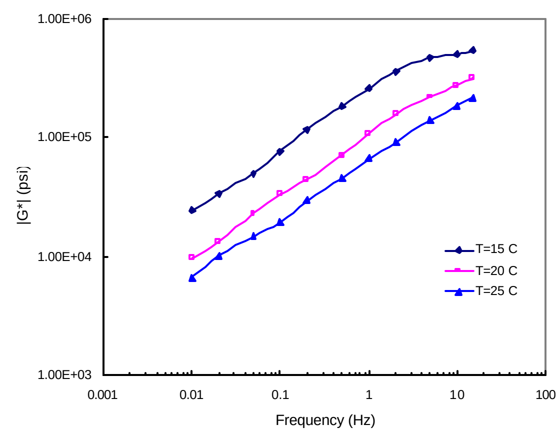
SP 12.5-mm mix with opti.-0.5% AC, V_a=3.6%



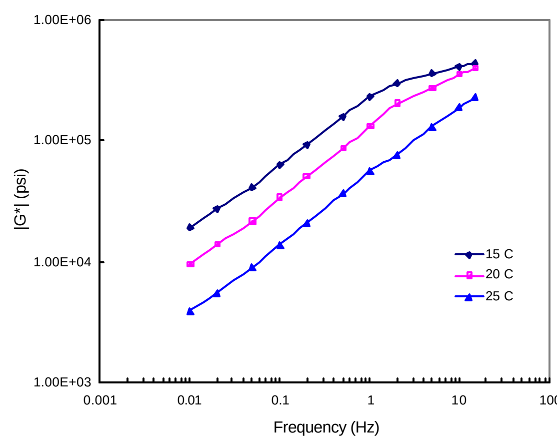
SP 12.5-mm mix with optimum AC, V_a=6.2%



SP 12.5-mm mix with opti.-0.5% AC, V_a=5.9%

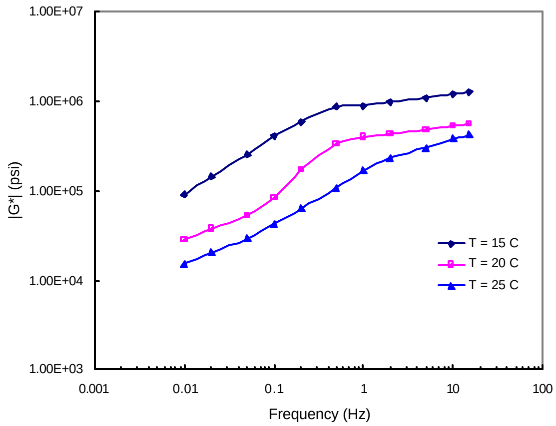


SP 12.5-mm mix with optimum AC, V_a=7%

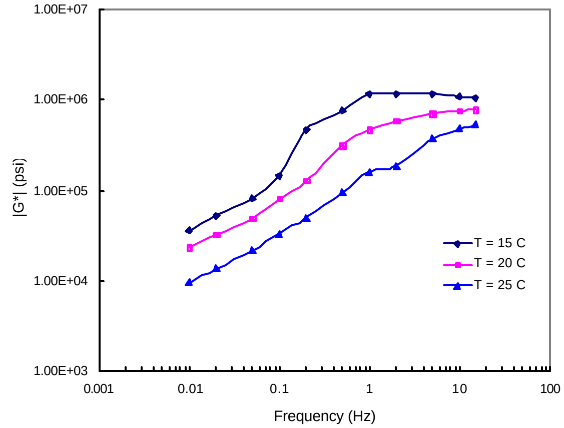


SP 12.5-mm mix with opti.-0.5% AC, V_a=7.8%

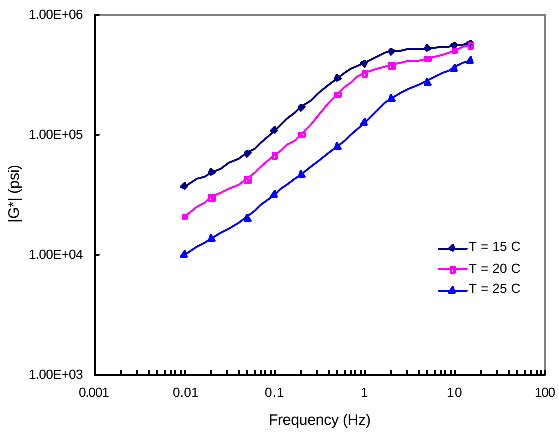
Figure 6-1 Shear stiffness versus frequency for SP 12.5-mm mixes



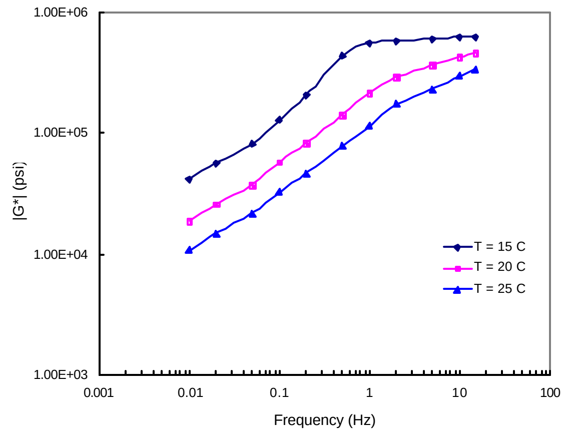
SP 19-mm mix with optimum asphalt content, V_a=3.96%



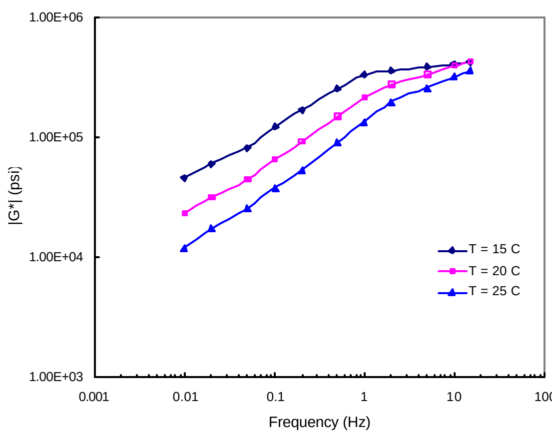
SP 19-mm mix with opti.-0.5% asphalt content, V_a=3.96%



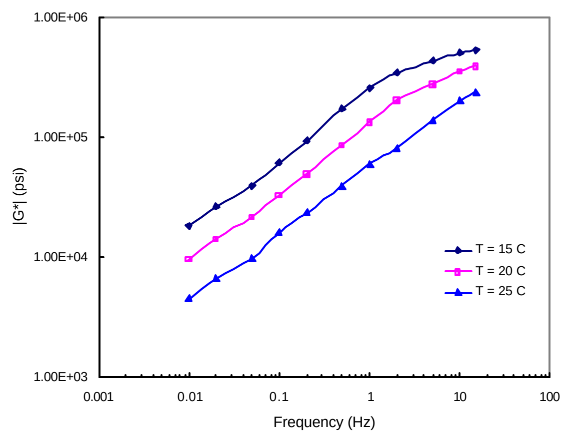
SP 19-mm mix with optimum asphalt content, V_a=5.54%



SP 19-mm mix with opti.-0.5% asphalt content, V_a=5.66%



SP 19-mm mix with optimum asphalt content, V_a=6.33%



SP 19-mm mix with opti.-0.5% asphalt content, V_a=8.06%

Figure 6-2 Shear stiffness versus frequency for SP 19-mm mixes

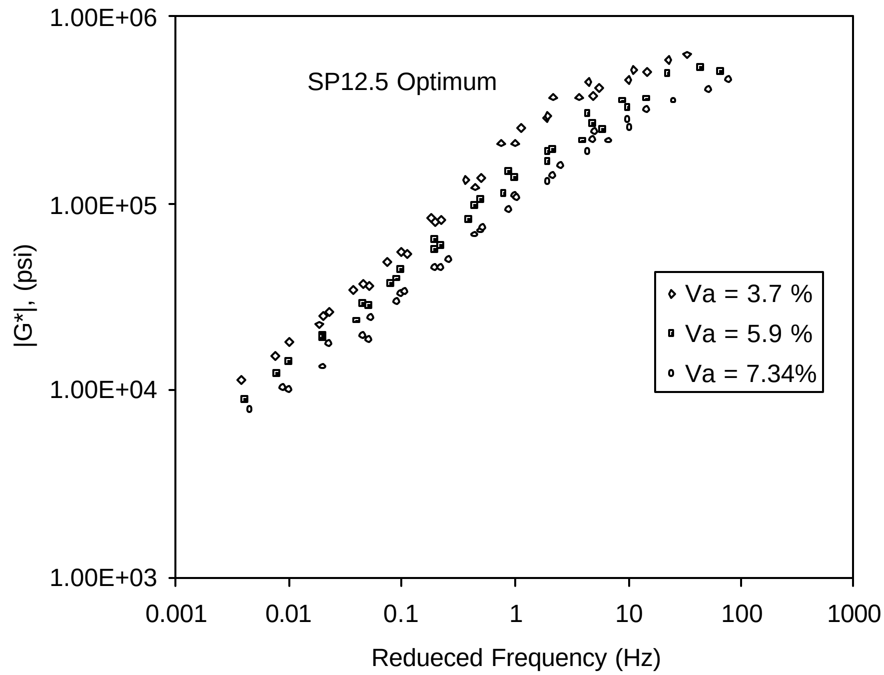


Figure 6-3 Master curves for SP 12.5-mm mix with optimum AC, 20° C

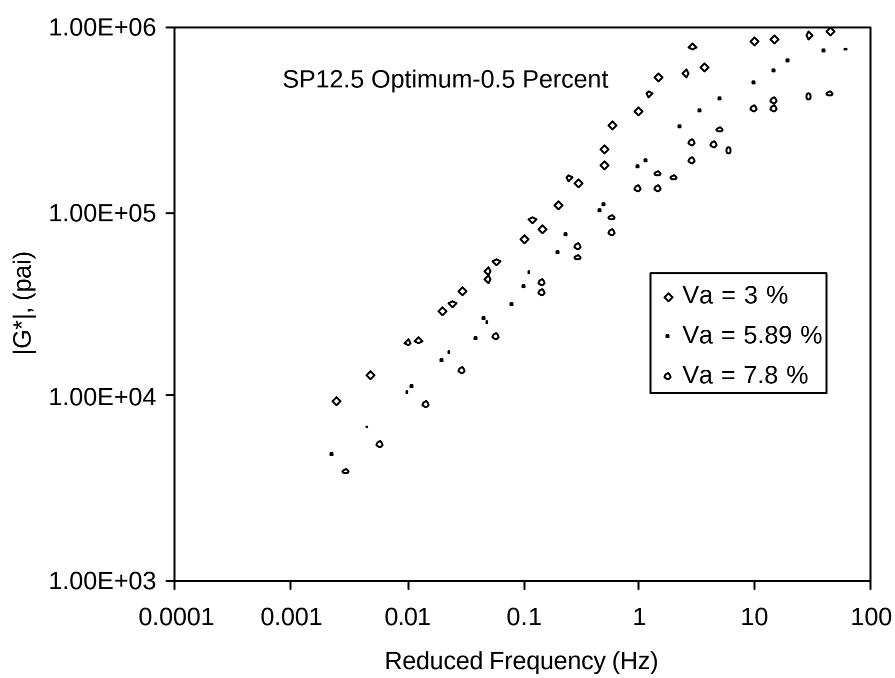


Figure 6-4 Master curves for SP 12.5-mm with optimum minus 0.5-percent AC, 20°C

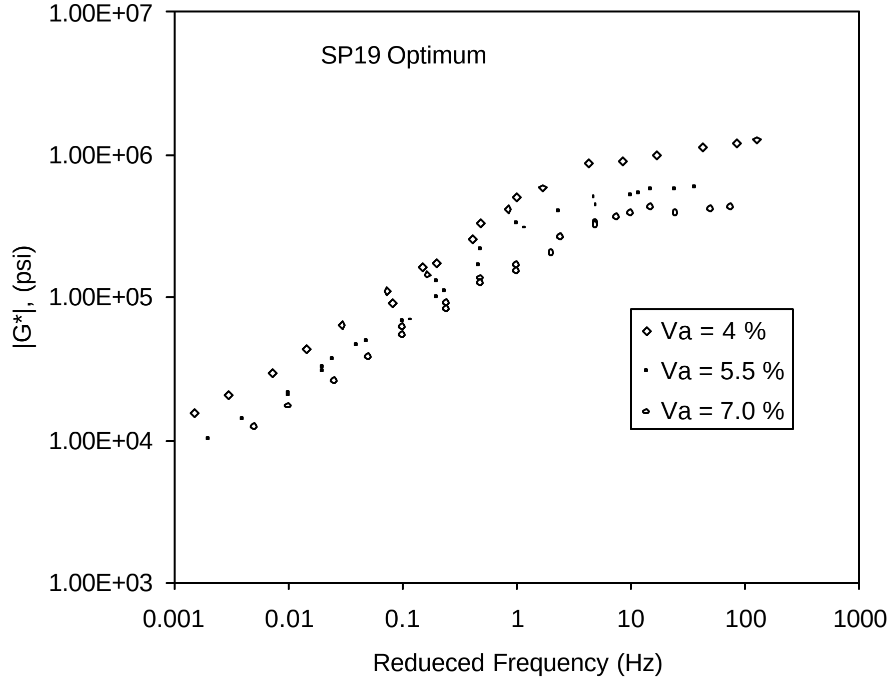


Figure 6-5 Master curves for SP 19-mm mix with optimum AC, 20°C

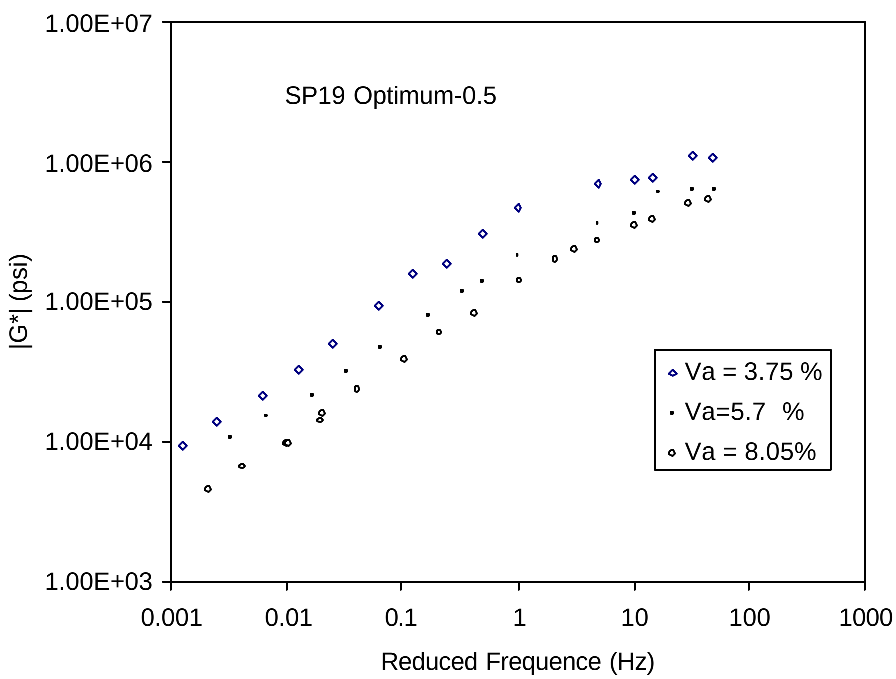


Figure 6-6 Master curves for SP 19-mm with optimum minus 0.5-percent AC, 20°C

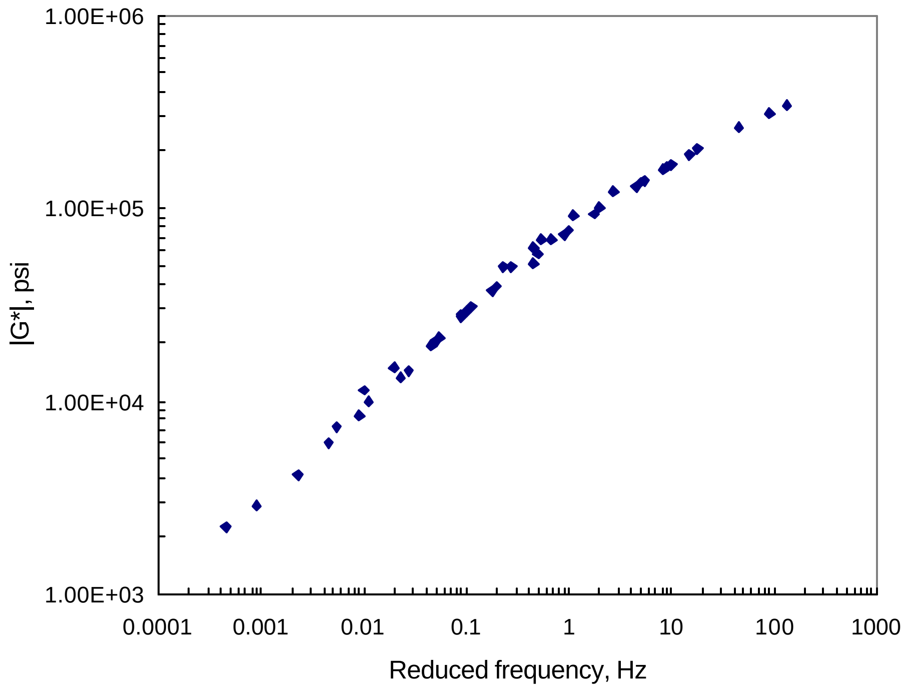


Figure 6-7 Master curve for SP 12.5-mm mix with average V_a=7.5%, 20° C

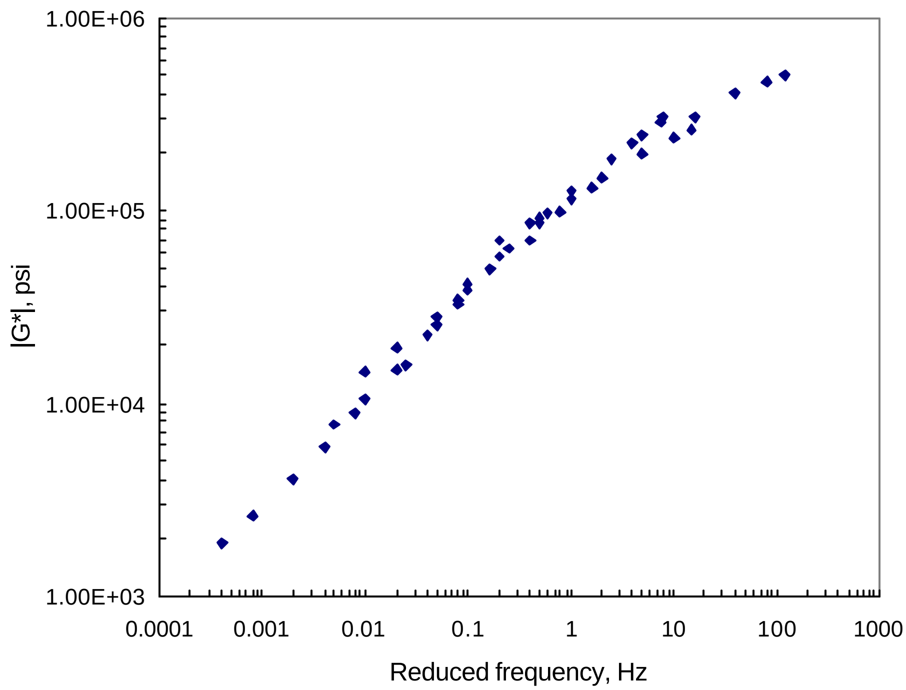


Figure 6-8 Master curve for SP 19-mm mix with average V_a=7.9%, 20° C

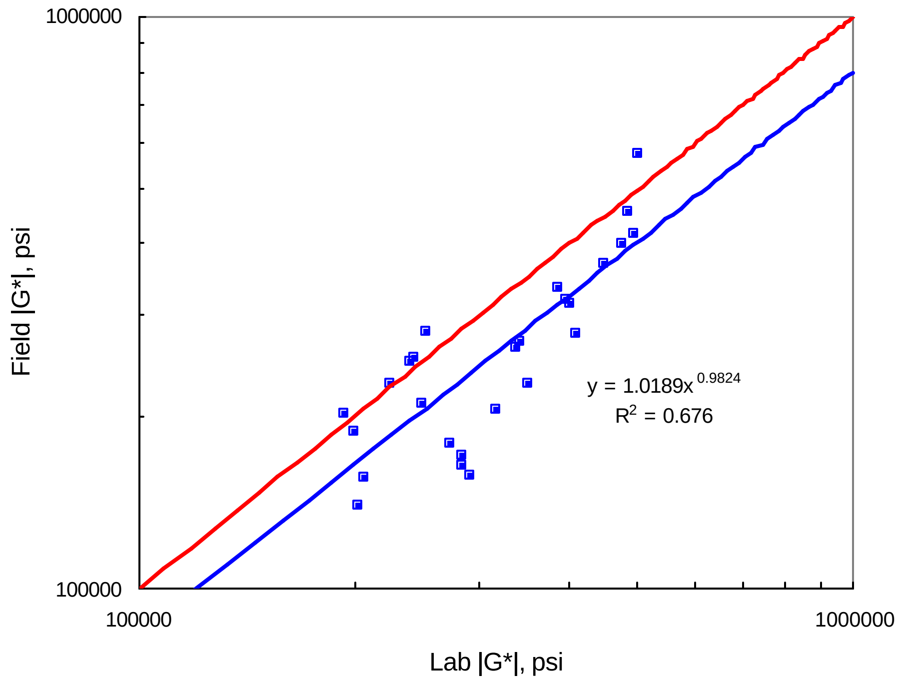


Figure 6-9 Field $|G^*|$ versus lab $|G^*|$ at 10 Hz

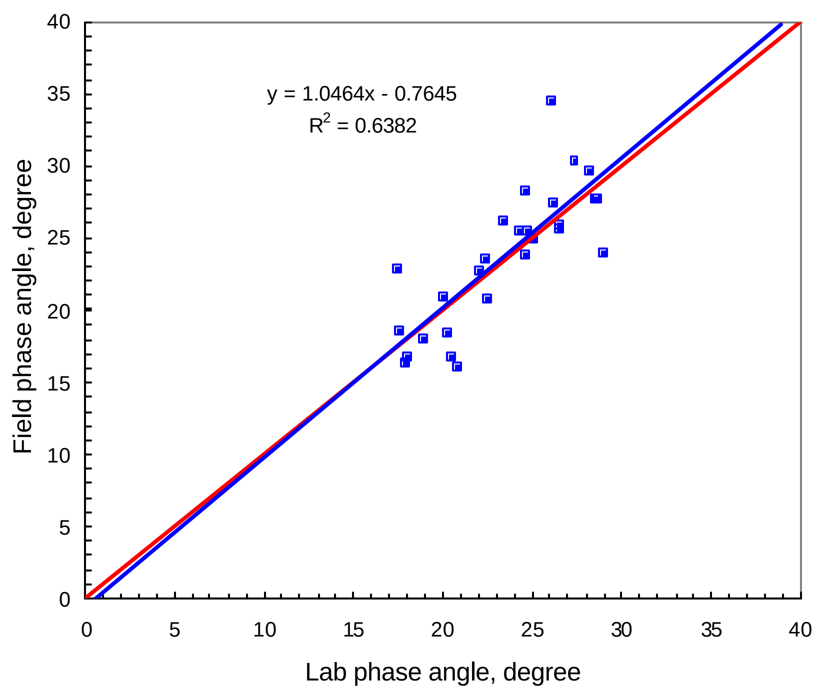


Figure 6-10 Field phase angle versus lab phase angle at 10 Hz

7. Fatigue models and procedure for fatigue analysis

7.1 Introduction

In chapters 4 to 6, the effect of various mix and test variables on fatigue life, stiffness and shear stiffness was presented. The objective of this section is to present the result of an effort to calibrate the strain and stiffness based fatigue models; and present procedure for fatigue analysis of typical asphalt pavement sections.

In chapter 4, it was shown that the flexural stiffness (S_0) is not a true measure of initial stiffness of the mix as it is influenced by the strain level, especially at higher temperatures. That is, at higher strain levels and higher temperatures, the flexural beam is subjected to damage from the beginning. Therefore, in the following sections, the fatigue models developed are based on the axial stiffness, which has been evaluated at lower strain levels so as not to subject given mix to undue damage.

7.2 Fatigue models

In this study, the asphalt content and air void content were both variables. The generally accepted norm in literature for taking into account the effect of asphalt content and air void content on fatigue life is through the use of VFA (voids filled with asphalt). In this study, the fatigue models are therefore based on VFA rather than asphalt content and air void content.

There are three sets of fatigue models presented herein. First, the two data sets present the equations separately for the SP 12.5-mm and SP 19-mm mixes, based on initial axial stiffness and axial loss stiffness, respectively. Second, generalized fatigue models are presented that include the aggregate gradation as a variable.

Table 7-1 through Table 7-6 show the results of the regression analysis. It may be noted that the R^2 in general, is approximately 0.8, with a coefficient of variation of 95-percent. These results are in line with those reported by SHRP-A-003A fatigue study [4].

The fatigue models are the following:

SP 12.5-mm mix

$$N_f = 4.9016 \times 10^{-2} \cdot (e)^{0.03029VFA} \cdot e_0^{-3.28034} \cdot \left|E^*\right|^{-0.98505} \qquad R^2 = 0.81 \qquad (7.1)$$

$$N_f = 2.31 \times 10^{10} \cdot e^{0.0221VFA} \cdot e_0^{-3.27807} \cdot (E^")^{-3.11293} \qquad R^2 = 0.82 \qquad (7.2)$$

SP 19-mm mix

$$N_f = 1.54 \times 10^{-3} \cdot e^{0.07007VFA} \cdot e_0^{-3.65657} \cdot \left|E^*\right|^{-1.17087} \qquad R^2 = 0.80 \qquad (7.3)$$

$$N_f = 1.13 \times 10^{4} \cdot e^{0.05741VFA} \cdot e_0^{-3.58427} \cdot (E^")^{-2.38231} \qquad R^2 = 0.79 \qquad (7.4)$$

Generalized models

$$N_f = 1.13 \times 10^{-2} \cdot e^{0.04789VFA} \cdot e_0^{-3.44019} \cdot \left|E^*\right|^{-1.07005} \cdot (e^{GR})^{-0.26812} \qquad R^2 = 0.81 \qquad (7.5)$$

$$N_f = 1.09 \times 10^{7} \cdot e^{0.03759VFA} \cdot e_0^{-3.39963} \cdot (E^")^{-2.68589} \cdot (e^{GR})^{-0.27449} \qquad R^2 = 0.79 \qquad (7.6)$$

where,

N_f = fatigue life;

VFA = void filled with asphalt in percent;

ε_0 = initial strain, in./in.;

$|E^*|$, $E^"$ = initial axial stiffness, and loss stiffness;

GR = -1 for 12.5-mm, and 1 for 19-mm mix; and

e = exponent of the natural logarithm.

7.3 Fatigue analysis of typical pavement sections

The objective of this section is to present a step by step procedure for fatigue analysis of in-situ pavement sections.

The analysis assumes that a trial mix has been proportioned and that the approximate pavement cross-section has been designed. The steps for the analysis are as follows:

1. Determine the expected distribution of in-situ pavement temperature.
2. Estimate design traffic demand (N_{demand} = ESALs).
3. Design pavement structural section.
4. Determine design strain under standard axle load.
5. Determine the resistance of trial mix to fatigue (N_{supply}) using regression estimate.
6. Apply shift factor to fatigue resistance to account for differences between estimated fatigue resistance and in-situ conditions (such as traffic wander and crack propagation).
7. Compare the N_{demand} (ESALs) to pavement fatigue resistance (N_{supply}).
8. If N_{demand} exceeds N_{supply}, re-analyze current trial mix by altering the trial mix and/or structural section as appropriate and reiterate.

7.3.1 Traffic loading and temperature consideration

Traffic loading is typically expressed as the number of ESALs that is expected during the pavement design life. This can be estimated using the AASHTO load equivalency factors.

For analysis purposes, temperature regime for pavement section under consideration will be necessary. Typically, most fatigue damage is expected to occur under moderate temperatures near or around 20°C. As will be shown later, the NCDOT fatigue models for both SP 12.5-mm and SP 19-mm mixes are sensitive to temperature between 15°C and 25°C.

7.3.2 Design pavement structure

The analysis procedure described herein can be used for new design, overlay design, or for forensic analysis of existing pavement sections that may have failed prematurely. For analysis purposes, in this study, two hypothetical pavement sections were selected based on data available from Rutherford County, NC. The sections are shown in Figure 7-1 and Figure 7-2. The pavement section shown in Figure 7-1 constitutes SP 12.5-mm mix asphalt layer of varying thickness between 3 in. and 8 in., underlain by an 8 in. layer of ABC, and 7 in. layer of CT subbase over the subgrade. The pavement section shown in Figure 7-2 consists of 3.5 in. SP 19-mm mix asphalt concrete overlaid with a surface layer of 2.5 in. SP 12.5-mm mix asphalt concrete, with underlying layers consisting of 8 in. ABC, and 7 in. CT subbase over subgrade.

7.3.3 Analysis procedure

The maximum principal tensile strain at underside of the asphalt layer governs the initiation of fatigue cracking in-situ. For analysis purposes, a multilayered elastic analysis provides a convenient means for estimating the maximum strain anticipated at given temperature under the standard axle load. The standard axle load (ESAL) is an 18 kip loading on an axle with a dual set of tires. In this study, it is assumed that the wheel spacing is 12 in. with tire pressure of 100 psi. Given the pavement structure and the loading condition, the following procedure is used to find the maximum tensile strain, and the corresponding fatigue life of the pavement:

1. Select the temperature at which the analysis is to be conducted;
2. For given temperature and mix properties, estimate the axial stiffness $|E^*|$ at 10 Hz frequency using equation 5.2. Note, the loss-stiffness can also be evaluated at this point using equation 5.4 if it is desirable to use the fatigue equation based on loss-stiffness.
3. Assume a value for the Poisson's ratio. This value will vary from 0.35 to 0.45 for asphalt mixes. At moderate temperatures a value of 0.35 to 0.4 is reasonable.

4. Conduct the analysis using any available computer program and determine the maximum principal tensile strain under the layer of interest.
5. Calculate fatigue life of pavement section (N_{supply}) using appropriate model from equations 7.1 to 7.6.
6. Apply appropriate shift factor (SF) to N_{supply}. Generally, a shift factor of 10 to 18 has been reported in literature. However, each department of transportation needs to determine a shift factor appropriate for the site under consideration. The shift factor can be determined based on experience of individual DOT. For this study, a shift factor of 1.0 has been assumed.
7. Compare N_{supply} to N_{demand}, ($SF \cdot N_{supply} \geq N_{demand}$). If the factored N_{supply} is greater than N_{demand}, the pavement section will perform adequately. If not, alter the mix selected, and/or increase the design thickness and reiterate analysis.
8. If the analysis is conducted at different temperatures, then fatigue life supply versus traffic demand may be compared using the damage ratios:

$$\frac{N_{demand\_15°C}}{SF \cdot N_{supply\_15°C}} + \frac{N_{demand\_20°C}}{SF \cdot N_{supply\_20°C}} + \frac{N_{demand\_25°C}}{SF \cdot N_{supply\_25°C}} + \cdots \leq 1.0 \qquad (7.7)$$

The above procedure was used to evaluate the pavement sections shown in Figure 7-1 and Figure 7-2 for varying mix and temperature variables. The effect of the mix and temperature variables is discussed in the following section.

7.4 Effect of mix variables and temperature on fatigue life of pavement section

One of main objectives of this study was to determine the sensitivity of Superpave mixes to mix variables and temperature with regard to fatigue distress. In this section, the two hypothetical pavement sections presented in Figure 7-1 and Figure 7-2 are used to determine the sensitivity of the SP 12.5-mm and SP 19-mm mixes.

7.4.1 Effect of asphalt concrete layer thickness

The mechanistic analysis procedure outlined in section 7.3 was used to investigate the effect of layer thickness. Table 7-7 shows the results of the analysis for SP 12.5-mm mix at optimum asphalt content (5.2-percent by weight of mix) with 4-percent voids and at 20°C.

As expected, the fatigue life (N_{supply}) of the pavement section under consideration increases as the layer thickness increases. Figure 7-3 shows the relationship between the layer thicknesses versus the fatigue life. The results indicate that an increase of 1 in. layer thickness will increase the fatigue life of pavement section by approximately 100-percent.

7.4.2 Effect of mix variables and temperature

To evaluate the effect of mix variables and temperature on fatigue life, the layer thickness for the SP 12.5-mm mix was selected to be 6 in. for the pavement section shown in Figure 7-1. The 6 in. layer thickness was selected to equal the combined layer thickness of SP 12.5-mm and SP 19-mm mixes in Figure 7-2. For both pavement sections, the mix variables were the air void content (4, 6 and 8-percent), asphalt contents (optimum and optimum minus 0.5-percent), and temperature (15, 20 and 25°C). The results of the analysis are presented in Table 7-8 to Table 7-11. Summary of the comparisons are presented in Table 7-12 to Table 7-14.

7.4.2.1 Effect of asphalt content

Table 7-12 summarizes the effect of asphalt content on pavement fatigue life. For both mixes, the fatigue life reduces with decrease in asphalt content. However, the effect of lower asphalt content on the two mixes is different. The reduction in life for SP 12.5-mm mix is about 18-percent compared to the SP 19-mm mix for which the reduction is about 24-percent. The slightly more sensitivity of the SP 19-mm mix is expected as it contains 0.5-percent less asphalt compared to the SP 12.5-mm mix.

7.4.2.2 Effect of air void content

Table 7-13 shows the effect of air void content on fatigue life. It may be noted that the values shown in the table are averages over all temperatures. The effect of air voids is quite pronounced for both mixes. For the SP 12.5-mm mix, an increase of 2-percent air void content results in a decrease of 35 to 40-percent fatigue life. For SP 19-mm mix, an increase of 2-percent air void content results in a decrease of 55 to 60-percent in fatigue life.

7.4.2.3 Effect of temperature

Table 7-14 shows the effect of temperature on fatigue life of the mixes. The fatigue life shown is an average across all air voids. In general, an increase of 5°C will result in a decrease of fatigue life by about 25 to 29-percent. The SP 19-mm mixes are slightly more sensitive to temperature compared to the SP 12.5-mm mixes. This is probably the result of the lower asphalt content.

In chapter 3 and 4, the lab fatigue data indicated that the laboratory fatigue life of mixes was lower at lower temperature in controlled-strain mode-of-loading (reverse trend is expected in controlled-stress mode-of-loading). However, it is interesting to note that for the temperature range considered in this study, the fatigue life of the pavement sections will increase with decrease in temperature. This is in line with general norm expected for in-situ field condition.

7.4.2.4 Comparison of NCDOT models with SHRP model

During the Strategic Highway Research Program (SHRP), a major study was undertaken [3] to develop a fatigue model based on testing of 44 mixes. This model reported in SHRP Report SHRP-404 [3] is following:

$$N_f = 2.738 \times 10^5 \cdot e^{0.077 VFA} \cdot (e_0)^{-3.624} \cdot (S_0^{''})^{-2.720} \qquad R^2 = 0.79 \qquad (7.8)$$

where,

N_f = fatigue life,

e = base of the natural logarithms,

ε_0 = critical tensile strain,

S_0'' = the initial flexural loss stiffness in psi and,

VFA = the voids filled with asphalt in percent.

Table 7-8 to Table 7-11 also shows the fatigue life of NCDOT mixes evaluated using the above model. In general, the results show that the fatigue life of pavement sections evaluated using NCDOT model is fairly comparable to the fatigue life evaluated using the SHRP model. However, there is one major difference, which is, that the SHRP model is not sensitive to temperature; i.e., for a given mix with fixed parameters (air void content, and asphalt content), change in temperature does not result in change in fatigue life. This is not surprising considering that the SHRP model was developed based on fatigue testing at a single temperature of 20°C.

7.5 Summary

In this section, fatigue models for NCDOT mixes were developed. A mechanistic analysis procedure is outlined for evaluating the fatigue life of a given pavement section. Based on the results of the analysis for the pavement sections considered, the following conclusions may be drawn:

(1) Fatigue models developed for NCDOT mixes are sensitive to the mix variable and test temperature considered in this study.

(2) NCDOT fatigue models yields fatigue life similar to those obtained using SHRP fatigue model. However, NCDOT models are sensitive to temperature in comparison to the SHRP model.

(3) An increase in temperature results in decrease in fatigue life of pavement section under consideration. A 5°C increase in temperature results in about 25-percent reduction in life. This trend is opposite to the trend shown by laboratory fatigue data where increase in temperature will result in increase in laboratory fatigue life.

(4) NCDOT mixes are sensitive to asphalt content. A decrease in asphalt content by 0.5-percent (by wt. of mix) results in decrease of 18 to 25-percent fatigue life.

(5) NCDOT mixes are also sensitive to air void content as expected. An increase in 2-percent air void content will reduce pavement life by about 40-percent for SP 12.5-mm mixes, and by almost 60-percent for SP 19-mm mixes.

(6) Based on the overall result of the analysis, it appears that SP 19-mm mixes are more sensitive to mix variables as compared to the SP 12.5-mm mixes.

Table 7-1 Summary of analysis of N_f with $|E^*|$, SP 12.5-mm mix

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	176.0097	58.66989	174.67	<.0001
Error	116	38.96326	0.33589		
Corrected Total	119	214.9729			
Root MSE	0.57956	Coeff. Var.	5.12789	R_Square	0.8188
Dependent Mean	11.30212			Adj R_Sq	0.8141
Variable	Parameter Estimate	Standard error	t Value	Pr > |t|	Variance Inflation
Intercept	-3.01561	2.64317	-1.14	0.2563	0
VFA	0.03029	0.00871	3.48	0.0007	1.39458
Strain	-3.28034	0.14355	-22.85	<.0001	1.02754
$\|E^*\|$	-0.98505	0.20455	-4.82	<.0001	1.40385

Table 7-2 Summary of analysis of N_f with E'', SP 12.5-mm mix

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	176.4375	58.81249	177.04	<.0001
Error	116	38.53545	0.3322		
Corrected Total	119	214.9729			
Root MSE	0.57637	Coeff. Var.	5.09966	R_Square	0.8207
Dependent Mean	11.30212			Adj R_Sq	0.8161
Variable	Parameter Estimate	Standard error	t Value	Pr > |t|	Variance Inflation
Intercept	23.86466	7.76406	3.07	0.0026	0
VFA	0.02221	0.00788	2.82	0.0057	1.15353
Strain	-3.27807	0.14261	-22.99	<.0001	1.02531
E"	-3.11293	0.62589	-4.97	<.0001	1.16523

Table 7-3 Summary of regression analysis of N_f with $|E^*|$, SP 19-mm mix

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	236.448	78.81601	163.41	<.0001
Error	117	56.43302	0.48233		
Corrected Total	120	292.881			
Root MSE	0.6945	Coeff. Var.	6.30978	R_Square	0.8073
Dependent Mean	11.00675			Adj R_Sq	0.8024
Variable	Parameter Estimate	Standard error	t Value	Pr > |t|	Variance Inflation
Intercept	-6.47814	3.20091	-2.02	0.0453	0
VFA	0.07007	0.01116	6.28	<.0001	1.45865
Strain	-3.65657	0.16546	-22.1	<.0001	1.12729
$\|E^*\|$	-1.17087	0.24914	-4.7	<.0001	1.35617

Table 7-4 Summary of regression analysis of N_f with E'', SP 19-mm mix

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	229.6826	76.56085	141.74	<.0001
Error	117	63.19848	0.54016		
Corrected Total	120	292.881			
Root MSE	0.73495	Coeff. Var.	6.6773	R_Square	0.7842
Dependent Mean	11.00675			Adj R_Sq	0.7787
Variable	Parameter Estimate	Standard error	t Value	Pr > |t|	Variance Inflation
Intercept	9.32855	10.91001	0.86	0.3943	0
VFA	0.05741	0.01144	5.02	<.0001	1.36805
Strain	-3.58427	0.1745	-20.54	<.0001	1.11963
E''	-2.38231	0.88797	-2.68	0.0084	1.27248

Table 7-5 Summary of general regression analysis of N_f with $|E^*|$

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	413.4471	103.3618	244.76	<.0001
Error	236	99.66317	0.4223		
Corrected Total	240	513.1102			
Root MSE	0.64985	Coeff. Var.	5.82623	R_Square	0.8058
Dependent Mean	11.15383			Adj R_Sq	0.8025
Variable	Parameter Estimate	Standard error	t Value	Pr > |t|	Variance Inflation
Intercept	-4.48682	2.10273	-2.13	0.0339	0
VFA	0.04789	0.0071	6.75	<.0001	1.41289
Strain	-3.44019	0.11077	-31.06	<.0001	1.08002
$\|E^*\|$	-1.07005	0.16345	-6.55	<.0001	1.3942
GR	-0.26812	0.04249	-6.31	<.0001	1.03005

Table 7-6 Summary of general regression analysis of N_f with E'

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	406.4466	101.6117	224.82	<.0001
Error	236	106.6636	0.45196		
Corrected Total	240	513.1102			
Root MSE	0.67228	Coeff. Var.	6.02738	R_Square	0.7921
Dependent Mean	11.15383			Adj R_Sq	0.7886
Variable	Parameter Estimate	Standard error	t Value	Pr > |t|	Variance Inflation
Intercept	16.20155	6.69834	2.42	0.0163	0
VFA	0.03759	0.00687	5.47	<.0001	1.23595
Strain	-3.39963	0.11418	-29.77	<.0001	1.07228
E''	-2.68589	0.54199	-4.96	<.0001	1.22516
GR	-0.27449	0.04397	-6.24	<.0001	1.03094

Table 7-7 Surface layer thickness vs. N_f, SP 12.5-mm mix

Thickness	Temp	VFA	|E*|	Strain	N_{opt-AC}

(in.)	(Celsius)		(psi)	(in./in).	
3				1.93E-04	7.41E+05
4				1.53E-04	1.59E+06
5	20	72.46	1,130,000	1.23E-04	3.22E+06
6				1.01E-04	6.17E+06
7				8.42E-05	1.12E+07
8				7.15E-05	1.91E+07

Table 7-8 Fatigue life of SP 12.5-mm mix with optimum AC

Temp (Celsius)	V_a (%)	VFA (%)	Strain (in./in.)	|E*| (psi)	S"=E" (psi)	N_f Eq. (7.1)	N_f SHRP
15	4	72.46412	8.29E-05	1.55E+06	6.17E+05	8.63E+06	7.99E+06
15	6	63.20644	9.63E-05	1.22E+06	5.04E+05	5.01E+06	3.94E+06
15	8	55.77154	1.11E-04	9.69E+05	4.12E+05	3.19E+06	2.32E+06
20	4	72.46412	1.01E-04	1.13E+06	4.87E+05	6.17E+06	7.47E+06
20	6	63.20644	1.16E-04	8.93E+05	3.98E+05	3.69E+06	3.80E+06
20	8	55.77154	1.33E-04	7.07E+05	3.25E+05	2.39E+06	2.29E+06
25	4	72.46412	1.22E-04	8.24E+05	3.84E+05	4.55E+06	7.22E+06
25	6	63.20644	1.39E-04	6.52E+05	3.14E+05	2.80E+06	3.80E+06
25	8	55.77154	1.57E-04	5.16E+05	2.56E+05	1.87E+06	2.36E+06

Table 7-9 Fatigue life of SP 12.5-mm mix with optimum-0.5% AC

Temp (Celsius)	V_a (%)	VFA (%)	Strain (in./in.)	|E*| (psi)	S"=E" (psi)	N_f Eq. (7.1)	N_f SHRP
15	4	70.20736	8.72E-05	1.50E+06	6.35E+05	7.00E+06	5.17E+06
15	6	60.60344	1.01E-04	1.19E+06	5.19E+05	4.08E+06	2.52E+06
15	8	53.03339	1.16E-04	9.43E+05	4.24E+05	2.59E+06	1.47E+06
20	4	70.20736	1.06E-04	1.10E+06	5.01E+05	5.02E+06	4.85E+06
20	6	60.60344	1.22E-04	8.70E+05	4.09E+05	3.01E+06	2.44E+06
20	8	53.03339	1.39E-04	6.89E+05	3.34E+05	1.96E+06	1.47E+06
25	4	70.20736	1.27E-04	8.02E+05	3.95E+05	3.75E+06	4.76E+06
25	6	60.60344	1.45E-04	6.35E+05	3.23E+05	2.32E+06	2.47E+06
25	8	53.03339	1.64E-04	5.03E+05	2.64E+05	1.55E+06	1.53E+06

Table 7-10 Fatigue life of SP 19-mm mix with optimum AC

Temp (Celsius)	V_a (%)	VFA (%)	Strain (in./in.)	|E*| (psi)	S"=E" (psi)	N_f	
						Eq. (7.3)	SHRP
15	4	71.26469	8.04E-05	1.58E+06	6.61E+05	1.17E+07	6.74E+06
15	6	61.81624	9.33E-05	1.25E+06	5.40E+05	4.61E+06	3.28E+06
15	8	54.30352	1.07E-04	9.94E+05	4.42E+05	2.14E+06	1.92E+06
20	4	71.26469	9.78E-05	1.16E+06	5.22E+05	8.30E+06	6.32E+06
20	6	61.81624	1.13E-04	9.16E+05	4.26E+05	3.33E+06	3.15E+06
20	8	54.30352	1.29E-04	7.25E+05	3.48E+05	1.58E+06	1.88E+06
25	4	71.26469	1.18E-04	8.45E+05	4.11E+05	5.99E+06	6.06E+06
25	6	61.81624	1.35E-04	6.69E+05	3.36E+05	2.49E+06	3.13E+06
25	8	54.30352	1.53E-04	5.30E+05	2.75E+05	1.22E+06	1.92E+06

Table 7-11 Fatigue life of SP 19-mm mix with optimum-0.5% AC

Temp (Celsius)	V_a (%)	VFA (%)	Strain (in./in.)	|E*| (psi)	S"=E" (psi)	N_f	
						Eq. (7.3)	SHRP
15	4	68.78089	8.46E-05	1.46E+06	6.80E+05	8.98E+06	4.29E+06
15	6	58.98576	9.78E-05	1.16E+06	5.56E+05	3.50E+06	2.07E+06
15	8	51.35438	1.13E-04	9.18E+05	4.54E+05	1.61E+06	1.19E+06
20	4	68.78089	1.03E-04	1.07E+06	5.37E+05	6.37E+06	4.03E+06
20	6	58.98576	1.18E-04	8.46E+05	4.38E+05	2.53E+06	1.98E+06
20	8	51.35438	1.35E-04	6.70E+05	3.58E+05	1.20E+06	1.18E+06
25	4	68.78089	1.24E-04	7.80E+05	4.23E+05	4.65E+06	3.91E+06
25	6	58.98576	1.41E-04	6.18E+05	3.46E+05	1.91E+06	1.98E+06
25	8	51.35438	1.60E-04	4.89E+05	2.83E+05	9.30E+05	1.21E+06

Table 7-12 Comparison of fatigue life for opt. AC and opt.-0.5% AC

Temp (Celsius)	V_a (%)	SP 12.5-mm mix			SP 19-mm mix		
		N_f at opt. AC	N_f at opt.-0.5% AC	Percent difference	N_f at opt. AC	N_f at opt.-0.5% AC	Percent difference
15	4	8.63E+06	7.00E+06	-18.91%	1.17E+07	8.98E+06	-23.45%
15	6	5.01E+06	4.08E+06	-18.53%	4.61E+06	3.50E+06	-24.09%
15	8	3.19E+06	2.59E+06	-18.92%	2.14E+06	1.61E+06	-24.94%
20	4	6.17E+06	5.02E+06	-18.67%	8.30E+06	6.37E+06	-23.27%
20	6	3.69E+06	3.01E+06	-18.45%	3.33E+06	2.53E+06	-24.17%
20	8	2.39E+06	1.96E+06	-18.04%	1.58E+06	1.20E+06	-24.23%
25	4	4.55E+06	3.75E+06	-17.46%	5.99E+06	4.65E+06	-22.40%
25	6	2.80E+06	2.32E+06	-17.38%	2.49E+06	1.91E+06	-23.45%
25	8	1.87E+06	1.55E+06	-17.23%	1.22E+06	9.30E+05	-23.51%

Table 7-13 Effect of air void content on fatigue life

Va (%)	SP 12.5-mm opt.		SP 12.5-mm opt.-0.5%		SP 19-mm opt.		SP 19-mm opt.-0.5%	
	N_f	Percent difference	N_f	Percent difference	N_f	Percent difference	N_f	Percent difference
4	6.45E+06		5.26E+06		8.68E+06		6.67E+06	
6	3.84E+06	-40%	3.14E+06	-40%	3.48E+06	-60%	2.65E+06	-60%
8	2.48E+06	-36%	2.03E+06	-35%	1.65E+06	-55%	1.25E+06	-53%

Note: The percent difference is the difference expressed as a percentage of the higher value.

Table 7-14 Effect of temperature on fatigue life

Temp (°C)	SP 12.5-mm opt.		12.5-mm opt.-0.5%		SP 19-mm opt.		SP 19-mm opt.-0.5%	
	N_f	Percent difference	N_f	Percent difference	N_f	Percent difference	N_f	Percent difference
15	5.61E+06		4.56E+06		6.16E+06		4.70E+06	
20	4.08E+06	-27%	3.33E+06	-27%	4.40E+06	-29%	3.36E+06	-29%
25	3.07E+06	-25%	2.54E+06	-24%	3.23E+06	-27%	2.50E+06	-26%

Note: The percent difference is the difference expressed as a percentage of the higher value.

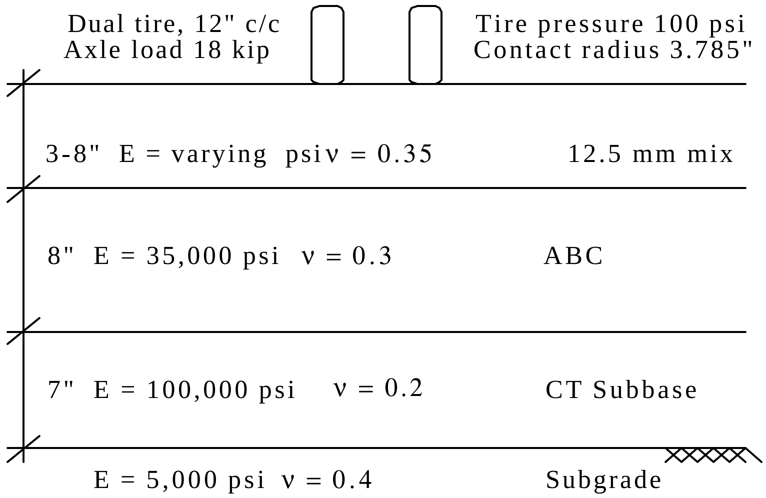


Figure 7-1 Pavement structure for SP 12.5-mm mix

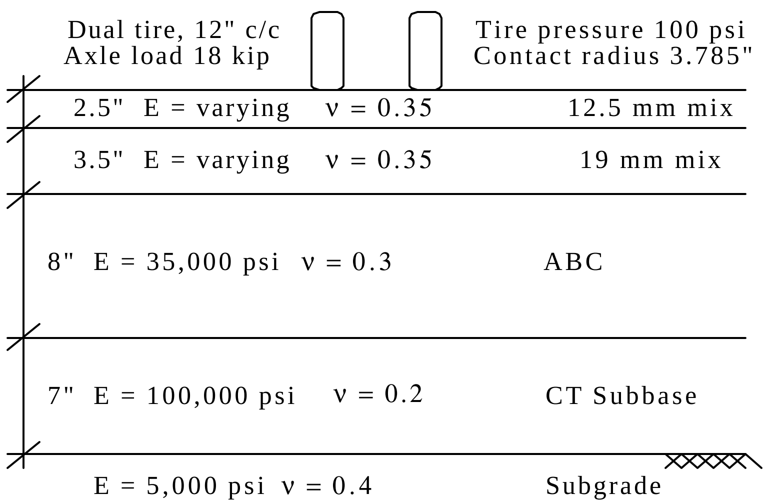


Figure 7-2 Pavement structure for SP 19-mm mix

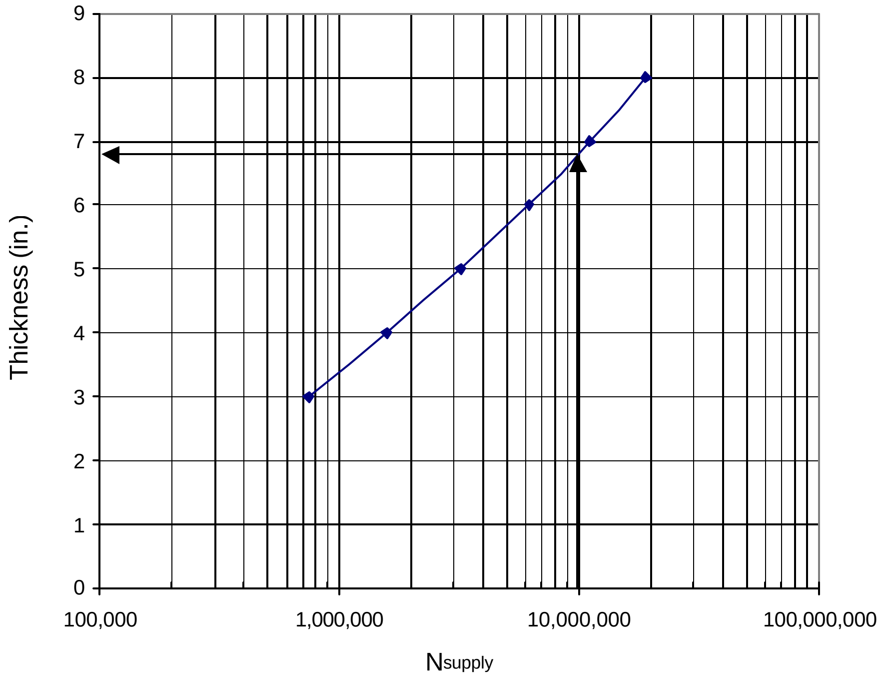


Figure 7-3 Surface layer thickness vs. N_f

8. Summary and conclusions

The primary objectives of this research study were to characterize properties of two NCDOT Superpave mixes, and to develop phenomenological fatigue relationships for these mixes based on various levels of strain, asphalt content, air void content, and temperatures. Of particular importance was the sensitivity of the Superpave mixes to asphalt content and air void content that are usually expected in-situ. This study included laboratory investigation of an SP 12.5-mm and SP 19-mm mixes at moderate temperatures of 15°C, 20°C and 25°C where predominant fatigue cracking is expected to be significant.

Specific work tasks that were considered are the following:

- Verification of the JMF,
- Specimen fabrication for the fatigue and stiffness testing,
- Flexural fatigue testing of beam specimens at 15°C, 20°C and 25°C , and at 3 different strain levels,
- Axial and shear frequency sweep testing,
- Shear frequency sweep testing on field cores, and
- Analysis of test results and development of fatigue and stiffness models along with mechanistic analysis procedure for fatigue distress.

Materials used in this study were the same as those used for the SPS-9A Project 370900, Highway US-1 in Sanford, NC. Based on the raw materials obtained, verification of the JMF was conducted for both SP 12.5-mm and SP 19-mm mixes. It was found that both mixes conformed to the JMF volumetric requirements. Based on the mix design, laboratory specimens were fabricated using a rolling wheel compactor. 2 ft. by 2 ft. slabs were compacted at target air void contents of 4, 6, and 8-percent; and at optimum and optimum minus 0.5-percent asphalt content. Flexure beam specimens (2 in. x 2.5 in. x 15 in.) and core specimens (6 in. diameter x 2 in. height) were then sawn and cored for fatigue testing and for determination of shear stiffness. Prismatic specimens for the axial stiffness testing were obtained by sawing the flexure beam specimens to 6 in. height with a cross section of 2 in. by 2.5 in.

In all, more than 240 fatigue tests and 144 frequency sweep tests were conducted. Statistical analysis of fatigue data indicated the following:

- Both asphalt content and gradation have significant impact on laboratory fatigue life of Superpave SP 12.5-mm and SP 19-mm mixes. On average, change in asphalt content from optimum to optimum minus 0.5-percent decreased the laboratory fatigue life by about 50-percent. For the gradation, 12.5-mm mix appears to be more resistant to fatigue compared to the SP 19-mm mix. This could partly be due to the lower asphalt content in SP 19-mm mixes.
- In general, for the same strain level, increase in temperature increased laboratory fatigue life. This behavior is typical for the controlled-strain mode-of-loading applied in laboratory. However, conventional wisdom generally suggests that fatigue life of in-situ pavement section should increase with decrease in temperature. This was shown to be the case during the mechanistic analysis of typical pavement sections.
- In fatigue testing, strain level had a significant impact on initial stiffness, especially at higher temperature. This result is somewhat expected as high strain levels and high temperatures will induce damage during fatigue testing early on. However, this result is very undesirable as the so-called “initial stiffness” is no longer a true measure of the initial mix property. It is therefore suggested that when conducting laboratory fatigue testing for a given specimen, a two step procedure be followed: first, the initial flexural stiffness should be measured at strain level small enough so as not to induce damage to the specimen; and second, subject the specimen to fatigue testing at the desired strain level.
- Asphalt content or gradation does not seem to have an effect on “initial flexural stiffness” as defined in this study to correspond to 50^{th} loading cycle. This can again be attributed to the damage caused by large strain levels at high temperature that may mask any effect of asphalt content or gradation.

Following fatigue testing, axial and shear frequency sweep testing was conducted. The analysis of the results indicated that both axial and shear stiffness are sensitive to mix parameters and test temperatures, including the asphalt content and gradation. The regression models calibrated for dynamic axial and shear stiffness at 10 Hz are:

$$\left|E^*\right|_{10Hz} = 17.5153\times 10^5 \exp(0.03956\ AC + 0.01256\ GR - 0.31472\ Temp - 0.11671 V_a)$$

$$\left|G^*\right|_{10Hz} = 10.7313\times 10^5 \cdot \exp(-0.04504\cdot AC + 0.05947\cdot GR - 0.34265\cdot Temp - 0.1564\cdot V_a)$$

where,

$|E^*|$ = axial stiffness, and loss stiffness in psi;

$|G^*|$ = shear stiffness, and loss stiffness in psi;

AC = asphalt content: -1 for opt.-0.5%, +1 for opt.;

GR = aggregate gradation: -1 for SP 12.5-mm, +1 for SP 19-mm;

V_a = air void content in percent; and

Temp = test temperature: -1, 0, +1 for 15°C, 0 is 20°C, +1 is 25°C.

The relationship between the dynamic axial and shear stiffness for the mixes considered in this study was found to be the following:

$$\left|E^*\right|_{10Hz} = 37.6\cdot \left|G^*\right|_{10Hz}^{0.78114}$$

Based on the fatigue test results, the laboratory fatigue life model that could be used for pavement analysis is the following:

$$N_f = 1.13\times 10^{-2}\cdot e^{(0.04789VFA - 0.26812GR)}\cdot e_0^{-3.44019}\cdot \left|E^*\right|^{-1.07005}$$

where,

N_f = laboratory fatigue life;

VFA = void filled with asphalt in percent;

ε_0 = initial strain, in./in.;

$|E^*|$ = initial axial stiffness, and loss stiffness;

GR = -1 for 12.5-mm, and 1 for 19-mm gradation; and

e = exponent of the natural logarithm.

Mechanistic analysis of typical pavement sections was conducted to evaluate the effect of mix and temperature variables on pavement fatigue life using the laboratory fatigue relationship developed for NCDOT mixes. The results of the analysis suggest the following:

- Pavement fatigue life based on NCDOT fatigue models is sensitive to the mix variables and test temperatures considered in this study.
- NCDOT fatigue models yield fatigue life similar to those obtained using SHRP fatigue model. However, NCDOT models are sensitive to temperature, whereas the SHRP fatigue model per-se is not sensitive to temperature.
- An increase in temperature results in decrease in fatigue life of pavement section under consideration. A 5°C increase in temperature results in about 25-percent reduction in life. This trend is opposite to the trend shown by laboratory fatigue data where increase in temperature will result in increase in laboratory fatigue life.
- NCDOT mixes are sensitive to asphalt content. A decrease in asphalt content by 0.5-percent (by wt. of mix) results in decrease of 18 to 25-percent fatigue life.
- NCDOT mixes are also sensitive to air void content as expected. An increase in 2-percent air void content will reduce pavement life by about 40-percent for SP 12.5-mm mixes, and by almost 60-percent for SP 19-mm mixes.
- Based on the overall result of analysis, it appears that SP 19-mm mixes are more sensitive to mix variables as compared to the SP 12.5-mm mixes.

References

1. Asphalt Institute. "Superpave Mix Design," Superpave Series No.2 (SP-2).
2. Tayebali, A.A., G.S. Natu, and M.B. Kulkarni. "Comparison of Material Properties and Life of Pavement Sections Containing Mixes With and Without Non-strip Additives," Center for Transportation Engineering Studies, Department of Civil Engineering, North Carolina State University, June 1998.
3. Tayebali, A.A., J.S. Coplantz, J.A. Deacon, F.N. Finn, and C.L. Monismith. "Fatigue Response of Asphalt-Aggregate Mixtures," Report No. SHRP-A-404, Strategic Highway Research Program, National Research Council, Washington, D.C., June 1994.
4. Tayebali, A.A. (1992a). "Surrogate flexural stiffness models based on shear stiffness," Technical memorandum prepared for SHRP Project A-003A. Institute of Transportation Studies, University of California, Berkeley.
5. American Association of State Highway and Transportation Officials. “Standard Test Method for Determining the Permanent Deformation and Fatigue Cracking Characteristics of Hot Mix Asphalt Using a Simple Shear Test Device," AASHTO Designation TP7, (1996).

Bibliography

1. Asphalt Institute (AI). (1981). "Thickness Design-Asphalt Pavement for Highways and Streets," Manual Series No. 1 (MS-1), Lexington, Ky.
2. Asphalt Institute (AI). (1982). "Research and development of the Asphalt Institute's Thickness Design Manual (MS-1), 9th, Ed," Res. Rep 82-2, Lexington, Ky.
3. Baumgaertel, M. and H. H. Winter. “Determination of Discrete Relaxation and Retardation Time Spectra from Dynamic Mechanical Data," Rheol. Acta 28, 511 (1989).
4. Bergan, A.T., and Pulles, B. C. (1973). "Fatigue design procedure for cold climates," Proc., Canadian Technical Asphalt Association, Victoria, B.C, Canada.
5. Brunton, J.M., Brown, S. F., and Pell, P . S. (1987). "Development of the Nottingham analytical design method for asphalt pavements," Proc., 6th Int. Conf. On Structural design of Asphalt Pavements, University of Michigan, Ann Arbor, Mich., International Society for Asphalt Pavements (ISAP), Lexington, Ky., 1, 366-377.
6. Button, J.W., Little, D.N., Kim, Y., and Ahmed, S.J. (1987). "Mechanistic evaluation of selected asphalt mixes," Journal of the Association of Asphalt Paving Technologists, Vol. 56, pp. 62-90.
7. Chomto, G., and P.J. Valayer (1972). "Applied rheology of asphalt mixes," practical applications. Proceedings, Third International Conference on the Structural Design of Asphalt Pavements, London, vol. I, September.
8. Epps, J.A. and Monismith, C.L. (1969). "Influence of mixture variables on the flexural fatigue properties of asphalt concrete," Journal of the Association of Asphalt Paving Technologists, Vol. 38, pp. 423-464.
9. Finn, F., Saraf. C.L., Kulkarni, R., Nair, K., Smith, W. and Abdullah, A. (1986). "Development of pavement structural subsystems," NCHRP Report 291m 59p.
10. H. Henning Winter, Marian Mours. IRIS Version 7.32. Innovative Rheological Interface Software.
11. Harvey, J.T., Deacon, J.A., Tsai, B-W, and Monismith, C.L. (1995). "Fatigue performance of asphalt concrete mixes and its relationship to asphalt concrete pavement performance in California," Report No. RTA No. RTA-65W485-2, Institute of Transportation Studies, University of California at Berkeley.

12. Honerkamp, J. and J. Weese. “Determination of the Relaxation Spectrum by a Regularization Method,” Macromolecules 22, 4372 (1989).

13. Laun, H. M. “Prediction of Elastic Strains of Polymer Melts in Shear and Elongation,” J. Rheol. 30, 459 (1986).

14. Monismith, C.L. (1966b). "Fatigue of asphalt paving mixtures," Paper prepared for presentation at the First Annual Street and Highway Conference, University of Nevada, March.

15. Monismith, C.L., Epps, J.A. and Finn, F.N. (1985) "Improved asphalt mix design," Journal of the Association of Asphalt Paving Technologists, Vol. 54, pp. 347-406.

16. Pell, P.S. (1973). "Characterization of fatigue behavior," Highway Research board Special Report No. 140, National Research Council, Washington, D.C., pp.49-64.

17. Pronk, A.C., and P.C. Hopman (1990). "Energy dissipation: The leading factor of fatigue," Proceedings, United States Strategic highway Research Program-Sharing the Benefits, Oct. 29-31, London.

18. Santucci, L.E. (1977). "Thickness design procedure for asphalt and emulsified asphalt mixes," Proceedings Fourth International Conference on Structural Design of Asphalt pavements, Ann Arbor, Michigan, USA, Vol. 1, pp.424-456.

19. SHRP (1994b). "Fatigue response of asphalt-aggregate mixes," SHRP A 404, Strategic Highway Research Program, Washington, D.C.

20. Tangella, R., J.A. Deacon, and C.L. Monismith (1990). "Summary report of fatigue response of asphalt mixtures," Technical Memorandum No. TM-UCB-A-003A-89-3M, prepared for SHRP Project A-003A. Institute of Transportation Studies, University of California, Berkeley.

21. Tanner RI (1968). Journal of Applied Polymer Science, 12: 1649.

22. Tayebali, A.A., Deacon J.A., Coplantz, J.S., and Monismith, C.L. (1993). "Modeling fatigue response for asphalt-aggregate mixtures," Journal of the Association of Asphalt Paving Technologists, Vol. 63, pp. 385-421.

23. Thompson, M.R. (1987). "ILLI-Pave based full-depth asphalt pavement design procedure," Proc., 6th Int. Conf. On Structural design of Asphalt Pavements, University of Michigan, Ann Arbor, Mich.

24. Timm, D., Birgisson, B., and Newcomb, D. (1998). "Development of mechanistic-empirical pavement design in Minnesota," Transportation Research Record 1629, Transportation Research Board, Washington, D.C., 181-188.

25. Van Dijk, W. (1975). "Practical fatigue characterization of bituminous mixes," Proceedings, Association of Asphalt Paving Technologists, vol. 44, AZ, February.

26. Van Dijk, W., and W. Visser (1977). "The energy approach to fatigue for pavement design,' Proceedings, Association of Asphalt Paving Technologists, San Antonio, TX, February.

Appendix A.

CORRECTED COPY

NORTH CAROLINA DEPARTMENT OF TRANSPORATION
RALEIGH, NORTH CAROLINA 27611

SUPERPAVE HOT MIX ASPHALT JOB MIX FORMULA

LEE PAVING COMPANY	TYPE MIX: ACBC, TYPE SP 12.5
SANFORD NC	JOB MIX FORM NO: 97-442-021
	EFFECTIVE DATE: 05-09-97
PLANT CERTIFICATION NO.: B-033	PROJECT NO: 6.549001T
	COUNTY: LEE-CHATHAM

AGGREGATE SOURCES AND BLEND PERCENTAGES

SUPPLIER	LOCATION/SOURCE	MATERIAL	BLEND (%)
MARTIN MARIETTA	LEMON SPRINGS QUARRY	#67	15.0
MARTIN MARIETTA	LEMON SPRINGS QUARRY	#78M	55.0
MARTIN MARIETTA	LEMON SPRINGS QUARRY	REG. SCRGS.	20.0
LEE PAVING COMPANY	RAMBEAUT PIT	N. SAND	10.0
		TOTAL	100.0%

JMF COMBINED GRADATION

SIEVE SIZE		% PASSING
2 "	(50.0 mm)	
1 1/2"	(37.5 mm)	
1"	(25.0 mm)	
3/4"	(19.0 mm)	100
1/2"	(12.5 mm)	94
3/8"	(9.5 mm)	84
No. 4	(4.75 mm)	43
No. 8	(2.36 mm)	29
No. 16	(1.18 mm)	23
No. 30	(0.600 mm)	17
No. 50	(0.300 mm)	9
No. 100	(0.150 mm)	7
No. 200	(0.075 mm)	4.4

*ASPHALT BINDER % (TOT)	5.2
GRADE	PG 64-22
MAX. SP. GR.	2.464
GYRATORY SP. GR.: $G_{mb}@N_d$	2.356
VOIDS IN TOTAL MIX %	4.0
VOIDS IN MIN. AGG. %	14.8
VOIDS FILLED W/ASPH %	73
MIN. % COMPACTION % G_{mm}	92.0
MIX TEMPERATURE F.	300
NON-STRIP ADDITIVE %	0.25
MODIFIER %	0.00
$N_{ini}/N_{des}/N_{max}$	8/106/169

ASPHALT CEMENT SUPPLIER : CITGO WILMINGTON
TACK COAT SUPPLIER : SEACO, COLUMBIA, SC CRS-1
NON-STRIP ADD. SUPPLIER : AD-HERE - ARR MAZ LOF 65-00
COMMENTS:

APPROVED BY:
J. E. GRADY, JR., PE
PAVEMENT CONSTRUCTION ENGINEER

DATE JMF VOID:

CORRECTED COPY

NORTH CAROLINA DEPARTMENT OF TRANSPORATION
RALEIGH, NORTH CAROLINA 27611

SUPERPAVE HOT MIX ASPHALT JOB MIX FORMULA

LEE PAVING COMPANY

SANFORD NC

PLANT CERTIFICATION NO.: B-033

TYPE MIX: ACBC, TYPE SP 19.0

JOB MIX FORM NO: 97-441-021

EFFECTIVE DATE: 05-09-97

PROJECT NO: 6.549001T

COUNTY: LEE-CHATHAM

AGGREGATE SOURCES AND BLEND PERCENTAGES

SUPPLIER	LOCATION/SOURCE	MATERIAL	BLEND (%)
MARTIN MARIETTA	LEMON SPRINGS QUARRY	#67	50.0
MARTIN MARIETTA	LEMON SPRINGS QUARRY	#78M	22.0
MARTIN MARIETTA	LEMON SPRINGS QUARRY	REG. SCRGS.	18.0
LEE PAVING COMPANY	RAMBEAUT PIT	N. SAND	10.0

TOTAL 100.0%

JMF COMBINED GRADATION

SIEVE SIZE		% PASSING
2 "	(50.0 mm)	
1 1/2"	(37.5 mm)	
1"	(25.0 mm)	100
3/4"	(19.0 mm)	99
1/2"	(12.5 mm)	80
3/8"	(9.5 mm)	62
No. 4	(4.75 mm)	35
No. 8	(2.36 mm)	27
No. 16	(1.18 mm)	22
No. 30	(0.600 mm)	16
No. 50	(0.300 mm)	9
No. 100	(0.150 mm)	6
No. 200	(0.075 mm)	4.2

*ASPHALT BINDER % (TOT)	4.7
GRADE	PG 64-22
MAX. SP. GR.	2.483
GYRATORY SP. GR.: $G_{mb}@N_d$	2.384
VOIDS IN TOTAL MIX %	4.0
VOIDS IN MIN. AGG. %	14.0
VOIDS FILLED W/ASPH %	70
MIN. % COMPACTION % G_{mm}	92.0
MIX TEMPERATURE F.	300
NON-STRIP ADDITIVE %	0.25
MODIFIER %	0.00
$N_{ini}/N_{des}/N_{max}$	8/106/169

ASPHALT CEMENT SUPPLIER : CITGO WILMINGTON
TACK COAT SUPPLIER : SEACO, COLUMBIA, SC CRS-1
NON-STRIP ADD. SUPPLIER : AD-HERE - ARR MAZ LOF 65-00
COMMENTS:

APPROVED BY:
J. E. GRADY, JR., PE
PAVEMENT CONSTRUCTION ENGINEER

DATE JMF VOID:

Appendix B. Fatigue test data

Nomenclature:

AC = Asphalt content.	-1 = optimum minus 0.5% asphalt content;
	1 = optimum asphalt content;
GR = Gradation.	-1 = SP 12.5-mm mix;
	1 = SP19-mm mix.
RT = Replicates.	-1 = one replicate;
	1 = two replicates.
Temp = Temperature.	-1 = 15°C; and
	0 = 20°C, and
	1 = 25°C.

AC	GR	RT	Temp	Air void	Strain	|E*|	Phase Angle	E"	Fatigue life	VFA	$V_b/(V_a+V_b)$
				%	in/in	psi	degree	psi	cycles	%	
1	-1	-1	-1	7.62	2.38E-04	1013348	22.72	391405	522000	50.55	0.611
1	-1	1	-1	7.87	2.73E-04	983863	23.29	388992	238955	49.44	0.603
1	-1	-1	-1	7.98	3.60E-04	971427	23.53	387852	81052	48.50	0.600
1	-1	1	-1	7.87	4.70E-04	983749	23.29	388982	29811	48.87	0.603
1	-1	-1	-1	7.67	5.77E-04	1006864	22.85	390909	19481	50.61	0.609
1	-1	1	-1	7.73	5.78E-04	999838	22.98	390350	15502	50.22	0.607
1	-1	-1	-1	4.98	5.94E-04	1378538	16.44	390145	18500	67.67	0.706
1	-1	1	-1	5.17	5.98E-04	1348778	16.91	392259	25500	66.81	0.698
1	-1	-1	-1	5.09	3.89E-04	1361589	16.71	391390	81052	67.18	0.702
1	-1	1	-1	4.97	3.65E-04	1379826	16.42	390046	115000	67.70	0.707
1	-1	-1	-1	5.13	3.39E-04	1354615	16.82	391871	274000	66.97	0.700
1	-1	1	-1	5.13	2.86E-04	1354615	16.82	391871	255909	66.97	0.700
1	-1	-1	-1	3.65	1.92E-04	1610022	13.02	362758	590000	74.33	0.769
1	-1	-1	-1	3.79	3.22E-04	1584854	13.38	366639	112500	73.60	0.762
1	-1	-1	-1	3.65	3.90E-04	1610022	13.02	362758	100002	74.33	0.769
1	-1	1	-1	3.76	4.00E-04	1590412	13.30	365800	67000	73.76	0.764
1	-1	-1	-1	3.88	5.80E-04	1567379	13.62	369208	30000	73.10	0.757
1	-1	1	-1	3.79	6.31E-04	1584854	13.38	366639	7500	73.60	0.762
-1	-1	-1	-1	8.18	2.00E-04	876412	25.45	376679	144273	54.08	0.561
-1	-1	1	-1	7.79	2.22E-04	917440	24.61	382046	800000	55.40	0.574
-1	-1	-1	-1	8.37	2.43E-04	857392	25.85	373904	142047	53.46	0.555
-1	-1	1	-1	8.50	2.87E-04	845073	26.12	372008	83504	53.06	0.551
-1	-1	-1	-1	8.18	3.07E-04	876412	25.45	376679	72500	54.08	0.561
-1	-1	1	-1	8.50	3.15E-04	845073	26.12	372008	82000	53.06	0.551
-1	-1	-1	-1	8.18	3.43E-04	876412	25.45	376679	50000	54.08	0.561
-1	-1	-1	-1	8.62	4.56E-04	832834	26.38	370046	13705	52.67	0.547
-1	-1	-1	-1	7.97	5.26E-04	898787	24.99	379710	9453	54.80	0.568
-1	-1	-1	-1	6.12	2.52E-04	1114609	20.85	396681	290000	61.67	0.636
-1	-1	1	-1	5.52	2.66E-04	1195459	19.43	397686	180000	64.23	0.661
-1	-1	-1	-1	6.42	2.77E-04	1077013	21.53	395256	145002	60.48	0.624
-1	-1	1	-1	6.24	2.79E-04	1099236	21.13	396173	147000	61.19	0.631
-1	-1	-1	-1	5.52	3.15E-04	1195459	19.43	397686	110000	64.23	0.661
-1	-1	-1	-1	6.42	3.81E-04	1077013	21.53	395256	40000	60.48	0.624
-1	-1	1	-1	6.24	4.12E-04	1099621	21.12	396187	37000	61.20	0.631
-1	-1	-1	-1	6.50	6.76E-04	1067253	21.71	394784	2000	60.17	0.621
-1	-1	-1	-1	4.34	1.83E-04	1372451	16.54	390605	350000	69.99	0.715
-1	-1	1	-1	4.32	2.02E-04	1376140	16.48	390328	340000	69.94	0.716
-1	-1	-1	-1	4.32	2.05E-04	1376140	16.48	390328	205000	69.94	0.716
-1	-1	1	-1	4.50	2.85E-04	1347060	16.93	392371	135000	68.99	0.707
-1	-1	-1	-1	4.50	4.01E-04	1347060	16.93	392371	32000	69.02	0.707
-1	-1	-1	-1	4.34	4.81E-04	1372451	16.54	390605	14000	69.99	0.715
-1	-1	1	-1	4.86	5.28E-04	1291635	17.82	395368	8000	67.25	0.690
-1	-1	-1	-1	4.50	6.55E-04	1347060	16.93	392371	5000	68.99	0.707
1	1	-1	-1	4.90	1.90E-04	1426533	15.70	386040	260000	66.72	0.689
1	1	1	-1	4.46	2.14E-04	1502053	14.57	377885	270000	68.88	0.710
1	1	-1	-1	4.36	2.40E-04	1518977	14.32	375779	720000	69.37	0.715
1	1	-1	-1	4.63	3.46E-04	1472373	15.01	381333	15002	68.03	0.702

(Continued)

AC	GR	RT	Temp	Air void	Strain	|E*|	Phase Angle	E'	Fatigue life	VFA	$V_b/(V_a+V_b)$
					in/in	psi	degree	psi	cycles	%	
1	1	1	-1	4.43	3.51E-04	1507849	14.49	377175	80001	69.05	0.712
1	1	-1	-1	4.62	4.04E-04	1474437	14.98	381104	27500	68.09	0.703
1	1	1	-1	4.94	4.40E-04	1420718	15.79	386583	17500	66.55	0.688
1	1	1	-1	4.51	4.60E-04	1492791	14.71	378994	14501	68.62	0.708
1	1	-1	-1	5.74	2.22E-04	1294223	17.78	395254	160000	62.94	0.653
1	1	-1	-1	5.50	2.77E-04	1330988	17.19	393362	75600	64.41	0.663
1	1	1	-1	5.87	2.79E-04	1274438	18.11	396054	240000	62.37	0.647
1	1	-1	-1	5.74	3.26E-04	1293317	17.80	395294	102500	62.91	0.653
1	1	1	-1	5.97	3.30E-04	1260091	18.34	396537	41000	61.63	0.644
1	1	-1	-1	5.31	4.04E-04	1360038	16.73	391499	37500	64.82	0.671
1	1	1	-1	5.74	4.30E-04	1294223	17.78	395254	9200	62.94	0.653
1	1	-1	-1	5.88	4.42E-04	1272060	18.14	396140	13500	62.31	0.647
1	1	1	-1	5.75	4.86E-04	1292111	17.82	395347	16000	62.88	0.652
1	1	-1	-1	6.56	1.95E-04	1175831	19.77	397696	550000	59.55	0.620
1	1	1	-1	6.64	2.14E-04	1164768	19.96	397630	320000	59.24	0.617
1	1	-1	-1	6.81	2.53E-04	1141619	20.37	397326	185002	58.57	0.610
1	1	1	-1	6.58	3.18E-04	1172269	19.83	397680	125002	59.45	0.619
1	1	-1	-1	6.73	3.60E-04	1153135	20.16	397506	32002	58.90	0.613
1	1	1	-1	6.71	3.97E-04	1154886	20.13	397528	47000	58.95	0.614
1	1	-1	-1	7.07	4.10E-04	1107885	20.97	396472	57500	57.60	0.601
1	1	1	-1	6.80	4.18E-04	1142552	20.35	397342	27000	58.60	0.610
1	1	-1	-1	6.73	5.38E-04	1153135	20.16	397506	10000	58.90	0.613
-1	1	-1	-1	4.20	1.70E-04	1431216	15.63	385594	350000	69.25	0.700
-1	1	1	-1	4.41	1.89E-04	1396075	16.17	388744	400000	68.14	0.689
-1	1	-1	-1	5.23	1.95E-04	1268958	18.20	396248	140000	61.67	0.652
-1	1	1	-1	4.33	2.16E-04	1409665	15.96	387580	180000	68.57	0.693
-1	1	-1	-1	4.08	2.30E-04	1451571	15.32	383563	85000	69.89	0.706
-1	1	-1	-1	4.17	4.31E-04	1436403	15.55	385091	27000	69.41	0.702
-1	1	-1	-1	3.70	6.81E-04	1517219	14.35	376002	3500	71.99	0.727
-1	1	-1	-1	4.13	8.80E-04	1442620	15.46	384475	350	69.61	0.704
-1	1	-1	-1	7.08	1.54E-04	1021698	22.56	392015	285000	56.40	0.573
-1	1	1	-1	6.58	1.76E-04	1083725	21.41	395556	600000	58.34	0.592
-1	1	-1	-1	6.83	2.60E-04	1053053	21.97	394022	142000	56.80	0.583
-1	1	1	-1	6.66	2.62E-04	1074155	21.58	395122	185001	58.04	0.589
-1	1	-1	-1	6.83	2.81E-04	1053053	21.97	394022	185000	57.38	0.583
-1	1	1	-1	6.78	3.03E-04	1058845	21.87	394344	32000	57.56	0.584
-1	1	-1	-1	6.87	3.10E-04	1047537	22.08	393701	57500	57.21	0.581
-1	1	-1	-1	6.58	6.39E-04	1083725	21.41	395556	9500	58.34	0.592
-1	1	1	-1	6.68	6.67E-04	1071151	21.64	394978	2700	57.95	0.588
-1	1	-1	-1	9.50	1.59E-04	770662	27.75	358863	286000	47.47	0.494
-1	1	1	-1	9.39	1.66E-04	780893	27.52	360846	110000	48.77	0.497
-1	1	-1	-1	9.41	1.86E-04	778799	27.57	360445	210000	48.70	0.496
-1	1	1	-1	9.67	2.19E-04	755610	28.09	355843	230001	47.96	0.489
-1	1	-1	-1	9.59	2.46E-04	762787	27.93	357299	180000	48.19	0.491
-1	1	-1	-1	9.27	3.52E-04	792091	27.27	362951	23000	49.13	0.500
-1	1	1	-1	8.63	3.67E-04	853422	25.94	373301	8750	51.09	0.520
1	-1	-1	0	4.06	2.43E-04	1120259	20.75	396842	537500	72.15	0.748
1	-1	1	0	3.84	2.85E-04	1149798	20.22	397459	535000	73.31	0.759
1	-1	-1	0	3.82	3.59E-04	1152889	20.17	397502	180000	73.44	0.761
1	-1	-1	0	4.28	4.05E-04	1091607	21.26	395883	130000	71.02	0.738
1	-1	1	0	3.76	4.29E-04	1160990	20.03	397596	125000	73.76	0.764

(Continued)

AC	GR	RT	Temp	Air void	Strain	|E*|	Phase Angle	E"	Fatigue life	VFA	$V_b/(V_a+V_b)$
					in/in	psi	degree	psi	cycles	%	
1	-1	-1	0	5.43	2.33E-04	954502	23.87	386183	385000	66.76	0.685
1	-1	1	0	6.29	2.43E-04	863651	25.72	374837	100000	62.03	0.652
1	-1	-1	0	6.29	2.61E-04	863651	25.72	374837	42000	61.51	0.653
1	-1	1	0	6.30	2.94E-04	862342	25.75	374644	435000	61.98	0.652
1	-1	-1	0	6.32	3.43E-04	860833	25.78	374420	185000	61.92	0.651
1	-1	1	0	5.43	3.48E-04	954502	23.87	386183	130000	66.76	0.685
1	-1	-1	0	5.76	3.67E-04	918760	24.58	382205	260000	64.21	0.673
1	-1	1	0	5.09	3.90E-04	993951	23.09	389863	80000	67.18	0.702
1	-1	-1	0	6.27	6.86E-04	865972	25.67	375179	10500	62.12	0.653
1	-1	1	0	5.99	7.38E-04	894739	25.07	379180	11000	63.26	0.664
1	-1	-1	0	8.31	2.41E-04	682342	29.82	339330	1500000	54.75	0.582
1	-1	1	0	8.18	3.26E-04	692855	29.57	341887	135002	55.18	0.586
1	-1	-1	0	8.30	3.61E-04	683139	29.80	339526	131800	54.78	0.582
1	-1	1	0	8.10	3.76E-04	698865	29.42	343321	92500	55.43	0.588
1	-1	-1	0	8.49	5.24E-04	668079	30.17	335756	25000	54.17	0.576
1	-1	1	0	8.22	5.65E-04	689547	29.65	341089	16500	55.05	0.584
-1	-1	-1	0	4.46	1.77E-04	987946	23.21	389350	648607	69.21	0.709
-1	-1	1	0	5.04	2.48E-04	923391	24.49	382756	339612	66.42	0.682
-1	-1	-1	0	4.48	2.67E-04	985873	23.25	389170	185002	69.13	0.708
-1	-1	1	0	4.46	2.82E-04	987946	23.21	389350	145000	69.21	0.709
-1	-1	-1	0	4.04	3.88E-04	1037459	22.26	393080	75000	71.37	0.730
-1	-1	1	0	4.56	3.89E-04	976825	23.43	388356	42500	68.73	0.705
-1	-1	-1	0	4.18	5.38E-04	1021003	22.58	391966	27000	70.65	0.723
-1	-1	1	0	4.32	5.82E-04	1003870	22.90	390674	12500	69.91	0.716
-1	-1	-1	0	6.54	2.47E-04	775187	27.65	359747	410000	61.38	0.618
-1	-1	1	0	6.41	2.60E-04	787222	27.38	362044	365002	64.05	0.620
-1	-1	-1	0	6.50	2.70E-04	779087	27.56	360500	230000	62.99	0.618
-1	-1	1	0	6.64	2.85E-04	766372	27.85	358015	120000	62.22	0.612
-1	-1	-1	0	6.62	3.29E-04	767714	27.82	358282	125000	63.64	0.611
-1	-1	1	0	6.60	3.38E-04	769778	27.77	358690	87000	62.17	0.614
-1	-1	-1	0	6.47	7.28E-04	781090	27.52	360884	3700	62.68	0.619
-1	-1	-1	0	7.65	2.55E-04	680599	29.86	338899	400000	53.02	0.582
-1	-1	1	0	7.76	2.57E-04	671917	30.08	336729	308000	52.67	0.578
-1	-1	-1	0	8.62	2.93E-04	607963	31.69	319358	140000	47.51	0.552
-1	-1	1	0	7.90	3.03E-04	661568	30.33	334085	138889	51.96	0.574
-1	-1	-1	0	7.88	3.94E-04	662804	30.30	334404	37000	51.68	0.575
-1	-1	-1	0	7.19	5.84E-04	718556	28.96	347872	14000	56.03	0.597
-1	-1	1	0	7.44	5.89E-04	697730	29.45	343052	12002	54.16	0.589
1	1	-1	0	4.84	2.18E-04	1049412	22.04	393812	230000	67.03	0.692
1	1	1	0	4.13	3.01E-04	1140075	20.39	397297	120000	70.60	0.727
1	1	-1	0	4.37	4.00E-04	1107937	20.97	396474	70000	69.33	0.715
1	1	1	0	4.09	4.09E-04	1145009	20.31	397385	90000	70.79	0.729
1	1	-1	0	4.28	5.77E-04	1119636	20.76	396825	6002	69.79	0.719
1	1	1	0	4.04	6.39E-04	1151710	20.19	397486	8000	71.06	0.731
1	1	-1	0	5.67	2.53E-04	951636	23.92	385887	180000	63.21	0.655
1	1	1	0	5.43	2.64E-04	979125	23.38	388566	136065	64.80	0.665
1	1	-1	0	5.68	2.89E-04	951302	23.93	385852	93000	63.45	0.655
1	1	1	0	5.80	3.80E-04	938182	24.19	384444	25000	62.42	0.651
1	1	-1	0	5.68	4.93E-04	951080	23.93	385829	16000	62.64	0.656
1	1	1	0	5.68	5.14E-04	951302	23.93	385852	12000	63.19	0.655
1	1	-1	0	6.43	2.20E-04	870861	25.57	375888	550000	59.87	0.625

(Continued)

AC	GR	RT	Temp	Air void	Strain	$\lvert E^* \rvert$	Phase Angle	E''	Fatigue life	VFA	$V_b/(V_a+V_b)$
					in/in	psi	degree	psi	cycles	%	
1	1	1	0	6.49	2.70E-04	865289	25.69	375078	135000	59.72	0.623
1	1	-1	0	6.38	3.03E-04	876469	25.45	376687	87000	60.26	0.627
1	1	1	0	6.41	3.54E-04	873712	25.51	376296	70000	60.16	0.626
1	1	-1	0	6.44	3.77E-04	870048	25.59	375771	41000	60.12	0.624
1	1	1	0	6.36	4.66E-04	878825	25.40	377018	15500	60.53	0.627
-1	1	-1	0	4.46	2.38E-04	1012841	22.73	391367	280000	67.86	0.686
-1	1	1	0	4.07	2.88E-04	1060750	21.83	394446	105000	69.94	0.707
-1	1	-1	0	4.93	3.00E-04	959115	23.77	386652	64000	65.55	0.664
-1	1	1	0	3.70	3.62E-04	1107560	20.97	396461	33000	71.99	0.727
-1	1	-1	0	4.34	5.26E-04	1027606	22.45	392427	9000	68.50	0.693
-1	1	1	0	3.92	6.76E-04	1078854	21.50	395340	6002	70.73	0.715
-1	1	-1	0	6.53	1.73E-04	795464	27.20	363572	385000	58.53	0.594
-1	1	-1	0	6.59	2.00E-04	790374	27.31	362633	475000	58.31	0.592
-1	1	1	0	6.36	2.02E-04	811593	26.84	366457	115000	59.22	0.601
-1	1	-1	0	6.57	2.72E-04	791943	27.28	362924	77000	58.38	0.592
-1	1	1	0	6.56	2.83E-04	792961	27.25	363112	61000	58.42	0.593
-1	1	-1	0	5.92	5.34E-04	854658	25.91	373490	5500	61.06	0.619
-1	1	1	0	6.52	6.50E-04	796578	27.17	363776	5000	58.68	0.594
-1	1	-1	0	8.91	1.75E-04	602681	31.83	317811	210000	50.20	0.511
-1	1	-1	0	9.12	2.26E-04	588158	32.21	313469	100000	49.57	0.505
-1	1	1	0	9.57	2.80E-04	558131	33.01	304067	70000	48.24	0.491
-1	1	-1	0	8.91	4.38E-04	602752	31.82	317832	8000	50.21	0.511
-1	1	1	0	8.99	4.40E-04	597429	31.96	316256	6500	49.98	0.509
1	-1	-1	1	4.12	7.65E-04	811791	26.84	366491	13500	71.82	0.745
1	-1	1	1	4.24	7.40E-04	800454	27.09	364479	9500	71.56	0.739
1	-1	-1	1	3.84	4.36E-04	839639	26.23	371147	90000	73.33	0.760
1	-1	-1	1	6.12	3.51E-04	643018	30.79	329185	220000	62.71	0.659
1	-1	1	1	6.42	3.98E-04	621184	31.35	323152	150000	60.97	0.648
1	-1	-1	1	6.27	5.33E-04	632154	31.07	326220	33000	60.42	0.655
1	-1	1	1	5.22	5.48E-04	714068	29.06	346854	60000	66.56	0.696
1	-1	-1	1	5.64	6.72E-04	679830	29.88	338709	22000	64.71	0.678
1	-1	1	1	5.62	6.84E-04	681658	29.84	339161	15000	64.80	0.679
1	-1	-1	1	7.33	3.06E-04	558658	33.00	304237	317600	58.11	0.614
1	-1	1	1	6.91	3.15E-04	586656	32.25	313012	310000	59.65	0.629
1	-1	-1	1	7.19	3.50E-04	567596	32.75	307093	325000	58.61	0.619
1	-1	1	1	7.40	3.71E-04	553854	33.13	302680	200000	57.86	0.612
1	-1	-1	1	7.29	5.68E-04	561010	32.93	304993	75000	58.24	0.616
1	-1	-1	1	6.70	1.24E-03	600791	31.87	317253	4500	60.42	0.637
-1	-1	-1	1	3.68	2.75E-04	790297	27.31	362618	220000	73.33	0.749
-1	-1	1	1	3.90	3.36E-04	769814	27.77	358697	180000	72.11	0.737
-1	-1	-1	1	3.97	4.02E-04	763907	27.91	357523	80000	71.76	0.734
-1	-1	1	1	3.98	4.15E-04	763105	27.92	357363	40000	71.71	0.733
-1	-1	-1	1	3.74	4.43E-04	784324	27.45	361498	55000	72.98	0.746
-1	-1	1	1	4.10	4.59E-04	751790	28.18	355057	25000	71.03	0.727
-1	-1	-1	1	6.10	2.81E-04	595491	32.01	315678	310000	61.77	0.637
-1	-1	1	1	5.86	3.01E-04	612407	31.57	320645	260000	62.77	0.646
-1	-1	-1	1	6.46	3.70E-04	571190	32.66	308227	85000	60.32	0.623
-1	-1	1	1	5.89	4.32E-04	610409	31.62	320068	50000	62.65	0.645
-1	-1	-1	1	6.11	5.77E-04	594797	32.03	315470	25000	61.72	0.636
-1	-1	1	1	6.04	6.21E-04	599676	31.90	316923	20000	62.01	0.639
-1	-1	-1	1	7.03	2.00E-04	534303	33.67	296190	668000	58.12	0.601

(Continued)

AC	GR	RT	Temp	Air void	Strain	|E*|	Phase Angle	E''	Fatigue life	VFA	$V_b/(V_a+V_b)$
					in/in	psi	degree	psi	cycles	%	
-1	-1	1	1	7.62	2.70E-04	499041	34.66	283839	560000	56.01	0.580
-1	-1	-1	1	7.17	3.06E-04	525644	33.91	293234	174000	57.61	0.596
-1	-1	1	1	7.08	3.31E-04	531318	33.75	295177	160000	57.94	0.599
-1	-1	-1	1	6.83	3.40E-04	546922	33.32	300408	155000	58.87	0.608
-1	-1	-1	1	7.09	5.93E-04	530575	33.77	294924	20000	57.90	0.599
-1	-1	1	1	7.00	6.31E-04	536177	33.61	296823	11500	58.25	0.602
1	1	-1	1	3.55	3.00E-04	890118	25.17	378566	585000	73.73	0.757
1	1	1	1	3.44	3.00E-04	901409	24.94	380049	750000	75.84	0.761
1	1	-1	1	3.96	5.67E-04	848825	26.04	372594	55000	71.49	0.735
1	1	1	1	3.52	5.72E-04	893344	25.10	378996	51000	73.91	0.758
1	1	-1	1	4.33	5.86E-04	813141	26.81	366726	25000	69.57	0.717
1	1	1	1	3.54	5.96E-04	891262	25.15	378719	5500	73.80	0.757
1	1	-1	1	6.14	2.10E-04	657992	30.42	333156	720000	61.24	0.636
1	1	1	1	6.14	2.40E-04	658222	30.41	333216	685000	61.25	0.636
1	1	-1	1	6.15	2.79E-04	657147	30.44	332936	350000	61.19	0.636
1	1	1	1	6.00	2.83E-04	668753	30.15	335928	300000	61.82	0.642
1	1	-1	1	5.67	2.98E-04	695418	29.51	342501	567000	47.51	0.668
1	1	-1	1	5.21	4.13E-04	733345	28.61	351145	135000	65.27	0.676
1	1	1	1	5.69	4.14E-04	693068	29.56	341938	197000	63.12	0.655
1	1	-1	1	5.41	6.02E-04	716425	29.01	347390	5500	64.36	0.667
1	1	1	1	6.33	6.18E-04	643486	30.78	329312	4000	60.46	0.629
1	1	-1	1	5.49	6.60E-04	710181	29.15	345963	12502	64.04	0.663
1	1	1	1	6.13	6.60E-04	658452	30.41	333276	16000	61.26	0.637
1	1	-1	1	5.74	7.00E-04	689759	29.64	341141	19000	62.94	0.653
-1	1	-1	1	3.70	2.18E-04	808417	26.91	365900	610000	71.98	0.727
-1	1	1	1	3.86	2.58E-04	793276	27.25	363170	482000	71.07	0.718
-1	1	-1	1	3.82	3.77E-04	797174	27.16	363884	70000	71.31	0.720
-1	1	-1	1	3.82	4.59E-04	797360	27.16	363918	45000	71.32	0.720
-1	1	1	1	3.92	4.80E-04	787832	27.37	362158	25000	70.75	0.715
-1	1	-1	1	4.81	2.52E-04	709857	29.16	345889	300000	66.12	0.669
-1	1	-1	1	5.16	3.04E-04	681524	29.84	339128	80000	64.48	0.653
-1	1	1	1	5.12	3.50E-04	684473	29.77	339853	105000	64.62	0.654
-1	1	-1	1	4.80	4.24E-04	711100	29.13	346175	48750	66.19	0.670
-1	1	1	1	4.79	5.49E-04	711349	29.13	346232	14500	66.21	0.670
-1	1	-1	1	7.34	2.66E-04	528488	33.83	294211	270000	55.46	0.563
-1	1	1	1	7.80	2.70E-04	500805	34.61	284477	281000	53.83	0.547
-1	1	-1	1	7.29	3.03E-04	531767	33.74	295330	85000	55.66	0.565
-1	1	1	1	7.18	3.41E-04	538387	33.55	297566	52500	55.87	0.569
-1	1	-1	1	7.45	5.50E-04	521990	34.01	291972	4000	55.08	0.560
-1	1	1	1	7.27	5.50E-04	532575	33.71	295604	3800	55.70	0.566
-1	1	-1	1	7.79	6.00E-04	501682	34.59	284793	7500	53.88	0.548

Appendix C. Adjusted fatigue data based on GLM

Nomenclature:

AC = Asphalt content.	-1 = optimum minus 0.5% asphalt content; 1 = optimum asphalt content;
GR = Gradation.	-1 = SP 12.5-mm mix; 1 = SP19-mm mix.
RT = Replicates.	-1 = one replicate; 1 = two replicates.
Temp = Temperature.	-1 = 15°C; and 0 = 20°C, and 1 = 25°C.

Adjusted data for SP 12.5-mm with optimum asphalt content

AC	GR	Temp	Air void	Strain	N_f	S_0	S_0''
			%	in/in	cycles	psi	psi
1	-1	-1	4	0.0002	741774	1432455	646546
1	-1	-1	4	0.0004	59707	1249183	557825
1	-1	-1	4	0.0006	13676	1153026	511703
1	-1	-1	6	0.0002	730511	1143038	528924
1	-1	-1	6	0.0004	58800	996795	456343
1	-1	-1	6	0.0006	13468	920065	418570
1	-1	-1	8	0.0002	719420	912187	432657
1	-1	-1	8	0.0004	57907	795479	373286
1	-1	-1	8	0.0006	13263	734246	342422
1	-1	0	4	0.0002	1194813	1091867	549300
1	-1	0	4	0.0004	92513	952171	482434
1	-1	0	4	0.0006	20715	878877	447173
1	-1	0	6	0.0002	1176554	871264	449324
1	-1	0	6	0.0004	91108	759792	394668
1	-1	0	6	0.0006	20398	701306	365785
1	-1	0	8	0.0002	1158689	695231	367581
1	-1	0	8	0.0004	89725	606282	322836
1	-1	0	8	0.0006	20088	559669	299240
1	-1	1	4	0.0002	1924352	832177	466634
1	-1	1	4	0.0004	143344	725706	417233
1	-1	1	4	0.0006	31373	669911	390780
1	-1	1	6	0.0002	1895134	664108	381742
1	-1	1	6	0.0004	141153	579140	341294
1	-1	1	6	0.0006	30897	534560	319688
1	-1	1	8	0.0002	1866359	529930	312263
1	-1	1	8	0.0004	139010	462129	279205
1	-1	1	8	0.0006	30427	426556	261503

Adjusted data for SP 12.5-mm with optimum minus 0.5-percent asphalt content

AC	GR	Temp	Air void	Strain	N_f	S_0	S_0''
			%	in/in	cycles	psi	psi
-1	-1	-1	4	0.0002	399832	1563285	739922
-1	-1	-1	4	0.0004	32183	1363274	635140
-1	-1	-1	4	0.0006	7372	1258461	580880
-1	-1	-1	6	0.0002	393761	1247560	605252
-1	-1	-1	6	0.0004	31695	1087944	519540
-1	-1	-1	6	0.0006	7259	1004198	475157
-1	-1	-1	8	0.0002	387744	995500	495142
-1	-1	-1	8	0.0004	31213	868133	425024
-1	-1	-1	8	0.0006	7149	801307	388714
-1	-1	0	4	0.0002	643965	1191591	628568
-1	-1	0	4	0.0004	49866	1039136	549300
-1	-1	0	4	0.0006	11165	959147	507626
-1	-1	0	6	0.0002	634188	950934	514217
-1	-1	0	6	0.0004	49104	829269	449324
-1	-1	0	6	0.0006	10995	765435	415235
-1	-1	0	8	0.0002	624558	758805	420626
-1	-1	0	8	0.0004	48359	661721	367581
-1	-1	0	8	0.0006	10828	610785	339694
-1	-1	1	4	0.0002	1037267	908273	534026
-1	-1	1	4	0.0004	77258	792066	475014
-1	-1	1	4	0.0006	16911	731096	443610
-1	-1	1	6	0.0002	1021416	724763	436830
-1	-1	1	6	0.0004	76085	632098	388598
-1	-1	1	6	0.0006	16654	583442	362870
-1	-1	1	8	0.0002	1005907	578388	357360
-1	-1	1	8	0.0004	74929	504387	317871
-1	-1	1	8	0.0006	16399	465562	296855

Adjusted data for SP 19-mm with optimum asphalt content

AC	GR	Temp	Air void	Strain	N_f	S_0	S_0''
			%	in/in	cycles	psi	psi
1	1	-1	4	0.0002	472976	1717706	777470
1	1	-1	4	0.0004	38071	1497938	670782
1	1	-1	4	0.0006	8720	1382633	615260
1	1	-1	6	0.0002	371907	1370656	635966
1	1	-1	6	0.0004	29938	1195291	548696
1	1	-1	6	0.0006	6857	1103392	503329
1	1	-1	8	0.0002	292465	1093835	520268
1	1	-1	8	0.0004	23541	953887	448830
1	1	-1	8	0.0006	5392	880460	411720
1	1	0	4	0.0002	761770	1191591	590426
1	1	0	4	0.0004	58989	1039136	518554
1	1	0	4	0.0006	13207	959147	480653
1	1	0	6	0.0002	599050	950934	482965
1	1	0	6	0.0004	46384	829269	424217
1	1	0	6	0.0006	10386	765435	393210
1	1	0	8	0.0002	471041	758805	395102
1	1	0	8	0.0004	36476	661721	347007
1	1	0	8	0.0006	8167	610785	321644
1	1	1	4	0.0002	1227021	826702	448382
1	1	1	4	0.0004	91391	720932	400913
1	1	1	4	0.0006	20004	665438	375495
1	1	1	6	0.0002	964823	659673	366810
1	1	1	6	0.0004	71869	575273	327945
1	1	1	6	0.0006	15730	530991	307183
1	1	1	8	0.0002	758729	526391	300049
1	1	1	8	0.0004	56512	459043	268284
1	1	1	8	0.0006	12370	423750	251274

Adjusted data for SP 19-mm with optimum minus 0.5-percent asphalt content

AC	GR	Temp	Air void	Strain	N_f	S_0	S_0''
			%	in/in	cycles	psi	psi
-1	1	-1	4	0.0002	254919	1573794	770042
-1	1	-1	4	0.0004	20521	1372439	660994
-1	1	-1	4	0.0006	4700	1266794	604526
-1	1	-1	6	0.0002	200466	1255946	629890
-1	1	-1	6	0.0004	16136	1095257	540689
-1	1	-1	6	0.0006	3696	1010949	494499
-1	1	-1	8	0.0002	157645	1002192	515298
-1	1	-1	8	0.0004	12689	873969	442325
-1	1	-1	8	0.0006	2906	806694	404538
-1	1	0	4	0.0002	410610	1091867	584785
-1	1	0	4	0.0004	31793	952171	511038
-1	1	0	4	0.0006	7119	878877	472267
-1	1	0	6	0.0002	322868	871264	478399
-1	1	0	6	0.0004	25002	759792	418026
-1	1	0	6	0.0006	5598	701306	386312
-1	1	0	8	0.0002	253901	695231	391327
-1	1	0	8	0.0004	19659	606282	341977
-1	1	0	8	0.0006	4402	559669	316032
-1	1	1	4	0.0002	661325	757440	444142
-1	1	1	4	0.0004	49262	660531	395063
-1	1	1	4	0.0006	10782	609686	368944
-1	1	1	6	0.0002	520060	604405	363306
-1	1	1	6	0.0004	38735	527076	323191
-1	1	1	6	0.0006	8479	486552	301794
-1	1	1	8	0.0002	408930	482338	297212
-1	1	1	8	0.0004	30461	420626	264369
-1	1	1	8	0.0006	6667	388248	246890

Appendix D. Axial frequency sweep test data

Nomenclature:

AC = Asphalt content.	-1 = optimum minus 0.5% asphalt content;
	1 = optimum asphalt content;
GR = Gradation.	-1 = SP 12.5-mm mix;
	1 = SP19-mm mix.
RT = Replicates.	-1 = one replicate;
	1 = two replicates.
Temp = Temperature.	-1 = 15°C; and
	0 = 20°C, and
	1 = 25°C.

AC	GR	Temp	Va	Freq	|E*|	phi	G_{mb}	VFA	$V_b/(V_a+V_b)$	VMA	V_b
			(%)	(Hz)	(psi)	(Degree)		(%)		(%)	(%)
1	-1	-1	3.80	15.00	1.50E+06	15.69	2.3750	73.66	0.7611	14.43	12.11
1	-1	-1	3.80	10.00	1.40E+06	16.69	2.3750	73.66	0.7611	14.43	12.11
1	-1	-1	3.80	5.00	1.23E+06	18.63	2.3750	73.66	0.7611	14.43	12.11
1	-1	-1	3.80	2.00	1.02E+06	21.43	2.3750	73.66	0.7611	14.43	12.11
1	-1	-1	3.80	1.00	8.65E+05	23.84	2.3750	73.66	0.7611	14.43	12.11
1	-1	-1	3.80	0.50	7.25E+05	26.10	2.3750	73.66	0.7611	14.43	12.11
1	-1	-1	3.80	0.20	5.56E+05	29.21	2.3750	73.66	0.7611	14.43	12.11
1	-1	-1	3.80	0.10	4.51E+05	31.41	2.3750	73.66	0.7611	14.43	12.11
1	-1	-1	3.80	0.05	3.31E+05	30.79	2.3750	73.66	0.7611	14.43	12.11
1	-1	-1	3.80	0.02	2.58E+05	34.75	2.3750	73.66	0.7611	14.43	12.11
1	-1	-1	3.80	0.01	2.02E+05	35.42	2.3750	73.66	0.7611	14.43	12.11
1	-1	-1	3.80	15.00	1.55E+06	15.41	2.3750	73.66	0.7611	14.43	12.11
1	-1	-1	3.80	10.00	1.44E+06	16.39	2.3750	73.66	0.7611	14.43	12.11
1	-1	-1	3.80	5.00	1.27E+06	18.37	2.3750	73.66	0.7611	14.43	12.11
1	-1	-1	3.80	2.00	1.06E+06	21.13	2.3750	73.66	0.7611	14.43	12.11
1	-1	-1	3.80	1.00	8.97E+05	23.60	2.3750	73.66	0.7611	14.43	12.11
1	-1	-1	3.80	0.50	7.54E+05	26.04	2.3750	73.66	0.7611	14.43	12.11
1	-1	-1	3.80	0.20	5.78E+05	29.36	2.3750	73.66	0.7611	14.43	12.11
1	-1	-1	3.80	0.10	4.66E+05	31.65	2.3750	73.66	0.7611	14.43	12.11
1	-1	-1	3.80	0.05	3.37E+05	30.75	2.3750	73.66	0.7611	14.43	12.11
1	-1	-1	3.80	0.02	2.65E+05	35.40	2.3750	73.66	0.7611	14.43	12.11
1	-1	-1	3.80	0.01	2.06E+05	37.26	2.3750	73.66	0.7611	14.43	12.11
1	-1	-1	6.54	15.00	1.16E+06	18.96	2.3093	61.04	0.6428	16.79	11.77
1	-1	-1	6.54	10.00	1.06E+06	20.35	2.3093	61.04	0.6428	16.79	11.77
1	-1	-1	6.54	5.00	9.07E+05	23.01	2.3093	61.04	0.6428	16.79	11.77
1	-1	-1	6.54	2.00	7.17E+05	26.92	2.3093	61.04	0.6428	16.79	11.77
1	-1	-1	6.54	1.00	5.82E+05	30.23	2.3093	61.04	0.6428	16.79	11.77
1	-1	-1	6.54	0.50	4.63E+05	33.49	2.3093	61.04	0.6428	16.79	11.77
1	-1	-1	6.54	0.20	3.31E+05	37.66	2.3093	61.04	0.6428	16.79	11.77
1	-1	-1	6.54	0.10	2.52E+05	40.46	2.3093	61.04	0.6428	16.79	11.77
1	-1	-1	6.54	0.05	1.65E+05	40.73	2.3093	61.04	0.6428	16.79	11.77
1	-1	-1	6.54	0.02	1.23E+05	45.22	2.3093	61.04	0.6428	16.79	11.77
1	-1	-1	6.54	0.01	9.13E+04	46.92	2.3093	61.04	0.6428	16.79	11.77
1	-1	-1	5.64	15.00	1.40E+06	16.48	2.3316	64.71	0.6781	15.99	11.89
1	-1	-1	5.64	10.00	1.30E+06	17.65	2.3316	64.71	0.6781	15.99	11.89
1	-1	-1	5.64	5.00	1.13E+06	19.92	2.3316	64.71	0.6781	15.99	11.89
1	-1	-1	5.64	2.00	9.17E+05	23.31	2.3316	64.71	0.6781	15.99	11.89
1	-1	-1	5.64	1.00	7.64E+05	26.15	2.3316	64.71	0.6781	15.99	11.89
1	-1	-1	5.64	0.50	6.25E+05	29.12	2.3316	64.71	0.6781	15.99	11.89
1	-1	-1	5.64	0.20	4.66E+05	32.83	2.3316	64.71	0.6781	15.99	11.89
1	-1	-1	5.64	0.10	3.65E+05	35.06	2.3316	64.71	0.6781	15.99	11.89
1	-1	-1	5.64	0.05	2.57E+05	35.32	2.3316	64.71	0.6781	15.99	11.89
1	-1	-1	5.64	0.02	1.96E+05	39.00	2.3316	64.71	0.6781	15.99	11.89
1	-1	-1	5.64	0.01	1.48E+05	39.64	2.3316	64.71	0.6781	15.99	11.89
1	-1	-1	7.87	15.00	1.12E+06	19.58	2.2766	56.22	0.5960	17.97	11.61
1	-1	-1	7.87	10.00	1.02E+06	21.01	2.2766	56.22	0.5960	17.97	11.61
1	-1	-1	7.87	5.00	8.70E+05	23.76	2.2766	56.22	0.5960	17.97	11.61
1	-1	-1	7.87	2.00	6.78E+05	27.72	2.2766	56.22	0.5960	17.97	11.61
1	-1	-1	7.87	1.00	5.46E+05	30.64	2.2766	56.22	0.5960	17.97	11.61
1	-1	-1	7.87	0.50	4.32E+05	33.89	2.2766	56.22	0.5960	17.97	11.61
1	-1	-1	7.87	0.20	3.08E+05	37.28	2.2766	56.22	0.5960	17.97	11.61
1	-1	-1	7.87	0.10	2.35E+05	39.07	2.2766	56.22	0.5960	17.97	11.61
1	-1	-1	7.87	0.05	1.62E+05	38.96	2.2766	56.22	0.5960	17.97	11.61
1	-1	-1	7.87	0.02	1.23E+05	41.17	2.2766	56.22	0.5960	17.97	11.61
1	-1	-1	7.87	0.01	9.21E+04	40.66	2.2766	56.22	0.5960	17.97	11.61
1	-1	-1	7.87	15.00	9.38E+05	22.64	2.2766	56.22	0.5960	17.97	11.61
1	-1	-1	7.87	10.00	8.46E+05	24.31	2.2766	56.22	0.5960	17.97	11.61
1	-1	-1	7.87	5.00	6.99E+05	27.57	2.2766	56.22	0.5960	17.97	11.61
1	-1	-1	7.87	2.00	5.22E+05	32.20	2.2766	56.22	0.5960	17.97	11.61

(Continued)

AC	GR	Temp	V_a	Freq	|E*|	phi	G_{mb}	VFA	$V_b/(V_a+V_b)$	VMA	V_b
			(%)	(Hz)	(psi)	(Degree)		(%)		(%)	(%)
1	-1	-1	7.87	1.00	4.09E+05	35.56	2.2766	56.22	0.5960	17.97	11.61
1	-1	-1	7.87	0.50	3.09E+05	39.16	2.2766	56.22	0.5960	17.97	11.61
1	-1	-1	7.87	0.20	2.09E+05	43.27	2.2766	56.22	0.5960	17.97	11.61
1	-1	-1	7.87	0.10	1.52E+05	45.50	2.2766	56.22	0.5960	17.97	11.61
1	-1	-1	7.87	0.05	9.94E+04	45.86	2.2766	56.22	0.5960	17.97	11.61
1	-1	-1	7.87	0.02	6.98E+04	48.46	2.2766	56.22	0.5960	17.97	11.61
1	-1	-1	7.87	0.01	4.88E+04	48.66	2.2766	56.22	0.5960	17.97	11.61
1	-1	0	3.80	15.00	1.25E+06	19.40	2.3750	73.66	0.7611	14.43	12.11
1	-1	0	3.80	10.00	1.14E+06	20.62	2.3750	73.66	0.7611	14.43	12.11
1	-1	0	3.80	5.00	9.71E+05	22.92	2.3750	73.66	0.7611	14.43	12.11
1	-1	0	3.80	2.00	7.73E+05	26.03	2.3750	73.66	0.7611	14.43	12.11
1	-1	0	3.80	1.00	6.33E+05	28.63	2.3750	73.66	0.7611	14.43	12.11
1	-1	0	3.80	0.50	5.17E+05	30.80	2.3750	73.66	0.7611	14.43	12.11
1	-1	0	3.80	0.20	3.80E+05	33.52	2.3750	73.66	0.7611	14.43	12.11
1	-1	0	3.80	0.10	3.00E+05	34.99	2.3750	73.66	0.7611	14.43	12.11
1	-1	0	3.80	0.05	2.09E+05	32.58	2.3750	73.66	0.7611	14.43	12.11
1	-1	0	3.80	0.02	1.66E+05	36.70	2.3750	73.66	0.7611	14.43	12.11
1	-1	0	3.80	0.01	1.28E+05	36.04	2.3750	73.66	0.7611	14.43	12.11
1	-1	0	3.80	15.00	1.24E+06	19.20	2.3750	73.66	0.7611	14.43	12.11
1	-1	0	3.80	10.00	1.13E+06	20.51	2.3750	73.66	0.7611	14.43	12.11
1	-1	0	3.80	5.00	9.68E+05	23.00	2.3750	73.66	0.7611	14.43	12.11
1	-1	0	3.80	2.00	7.67E+05	26.35	2.3750	73.66	0.7611	14.43	12.11
1	-1	0	3.80	1.00	6.26E+05	29.22	2.3750	73.66	0.7611	14.43	12.11
1	-1	0	3.80	0.50	5.07E+05	31.78	2.3750	73.66	0.7611	14.43	12.11
1	-1	0	3.80	0.20	3.69E+05	34.83	2.3750	73.66	0.7611	14.43	12.11
1	-1	0	3.80	0.10	2.87E+05	36.87	2.3750	73.66	0.7611	14.43	12.11
1	-1	0	3.80	0.05	1.95E+05	35.58	2.3750	73.66	0.7611	14.43	12.11
1	-1	0	3.80	0.02	1.54E+05	39.94	2.3750	73.66	0.7611	14.43	12.11
1	-1	0	3.80	0.01	1.15E+05	39.65	2.3750	73.66	0.7611	14.43	12.11
1	-1	0	6.54	15.00	8.36E+05	24.91	2.3093	61.04	0.6428	16.79	11.77
1	-1	0	6.54	10.00	7.45E+05	26.59	2.3093	61.04	0.6428	16.79	11.77
1	-1	0	6.54	5.00	6.05E+05	29.82	2.3093	61.04	0.6428	16.79	11.77
1	-1	0	6.54	2.00	4.44E+05	34.09	2.3093	61.04	0.6428	16.79	11.77
1	-1	0	6.54	1.00	3.40E+05	37.47	2.3093	61.04	0.6428	16.79	11.77
1	-1	0	6.54	0.50	2.58E+05	39.94	2.3093	61.04	0.6428	16.79	11.77
1	-1	0	6.54	0.20	1.75E+05	42.88	2.3093	61.04	0.6428	16.79	11.77
1	-1	0	6.54	0.10	1.28E+05	44.23	2.3093	61.04	0.6428	16.79	11.77
1	-1	0	6.54	0.05	9.03E+04	44.60	2.3093	61.04	0.6428	16.79	11.77
1	-1	0	6.54	0.02	6.29E+04	45.40	2.3093	61.04	0.6428	16.79	11.77
1	-1	0	6.54	0.01	4.52E+04	45.43	2.3093	61.04	0.6428	16.79	11.77
1	-1	0	5.64	15.00	9.74E+05	23.18	2.3316	64.71	0.6781	15.99	11.89
1	-1	0	5.64	10.00	8.77E+05	24.78	2.3316	64.71	0.6781	15.99	11.89
1	-1	0	5.64	5.00	7.22E+05	27.70	2.3316	64.71	0.6781	15.99	11.89
1	-1	0	5.64	2.00	5.41E+05	31.74	2.3316	64.71	0.6781	15.99	11.89
1	-1	0	5.64	1.00	4.23E+05	34.72	2.3316	64.71	0.6781	15.99	11.89
1	-1	0	5.64	0.50	3.27E+05	37.30	2.3316	64.71	0.6781	15.99	11.89
1	-1	0	5.64	0.20	2.28E+05	39.55	2.3316	64.71	0.6781	15.99	11.89
1	-1	0	5.64	0.10	1.71E+05	40.55	2.3316	64.71	0.6781	15.99	11.89
1	-1	0	5.64	0.05	1.25E+05	40.29	2.3316	64.71	0.6781	15.99	11.89
1	-1	0	5.64	0.02	9.03E+04	40.30	2.3316	64.71	0.6781	15.99	11.89
1	-1	0	5.64	0.01	6.98E+04	39.47	2.3316	64.71	0.6781	15.99	11.89
1	-1	0	7.87	15.00	8.61E+05	24.73	2.2766	56.22	0.5960	17.97	11.61
1	-1	0	7.87	10.00	7.67E+05	26.55	2.2766	56.22	0.5960	17.97	11.61
1	-1	0	7.87	5.00	6.23E+05	29.91	2.2766	56.22	0.5960	17.97	11.61
1	-1	0	7.87	2.00	4.54E+05	34.46	2.2766	56.22	0.5960	17.97	11.61
1	-1	0	7.87	1.00	3.48E+05	37.64	2.2766	56.22	0.5960	17.97	11.61
1	-1	0	7.87	0.50	2.64E+05	40.56	2.2766	56.22	0.5960	17.97	11.61
1	-1	0	7.87	0.20	1.77E+05	43.16	2.2766	56.22	0.5960	17.97	11.61
1	-1	0	7.87	0.10	1.30E+05	43.69	2.2766	56.22	0.5960	17.97	11.61
1	-1	0	7.87	0.05	8.90E+04	43.47	2.2766	56.22	0.5960	17.97	11.61
1	-1	0	7.87	0.02	6.37E+04	43.08	2.2766	56.22	0.5960	17.97	11.61
1	-1	0	7.87	0.01	5.00E+04	39.67	2.2766	56.22	0.5960	17.97	11.61
1	-1	0	7.87	15.00	8.36E+05	26.73	2.2766	56.22	0.5960	17.97	11.61

(Continued)

AC	GR	Temp	V_a	Freq	|E*|	phi	G_{mb}	VFA	$V_b/(V_a+V_b)$	VMA	V_b
			(%)	(Hz)	(psi)	(Degree)		(%)		(%)	(%)
1	-1	0	7.87	10.00	7.36E+05	28.61	2.2766	56.22	0.5960	17.97	11.61
1	-1	0	7.87	5.00	5.80E+05	32.22	2.2766	56.22	0.5960	17.97	11.61
1	-1	0	7.87	2.00	4.06E+05	36.96	2.2766	56.22	0.5960	17.97	11.61
1	-1	0	7.87	1.00	2.91E+05	41.04	2.2766	56.22	0.5960	17.97	11.61
1	-1	0	7.87	0.50	2.29E+05	43.23	2.2766	56.22	0.5960	17.97	11.61
1	-1	0	7.87	0.20	1.50E+05	45.69	2.2766	56.22	0.5960	17.97	11.61
1	-1	0	7.87	0.10	1.08E+05	46.76	2.2766	56.22	0.5960	17.97	11.61
1	-1	0	7.87	0.05	7.16E+04	45.76	2.2766	56.22	0.5960	17.97	11.61
1	-1	0	7.87	0.02	4.89E+04	42.20	2.2766	56.22	0.5960	17.97	11.61
1	-1	0	7.87	0.01	3.56E+04	40.82	2.2766	56.22	0.5960	17.97	11.61
1	-1	1	3.80	15.00	1.05E+06	22.50	2.3750	73.66	0.7611	14.43	12.11
1	-1	1	3.80	10.00	9.49E+05	23.98	2.3750	73.66	0.7611	14.43	12.11
1	-1	1	3.80	5.00	7.86E+05	26.72	2.3750	73.66	0.7611	14.43	12.11
1	-1	1	3.80	2.00	5.96E+05	30.25	2.3750	73.66	0.7611	14.43	12.11
1	-1	1	3.80	1.00	4.72E+05	33.02	2.3750	73.66	0.7611	14.43	12.11
1	-1	1	3.80	0.50	3.69E+05	35.20	2.3750	73.66	0.7611	14.43	12.11
1	-1	1	3.80	0.20	2.62E+05	37.67	2.3750	73.66	0.7611	14.43	12.11
1	-1	1	3.80	0.10	2.00E+05	38.47	2.3750	73.66	0.7611	14.43	12.11
1	-1	1	3.80	0.05	1.46E+05	38.94	2.3750	73.66	0.7611	14.43	12.11
1	-1	1	3.80	0.02	1.09E+05	39.32	2.3750	73.66	0.7611	14.43	12.11
1	-1	1	3.80	0.01	8.29E+04	38.40	2.3750	73.66	0.7611	14.43	12.11
1	-1	1	3.80	15.00	9.76E+05	23.54	2.3750	73.66	0.7611	14.43	12.11
1	-1	1	3.80	10.00	8.75E+05	25.06	2.3750	73.66	0.7611	14.43	12.11
1	-1	1	3.80	5.00	7.19E+05	27.89	2.3750	73.66	0.7611	14.43	12.11
1	-1	1	3.80	2.00	5.41E+05	31.37	2.3750	73.66	0.7611	14.43	12.11
1	-1	1	3.80	1.00	4.25E+05	34.17	2.3750	73.66	0.7611	14.43	12.11
1	-1	1	3.80	0.50	3.31E+05	36.38	2.3750	73.66	0.7611	14.43	12.11
1	-1	1	3.80	0.20	2.32E+05	38.47	2.3750	73.66	0.7611	14.43	12.11
1	-1	1	3.80	0.10	1.77E+05	39.28	2.3750	73.66	0.7611	14.43	12.11
1	-1	1	3.80	0.05	1.29E+05	39.63	2.3750	73.66	0.7611	14.43	12.11
1	-1	1	3.80	0.02	9.53E+04	39.21	2.3750	73.66	0.7611	14.43	12.11
1	-1	1	3.80	0.01	7.21E+04	38.93	2.3750	73.66	0.7611	14.43	12.11
1	-1	1	6.54	15.00	7.00E+05	28.36	2.3093	61.04	0.6428	16.79	11.77
1	-1	1	6.54	10.00	6.14E+05	30.21	2.3093	61.04	0.6428	16.79	11.77
1	-1	1	6.54	5.00	4.85E+05	33.52	2.3093	61.04	0.6428	16.79	11.77
1	-1	1	6.54	2.00	3.44E+05	37.50	2.3093	61.04	0.6428	16.79	11.77
1	-1	1	6.54	1.00	2.59E+05	39.99	2.3093	61.04	0.6428	16.79	11.77
1	-1	1	6.54	0.50	1.93E+05	42.27	2.3093	61.04	0.6428	16.79	11.77
1	-1	1	6.54	0.20	1.29E+05	43.57	2.3093	61.04	0.6428	16.79	11.77
1	-1	1	6.54	0.10	9.47E+04	43.37	2.3093	61.04	0.6428	16.79	11.77
1	-1	1	6.54	0.05	6.72E+04	42.67	2.3093	61.04	0.6428	16.79	11.77
1	-1	1	6.54	0.02	5.05E+04	38.45	2.3093	61.04	0.6428	16.79	11.77
1	-1	1	6.54	0.01	4.09E+04	35.89	2.3093	61.04	0.6428	16.79	11.77
1	-1	1	5.64	15.00	7.78E+05	27.35	2.3316	64.71	0.6781	15.99	11.89
1	-1	1	5.64	10.00	6.87E+05	29.03	2.3316	64.71	0.6781	15.99	11.89
1	-1	1	5.64	5.00	5.46E+05	32.18	2.3316	64.71	0.6781	15.99	11.89
1	-1	1	5.64	2.00	3.92E+05	35.88	2.3316	64.71	0.6781	15.99	11.89
1	-1	1	5.64	1.00	2.99E+05	38.71	2.3316	64.71	0.6781	15.99	11.89
1	-1	1	5.64	0.50	2.25E+05	40.38	2.3316	64.71	0.6781	15.99	11.89
1	-1	1	5.64	0.20	1.53E+05	41.60	2.3316	64.71	0.6781	15.99	11.89
1	-1	1	5.64	0.10	1.15E+05	40.99	2.3316	64.71	0.6781	15.99	11.89
1	-1	1	5.64	0.05	8.46E+04	39.24	2.3316	64.71	0.6781	15.99	11.89
1	-1	1	5.64	0.02	6.29E+04	36.63	2.3316	64.71	0.6781	15.99	11.89
1	-1	1	5.64	0.01	5.12E+04	32.69	2.3316	64.71	0.6781	15.99	11.89
1	-1	1	7.87	15.00	6.64E+05	29.72	2.2766	56.22	0.5960	17.97	11.61
1	-1	1	7.87	10.00	5.79E+05	31.77	2.2766	56.22	0.5960	17.97	11.61
1	-1	1	7.87	5.00	4.50E+05	35.42	2.2766	56.22	0.5960	17.97	11.61
1	-1	1	7.87	2.00	3.12E+05	39.92	2.2766	56.22	0.5960	17.97	11.61
1	-1	1	7.87	1.00	2.29E+05	42.68	2.2766	56.22	0.5960	17.97	11.61
1	-1	1	7.87	0.50	1.68E+05	45.47	2.2766	56.22	0.5960	17.97	11.61
1	-1	1	7.87	0.20	1.09E+05	47.07	2.2766	56.22	0.5960	17.97	11.61
1	-1	1	7.87	0.10	7.82E+04	47.60	2.2766	56.22	0.5960	17.97	11.61
1	-1	1	7.87	0.05	5.24E+04	46.80	2.2766	56.22	0.5960	17.97	11.61

(Continued)

AC	GR	Temp	V_a	Freq	|E*|	phi	G_{mb}	VFA	$V_b/(V_a+V_b)$	VMA	V_b
			(%)	(Hz)	(psi)	(Degree)		(%)		(%)	(%)
1	-1	1	7.87	0.02	3.71E+04	45.33	2.2766	56.22	0.5960	17.97	11.61
1	-1	1	7.87	0.01	3.02E+04	44.19	2.2766	56.22	0.5960	17.97	11.61
1	-1	1	7.87	15.00	6.62E+05	32.85	2.2766	56.22	0.5960	17.97	11.61
1	-1	1	7.87	10.00	5.64E+05	34.96	2.2766	56.22	0.5960	17.97	11.61
1	-1	1	7.87	5.00	4.10E+05	38.71	2.2766	56.22	0.5960	17.97	11.61
1	-1	1	7.87	2.00	2.40E+05	44.87	2.2766	56.22	0.5960	17.97	11.61
1	-1	1	7.87	1.00	1.75E+05	47.14	2.2766	56.22	0.5960	17.97	11.61
1	-1	1	7.87	0.50	1.43E+05	49.37	2.2766	56.22	0.5960	17.97	11.61
1	-1	1	7.87	0.20	9.11E+04	51.28	2.2766	56.22	0.5960	17.97	11.61
1	-1	1	7.87	0.10	6.33E+04	51.75	2.2766	56.22	0.5960	17.97	11.61
1	-1	1	7.87	0.05	4.16E+04	50.08	2.2766	56.22	0.5960	17.97	11.61
1	-1	1	7.87	0.02	2.95E+04	49.12	2.2766	56.22	0.5960	17.97	11.61
1	-1	1	7.87	0.01	2.30E+04	47.62	2.2766	56.22	0.5960	17.97	11.61
1	-1	-1.6	3.65	15.00	1.86E+06	11.79	2.3807	74.33	0.7688	14.22	12.14
1	-1	-1.6	3.65	10.00	1.77E+06	12.32	2.3807	74.33	0.7688	14.22	12.14
1	-1	-1.6	3.65	5.00	1.59E+06	14.28	2.3807	74.33	0.7688	14.22	12.14
1	-1	-1.6	3.65	2.00	1.38E+06	16.73	2.3807	74.33	0.7688	14.22	12.14
1	-1	-1.6	3.65	1.00	1.22E+06	18.67	2.3807	74.33	0.7688	14.22	12.14
1	-1	-1.6	3.65	0.50	1.06E+06	20.08	2.3807	74.33	0.7688	14.22	12.14
1	-1	-1.6	3.65	0.20	8.93E+05	23.75	2.3807	74.33	0.7688	14.22	12.14
1	-1	-1.6	3.65	0.10	7.49E+05	26.36	2.3807	74.33	0.7688	14.22	12.14
1	-1	-1.6	3.65	0.05	6.03E+05	29.24	2.3807	74.33	0.7688	14.22	12.14
1	-1	-1.6	3.65	0.02	4.56E+05	32.12	2.3807	74.33	0.7688	14.22	12.14
1	-1	-1.6	3.65	0.01	3.72E+05	36.10	2.3807	74.33	0.7688	14.22	12.14
1	-1	2	3.65	15.00	6.98E+05	29.22	2.3807	74.33	0.7688	14.22	12.14
1	-1	2	3.65	10.00	6.11E+05	30.89	2.3807	74.33	0.7688	14.22	12.14
1	-1	2	3.65	5.00	4.80E+05	33.69	2.3807	74.33	0.7688	14.22	12.14
1	-1	2	3.65	2.00	3.32E+05	32.92	2.3807	74.33	0.7688	14.22	12.14
1	-1	2	3.65	1.00	2.29E+05	34.48	2.3807	74.33	0.7688	14.22	12.14
1	-1	2	3.65	0.50	1.89E+05	40.91	2.3807	74.33	0.7688	14.22	12.14
1	-1	2	3.65	0.20	1.31E+05	40.85	2.3807	74.33	0.7688	14.22	12.14
1	-1	2	3.65	0.10	9.84E+04	40.83	2.3807	74.33	0.7688	14.22	12.14
1	-1	2	3.65	0.05	7.53E+04	39.61	2.3807	74.33	0.7688	14.22	12.14
1	-1	2	3.65	0.02	5.53E+04	36.14	2.3807	74.33	0.7688	14.22	12.14
1	-1	2	3.65	0.01	4.30E+04	35.57	2.3807	74.33	0.7688	14.22	12.14
1	-1	-1.6	7.87	15.00	1.17E+06	16.78	2.2765	56.21	0.5959	17.97	11.61
1	-1	-1.6	7.87	10.00	1.08E+06	18.10	2.2765	56.21	0.5959	17.97	11.61
1	-1	-1.6	7.87	5.00	9.41E+05	20.58	2.2765	56.21	0.5959	17.97	11.61
1	-1	-1.6	7.87	2.00	7.67E+05	24.56	2.2765	56.21	0.5959	17.97	11.61
1	-1	-1.6	7.87	1.00	6.30E+05	27.61	2.2765	56.21	0.5959	17.97	11.61
1	-1	-1.6	7.87	0.50	5.30E+05	31.20	2.2765	56.21	0.5959	17.97	11.61
1	-1	-1.6	7.87	0.20	3.80E+05	34.68	2.2765	56.21	0.5959	17.97	11.61
1	-1	-1.6	7.87	0.10	3.05E+05	41.27	2.2765	56.21	0.5959	17.97	11.61
1	-1	-1.6	7.87	0.05	1.96E+05	34.11	2.2765	56.21	0.5959	17.97	11.61
1	-1	-1.6	7.87	0.02	1.88E+05	50.26	2.2765	56.21	0.5959	17.97	11.61
1	-1	-1.6	7.87	0.01	1.09E+05	33.97	2.2765	56.21	0.5959	17.97	11.61
1	-1	2	7.87	15.00	3.49E+05	40.30	2.2765	56.21	0.5959	17.97	11.61
1	-1	2	7.87	10.00	2.89E+05	42.69	2.2765	56.21	0.5959	17.97	11.61
1	-1	2	7.87	5.00	2.05E+05	45.30	2.2765	56.21	0.5959	17.97	11.61
1	-1	2	7.87	2.00	1.29E+05	50.70	2.2765	56.21	0.5959	17.97	11.61
1	-1	2	7.87	1.00	9.26E+04	52.80	2.2765	56.21	0.5959	17.97	11.61
1	-1	2	7.87	0.50	6.38E+04	52.75	2.2765	56.21	0.5959	17.97	11.61
1	-1	2	7.87	0.20	4.06E+04	51.99	2.2765	56.21	0.5959	17.97	11.61
1	-1	2	7.87	0.10	2.97E+04	48.02	2.2765	56.21	0.5959	17.97	11.61
1	-1	2	7.87	0.05	2.27E+04	43.35	2.2765	56.21	0.5959	17.97	11.61
1	-1	2	7.87	0.02	1.73E+04	41.40	2.2765	56.21	0.5959	17.97	11.61
1	-1	2	7.87	0.01	1.41E+04	36.50	2.2765	56.21	0.5959	17.97	11.61
-1	-1	-1.2	4.50	15.00	1.44E+06	17.26	2.3598	69.01	0.7072	14.52	10.87
-1	-1	-1.2	4.50	10.00	1.34E+06	18.51	2.3598	69.01	0.7072	14.52	10.87
-1	-1	-1.2	4.50	5.00	1.16E+06	20.98	2.3598	69.01	0.7072	14.52	10.87
-1	-1	-1.2	4.50	2.00	9.38E+05	24.65	2.3598	69.01	0.7072	14.52	10.87
-1	-1	-1.2	4.50	1.00	7.74E+05	28.06	2.3598	69.01	0.7072	14.52	10.87
-1	-1	-1.2	4.50	0.50	6.28E+05	31.25	2.3598	69.01	0.7072	14.52	10.87

(Continued)

AC	GR	Temp	V_a	Freq	|E*|	phi	G_{mb}	VFA	$V_b/(V_a+V_b)$	VMA	V_b
			(%)	(Hz)	(psi)	(Degree)		(%)		(%)	(%)
-1	-1	-1.2	4.50	0.20	4.62E+05	35.74	2.3598	69.01	0.7072	14.52	10.87
-1	-1	-1.2	4.50	0.10	3.53E+05	38.37	2.3598	69.01	0.7072	14.52	10.87
-1	-1	-1.2	4.50	0.05	2.33E+05	38.28	2.3598	69.01	0.7072	14.52	10.87
-1	-1	-1.2	4.50	0.02	1.75E+05	42.42	2.3598	69.01	0.7072	14.52	10.87
-1	-1	-1.2	4.50	0.01	1.32E+05	43.59	2.3598	69.01	0.7072	14.52	10.87
-1	-1	-1.2	4.50	15.00	1.53E+06	16.56	2.3598	69.01	0.7072	14.52	10.87
-1	-1	-1.2	4.50	10.00	1.42E+06	17.68	2.3598	69.01	0.7072	14.52	10.87
-1	-1	-1.2	4.50	5.00	1.24E+06	19.99	2.3598	69.01	0.7072	14.52	10.87
-1	-1	-1.2	4.50	2.00	1.02E+06	23.50	2.3598	69.01	0.7072	14.52	10.87
-1	-1	-1.2	4.50	1.00	8.48E+05	26.77	2.3598	69.01	0.7072	14.52	10.87
-1	-1	-1.2	4.50	0.50	6.91E+05	29.84	2.3598	69.01	0.7072	14.52	10.87
-1	-1	-1.2	4.50	0.20	5.02E+05	33.98	2.3598	69.01	0.7072	14.52	10.87
-1	-1	-1.2	4.50	0.10	4.00E+05	38.10	2.3598	69.01	0.7072	14.52	10.87
-1	-1	-1.2	4.50	0.05	2.66E+05	39.53	2.3598	69.01	0.7072	14.52	10.87
-1	-1	-1.2	4.50	0.02	1.98E+05	44.14	2.3598	69.01	0.7072	14.52	10.87
-1	-1	-1.2	4.50	0.01	1.40E+05	44.53	2.3598	69.01	0.7072	14.52	10.87
-1	-1	-1.2	6.12	15.00	1.40E+06	17.90	2.3197	61.67	0.6358	15.98	10.69
-1	-1	-1.2	6.12	10.00	1.29E+06	19.31	2.3197	61.67	0.6358	15.98	10.69
-1	-1	-1.2	6.12	5.00	1.11E+06	22.08	2.3197	61.67	0.6358	15.98	10.69
-1	-1	-1.2	6.12	2.00	8.85E+05	26.20	2.3197	61.67	0.6358	15.98	10.69
-1	-1	-1.2	6.12	1.00	7.21E+05	29.79	2.3197	61.67	0.6358	15.98	10.69
-1	-1	-1.2	6.12	0.50	5.73E+05	33.51	2.3197	61.67	0.6358	15.98	10.69
-1	-1	-1.2	6.12	0.20	4.06E+05	38.15	2.3197	61.67	0.6358	15.98	10.69
-1	-1	-1.2	6.12	0.10	3.05E+05	41.11	2.3197	61.67	0.6358	15.98	10.69
-1	-1	-1.2	6.12	0.05	2.06E+05	42.51	2.3197	61.67	0.6358	15.98	10.69
-1	-1	-1.2	6.12	0.02	1.44E+05	45.63	2.3197	61.67	0.6358	15.98	10.69
-1	-1	-1.2	6.12	0.01	1.05E+05	46.24	2.3197	61.67	0.6358	15.98	10.69
-1	-1	-1.2	6.12	15.00	1.25E+06	19.01	2.3197	61.67	0.6358	15.98	10.69
-1	-1	-1.2	6.12	10.00	1.15E+06	20.52	2.3197	61.67	0.6358	15.98	10.69
-1	-1	-1.2	6.12	5.00	9.79E+05	23.47	2.3197	61.67	0.6358	15.98	10.69
-1	-1	-1.2	6.12	2.00	7.67E+05	27.89	2.3197	61.67	0.6358	15.98	10.69
-1	-1	-1.2	6.12	1.00	6.16E+05	31.61	2.3197	61.67	0.6358	15.98	10.69
-1	-1	-1.2	6.12	0.50	4.82E+05	35.44	2.3197	61.67	0.6358	15.98	10.69
-1	-1	-1.2	6.12	0.20	3.35E+05	40.13	2.3197	61.67	0.6358	15.98	10.69
-1	-1	-1.2	6.12	0.10	2.48E+05	43.18	2.3197	61.67	0.6358	15.98	10.69
-1	-1	-1.2	6.12	0.05	1.65E+05	44.90	2.3197	61.67	0.6358	15.98	10.69
-1	-1	-1.2	6.12	0.02	1.14E+05	48.06	2.3197	61.67	0.6358	15.98	10.69
-1	-1	-1.2	6.12	0.01	7.85E+04	47.08	2.3197	61.67	0.6358	15.98	10.69
-1	-1	-1.2	7.79	15.00	1.16E+06	18.68	2.2785	55.40	0.5740	17.47	10.50
-1	-1	-1.2	7.79	10.00	1.07E+06	20.15	2.2785	55.40	0.5740	17.47	10.50
-1	-1	-1.2	7.79	5.00	9.14E+05	23.03	2.2785	55.40	0.5740	17.47	10.50
-1	-1	-1.2	7.79	2.00	7.18E+05	27.39	2.2785	55.40	0.5740	17.47	10.50
-1	-1	-1.2	7.79	1.00	5.79E+05	31.09	2.2785	55.40	0.5740	17.47	10.50
-1	-1	-1.2	7.79	0.50	4.58E+05	34.78	2.2785	55.40	0.5740	17.47	10.50
-1	-1	-1.2	7.79	0.20	3.17E+05	39.59	2.2785	55.40	0.5740	17.47	10.50
-1	-1	-1.2	7.79	0.10	2.37E+05	42.01	2.2785	55.40	0.5740	17.47	10.50
-1	-1	-1.2	7.79	0.05	1.56E+05	44.31	2.2785	55.40	0.5740	17.47	10.50
-1	-1	-1.2	7.79	0.02	1.04E+05	45.52	2.2785	55.40	0.5740	17.47	10.50
-1	-1	-1.2	7.79	0.01	7.55E+04	45.03	2.2785	55.40	0.5740	17.47	10.50
-1	-1	-1.2	7.79	15.00	9.99E+05	20.05	2.2785	55.40	0.5740	17.47	10.50
-1	-1	-1.2	7.79	10.00	9.13E+05	21.58	2.2785	55.40	0.5740	17.47	10.50
-1	-1	-1.2	7.79	5.00	7.72E+05	24.54	2.2785	55.40	0.5740	17.47	10.50
-1	-1	-1.2	7.79	2.00	6.03E+05	28.89	2.2785	55.40	0.5740	17.47	10.50
-1	-1	-1.2	7.79	1.00	4.83E+05	32.41	2.2785	55.40	0.5740	17.47	10.50
-1	-1	-1.2	7.79	0.50	3.77E+05	36.00	2.2785	55.40	0.5740	17.47	10.50
-1	-1	-1.2	7.79	0.20	2.61E+05	40.10	2.2785	55.40	0.5740	17.47	10.50
-1	-1	-1.2	7.79	0.10	1.93E+05	42.01	2.2785	55.40	0.5740	17.47	10.50
-1	-1	-1.2	7.79	0.05	1.30E+05	43.26	2.2785	55.40	0.5740	17.47	10.50
-1	-1	-1.2	7.79	0.02	8.92E+04	47.32	2.2785	55.40	0.5740	17.47	10.50
-1	-1	-1.2	7.79	0.01	6.52E+04	44.18	2.2785	55.40	0.5740	17.47	10.50
-1	-1	0	4.50	15.00	1.19E+06	21.35	2.3598	69.01	0.7072	14.52	10.87
-1	-1	0	4.50	10.00	1.08E+06	22.90	2.3598	69.01	0.7072	14.52	10.87
-1	-1	0	4.50	5.00	9.04E+05	26.09	2.3598	69.01	0.7072	14.52	10.87

(Continued)

AC	GR	Temp	V_a	Freq	|E*|	phi	G_{mb}	VFA	$V_b/(V_a+V_b)$	VMA	V_b
			(%)	(Hz)	(psi)	(Degree)		(%)		(%)	(%)
-1	-1	0	4.50	2.00	6.93E+05	30.48	2.3598	69.01	0.7072	14.52	10.87
-1	-1	0	4.50	1.00	5.47E+05	34.12	2.3598	69.01	0.7072	14.52	10.87
-1	-1	0	4.50	0.50	4.21E+05	37.42	2.3598	69.01	0.7072	14.52	10.87
-1	-1	0	4.50	0.20	2.87E+05	41.37	2.3598	69.01	0.7072	14.52	10.87
-1	-1	0	4.50	0.10	2.11E+05	43.63	2.3598	69.01	0.7072	14.52	10.87
-1	-1	0	4.50	0.05	1.44E+05	44.20	2.3598	69.01	0.7072	14.52	10.87
-1	-1	0	4.50	0.02	9.75E+04	46.66	2.3598	69.01	0.7072	14.52	10.87
-1	-1	0	4.50	0.01	7.14E+04	46.17	2.3598	69.01	0.7072	14.52	10.87
-1	-1	0	6.12	15.00	1.00E+06	23.10	2.3197	61.67	0.6358	15.98	10.69
-1	-1	0	6.12	10.00	9.03E+05	24.86	2.3197	61.67	0.6358	15.98	10.69
-1	-1	0	6.12	5.00	7.41E+05	28.19	2.3197	61.67	0.6358	15.98	10.69
-1	-1	0	6.12	2.00	5.52E+05	32.69	2.3197	61.67	0.6358	15.98	10.69
-1	-1	0	6.12	1.00	4.27E+05	36.15	2.3197	61.67	0.6358	15.98	10.69
-1	-1	0	6.12	0.50	3.24E+05	39.40	2.3197	61.67	0.6358	15.98	10.69
-1	-1	0	6.12	0.20	2.19E+05	42.03	2.3197	61.67	0.6358	15.98	10.69
-1	-1	0	6.12	0.10	1.61E+05	42.97	2.3197	61.67	0.6358	15.98	10.69
-1	-1	0	6.12	0.05	1.16E+05	43.40	2.3197	61.67	0.6358	15.98	10.69
-1	-1	0	6.12	0.02	8.11E+04	40.75	2.3197	61.67	0.6358	15.98	10.69
-1	-1	0	6.12	0.01	5.81E+04	38.04	2.3197	61.67	0.6358	15.98	10.69
-1	-1	0	6.12	15.00	1.02E+06	23.22	2.3197	61.67	0.6358	15.98	10.69
-1	-1	0	6.12	10.00	9.13E+05	24.97	2.3197	61.67	0.6358	15.98	10.69
-1	-1	0	6.12	5.00	7.50E+05	28.45	2.3197	61.67	0.6358	15.98	10.69
-1	-1	0	6.12	2.00	5.58E+05	33.19	2.3197	61.67	0.6358	15.98	10.69
-1	-1	0	6.12	1.00	4.34E+05	36.61	2.3197	61.67	0.6358	15.98	10.69
-1	-1	0	6.12	0.50	3.25E+05	40.42	2.3197	61.67	0.6358	15.98	10.69
-1	-1	0	6.12	0.20	2.17E+05	43.50	2.3197	61.67	0.6358	15.98	10.69
-1	-1	0	6.12	0.10	1.58E+05	45.24	2.3197	61.67	0.6358	15.98	10.69
-1	-1	0	6.12	0.05	1.09E+05	46.04	2.3197	61.67	0.6358	15.98	10.69
-1	-1	0	6.12	0.02	7.21E+04	45.48	2.3197	61.67	0.6358	15.98	10.69
-1	-1	0	6.12	0.01	5.65E+04	45.58	2.3197	61.67	0.6358	15.98	10.69
-1	-1	0	7.79	15.00	8.34E+05	25.80	2.2785	55.40	0.5740	17.47	10.50
-1	-1	0	7.79	10.00	7.40E+05	27.92	2.2785	55.40	0.5740	17.47	10.50
-1	-1	0	7.79	5.00	5.94E+05	31.91	2.2785	55.40	0.5740	17.47	10.50
-1	-1	0	7.79	2.00	4.27E+05	37.33	2.2785	55.40	0.5740	17.47	10.50
-1	-1	0	7.79	1.00	3.20E+05	41.41	2.2785	55.40	0.5740	17.47	10.50
-1	-1	0	7.79	0.50	2.32E+05	45.03	2.2785	55.40	0.5740	17.47	10.50
-1	-1	0	7.79	0.20	1.46E+05	48.96	2.2785	55.40	0.5740	17.47	10.50
-1	-1	0	7.79	0.10	1.02E+05	51.25	2.2785	55.40	0.5740	17.47	10.50
-1	-1	0	7.79	0.05	6.73E+04	50.76	2.2785	55.40	0.5740	17.47	10.50
-1	-1	0	7.79	0.02	4.17E+04	52.59	2.2785	55.40	0.5740	17.47	10.50
-1	-1	0	7.79	0.01	3.11E+04	49.90	2.2785	55.40	0.5740	17.47	10.50
-1	-1	0	7.79	15.00	8.15E+05	24.66	2.2785	55.40	0.5740	17.47	10.50
-1	-1	0	7.79	10.00	7.28E+05	26.55	2.2785	55.40	0.5740	17.47	10.50
-1	-1	0	7.79	5.00	5.92E+05	30.30	2.2785	55.40	0.5740	17.47	10.50
-1	-1	0	7.79	2.00	4.36E+05	35.23	2.2785	55.40	0.5740	17.47	10.50
-1	-1	0	7.79	1.00	3.34E+05	38.77	2.2785	55.40	0.5740	17.47	10.50
-1	-1	0	7.79	0.50	2.49E+05	41.97	2.2785	55.40	0.5740	17.47	10.50
-1	-1	0	7.79	0.20	1.63E+05	45.32	2.2785	55.40	0.5740	17.47	10.50
-1	-1	0	7.79	0.10	1.16E+05	46.06	2.2785	55.40	0.5740	17.47	10.50
-1	-1	0	7.79	0.05	8.05E+04	45.96	2.2785	55.40	0.5740	17.47	10.50
-1	-1	0	7.79	0.02	5.36E+04	46.92	2.2785	55.40	0.5740	17.47	10.50
-1	-1	0	7.79	0.01	4.04E+04	43.78	2.2785	55.40	0.5740	17.47	10.50
-1	-1	1	4.50	15.00	8.56E+05	28.14	2.3598	69.01	0.7072	14.52	10.87
-1	-1	1	4.50	10.00	7.54E+05	30.23	2.3598	69.01	0.7072	14.52	10.87
-1	-1	1	4.50	5.00	5.92E+05	34.12	2.3598	69.01	0.7072	14.52	10.87
-1	-1	1	4.50	2.00	4.15E+05	39.26	2.3598	69.01	0.7072	14.52	10.87
-1	-1	1	4.50	1.00	3.03E+05	43.88	2.3598	69.01	0.7072	14.52	10.87
-1	-1	1	4.50	0.50	2.22E+05	45.89	2.3598	69.01	0.7072	14.52	10.87
-1	-1	1	4.50	0.20	1.43E+05	48.64	2.3598	69.01	0.7072	14.52	10.87
-1	-1	1	4.50	0.10	1.01E+05	49.77	2.3598	69.01	0.7072	14.52	10.87
-1	-1	1	4.50	0.05	6.70E+04	48.79	2.3598	69.01	0.7072	14.52	10.87
-1	-1	1	4.50	0.02	4.51E+04	48.28	2.3598	69.01	0.7072	14.52	10.87
-1	-1	1	4.50	0.01	3.40E+04	46.79	2.3598	69.01	0.7072	14.52	10.87

(Continued)

AC	GR	Temp	V_a	Freq	|E*|	phi	G_{mb}	VFA	$V_b/(V_a+V_b)$	VMA	V_b
			(%)	(Hz)	(psi)	(Degree)		(%)		(%)	(%)
-1	-1	1	4.50	15.00	8.59E+05	28.07	2.3598	69.01	0.7072	14.52	10.87
-1	-1	1	4.50	10.00	7.55E+05	30.01	2.3598	69.01	0.7072	14.52	10.87
-1	-1	1	4.50	5.00	5.96E+05	33.57	2.3598	69.01	0.7072	14.52	10.87
-1	-1	1	4.50	2.00	4.20E+05	38.58	2.3598	69.01	0.7072	14.52	10.87
-1	-1	1	4.50	1.00	3.09E+05	43.07	2.3598	69.01	0.7072	14.52	10.87
-1	-1	1	4.50	0.50	2.32E+05	44.24	2.3598	69.01	0.7072	14.52	10.87
-1	-1	1	4.50	0.20	1.53E+05	46.24	2.3598	69.01	0.7072	14.52	10.87
-1	-1	1	4.50	0.10	1.10E+05	46.30	2.3598	69.01	0.7072	14.52	10.87
-1	-1	1	4.50	0.05	7.51E+04	46.05	2.3598	69.01	0.7072	14.52	10.87
-1	-1	1	4.50	0.02	5.54E+04	45.67	2.3598	69.01	0.7072	14.52	10.87
-1	-1	1	4.50	0.01	4.25E+04	41.82	2.3598	69.01	0.7072	14.52	10.87
-1	-1	1	6.12	15.00	7.67E+05	28.80	2.3197	61.67	0.6358	15.98	10.69
-1	-1	1	6.12	10.00	6.70E+05	30.90	2.3197	61.67	0.6358	15.98	10.69
-1	-1	1	6.12	5.00	5.28E+05	34.58	2.3197	61.67	0.6358	15.98	10.69
-1	-1	1	6.12	2.00	3.71E+05	39.11	2.3197	61.67	0.6358	15.98	10.69
-1	-1	1	6.12	1.00	2.76E+05	41.96	2.3197	61.67	0.6358	15.98	10.69
-1	-1	1	6.12	0.50	2.03E+05	43.66	2.3197	61.67	0.6358	15.98	10.69
-1	-1	1	6.12	0.20	1.33E+05	44.39	2.3197	61.67	0.6358	15.98	10.69
-1	-1	1	6.12	0.10	1.00E+05	43.08	2.3197	61.67	0.6358	15.98	10.69
-1	-1	1	6.12	0.05	7.21E+04	40.55	2.3197	61.67	0.6358	15.98	10.69
-1	-1	1	6.12	0.02	5.19E+04	39.49	2.3197	61.67	0.6358	15.98	10.69
-1	-1	1	6.12	0.01	4.26E+04	33.21	2.3197	61.67	0.6358	15.98	10.69
-1	-1	1	6.12	15.00	6.97E+05	30.87	2.3197	61.67	0.6358	15.98	10.69
-1	-1	1	6.12	10.00	6.06E+05	32.96	2.3197	61.67	0.6358	15.98	10.69
-1	-1	1	6.12	5.00	4.69E+05	36.73	2.3197	61.67	0.6358	15.98	10.69
-1	-1	1	6.12	2.00	3.24E+05	41.08	2.3197	61.67	0.6358	15.98	10.69
-1	-1	1	6.12	1.00	2.39E+05	43.48	2.3197	61.67	0.6358	15.98	10.69
-1	-1	1	6.12	0.50	1.76E+05	44.79	2.3197	61.67	0.6358	15.98	10.69
-1	-1	1	6.12	0.20	1.16E+05	44.60	2.3197	61.67	0.6358	15.98	10.69
-1	-1	1	6.12	0.10	8.69E+04	43.52	2.3197	61.67	0.6358	15.98	10.69
-1	-1	1	6.12	0.05	6.24E+04	40.57	2.3197	61.67	0.6358	15.98	10.69
-1	-1	1	6.12	0.02	4.74E+04	38.75	2.3197	61.67	0.6358	15.98	10.69
-1	-1	1	6.12	0.01	3.93E+04	35.23	2.3197	61.67	0.6358	15.98	10.69
-1	-1	1	7.79	15.00	6.36E+05	31.25	2.2785	55.40	0.5740	17.47	10.50
-1	-1	1	7.79	10.00	5.51E+05	33.42	2.2785	55.40	0.5740	17.47	10.50
-1	-1	1	7.79	5.00	4.23E+05	37.42	2.2785	55.40	0.5740	17.47	10.50
-1	-1	1	7.79	2.00	2.69E+05	41.03	2.2785	55.40	0.5740	17.47	10.50
-1	-1	1	7.79	1.00	2.03E+05	46.32	2.2785	55.40	0.5740	17.47	10.50
-1	-1	1	7.79	0.50	1.47E+05	47.28	2.2785	55.40	0.5740	17.47	10.50
-1	-1	1	7.79	0.20	9.45E+04	47.23	2.2785	55.40	0.5740	17.47	10.50
-1	-1	1	7.79	0.10	6.85E+04	46.39	2.2785	55.40	0.5740	17.47	10.50
-1	-1	1	7.79	0.05	4.69E+04	42.80	2.2785	55.40	0.5740	17.47	10.50
-1	-1	1	7.79	0.02	3.60E+04	36.96	2.2785	55.40	0.5740	17.47	10.50
-1	-1	1	7.79	0.01	2.94E+04	29.48	2.2785	55.40	0.5740	17.47	10.50
-1	-1	1	7.79	15.00	5.26E+05	33.69	2.2785	55.40	0.5740	17.47	10.50
-1	-1	1	7.79	10.00	4.50E+05	36.13	2.2785	55.40	0.5740	17.47	10.50
-1	-1	1	7.79	5.00	3.39E+05	40.06	2.2785	55.40	0.5740	17.47	10.50
-1	-1	1	7.79	2.00	2.20E+05	48.37	2.2785	55.40	0.5740	17.47	10.50
-1	-1	1	7.79	1.00	1.57E+05	48.40	2.2785	55.40	0.5740	17.47	10.50
-1	-1	1	7.79	0.50	1.13E+05	49.62	2.2785	55.40	0.5740	17.47	10.50
-1	-1	1	7.79	0.20	7.15E+04	49.70	2.2785	55.40	0.5740	17.47	10.50
-1	-1	1	7.79	0.10	5.08E+04	47.45	2.2785	55.40	0.5740	17.47	10.50
-1	-1	1	7.79	0.05	3.63E+04	45.05	2.2785	55.40	0.5740	17.47	10.50
-1	-1	1	7.79	0.02	2.70E+04	41.19	2.2785	55.40	0.5740	17.47	10.50
-1	-1	1	7.79	0.01	2.19E+04	33.88	2.2785	55.40	0.5740	17.47	10.50
-1	-1	-1.7	4.50	15.00	1.74E+06	13.59	2.3598	69.01	0.7072	14.52	10.87
-1	-1	-1.7	4.50	10.00	1.64E+06	14.55	2.3598	69.01	0.7072	14.52	10.87
-1	-1	-1.7	4.50	5.00	1.46E+06	16.60	2.3598	69.01	0.7072	14.52	10.87
-1	-1	-1.7	4.50	2.00	1.25E+06	19.97	2.3598	69.01	0.7072	14.52	10.87
-1	-1	-1.7	4.50	1.00	1.07E+06	22.55	2.3598	69.01	0.7072	14.52	10.87
-1	-1	-1.7	4.50	0.50	9.16E+05	25.19	2.3598	69.01	0.7072	14.52	10.87
-1	-1	-1.7	4.50	0.20	7.44E+05	30.33	2.3598	69.01	0.7072	14.52	10.87
-1	-1	-1.7	4.50	0.10	5.98E+05	34.54	2.3598	69.01	0.7072	14.52	10.87

(Continued)

AC	GR	Temp	V_a (%)	Freq (Hz)	|E*| (psi)	phi (Degree)	G_{mb}	VFA (%)	$V_b/(V_a+V_b)$	VMA (%)	V_b (%)
-1	-1	-1.7	4.50	0.05	4.66E+05	39.06	2.3598	69.01	0.7072	14.52	10.87
-1	-1	-1.7	4.50	0.02	3.33E+05	43.57	2.3598	69.01	0.7072	14.52	10.87
-1	-1	-1.7	4.50	0.01	2.46E+05	44.53	2.3598	69.01	0.7072	14.52	10.87
-1	-1	-1.6	6.42	15.00	1.48E+06	14.65	2.3124	60.48	0.6241	16.24	10.66
-1	-1	-1.6	6.42	10.00	1.38E+06	15.69	2.3124	60.48	0.6241	16.24	10.66
-1	-1	-1.6	6.42	5.00	1.23E+06	17.65	2.3124	60.48	0.6241	16.24	10.66
-1	-1	-1.6	6.42	2.00	1.05E+06	20.73	2.3124	60.48	0.6241	16.24	10.66
-1	-1	-1.6	6.42	1.00	8.87E+05	23.41	2.3124	60.48	0.6241	16.24	10.66
-1	-1	-1.6	6.42	0.50	7.72E+05	24.76	2.3124	60.48	0.6241	16.24	10.66
-1	-1	-1.6	6.42	0.20	6.24E+05	28.61	2.3124	60.48	0.6241	16.24	10.66
-1	-1	-1.6	6.42	0.10	5.13E+05	31.06	2.3124	60.48	0.6241	16.24	10.66
-1	-1	-1.6	6.42	0.05	4.05E+05	33.48	2.3124	60.48	0.6241	16.24	10.66
-1	-1	-1.6	6.42	0.02	2.96E+05	35.91	2.3124	60.48	0.6241	16.24	10.66
-1	-1	-1.6	6.42	0.01	2.35E+05	38.49	2.3124	60.48	0.6241	16.24	10.66
-1	-1	2.6	4.50	15.00	5.04E+05	37.44	2.3598	69.01	0.7072	14.52	10.87
-1	-1	2.6	4.50	10.00	4.23E+05	39.38	2.3598	69.01	0.7072	14.52	10.87
-1	-1	2.6	4.50	5.00	3.12E+05	42.93	2.3598	69.01	0.7072	14.52	10.87
-1	-1	2.6	4.50	2.00	2.07E+05	45.39	2.3598	69.01	0.7072	14.52	10.87
-1	-1	2.6	4.50	1.00	1.48E+05	46.92	2.3598	69.01	0.7072	14.52	10.87
-1	-1	2.6	4.50	0.50	1.04E+05	48.47	2.3598	69.01	0.7072	14.52	10.87
-1	-1	2.6	4.50	0.20	6.82E+04	47.08	2.3598	69.01	0.7072	14.52	10.87
-1	-1	2.6	4.50	0.10	4.91E+04	44.60	2.3598	69.01	0.7072	14.52	10.87
-1	-1	2.6	4.50	0.05	3.74E+04	43.25	2.3598	69.01	0.7072	14.52	10.87
-1	-1	2.6	4.50	0.02	2.90E+04	35.38	2.3598	69.01	0.7072	14.52	10.87
-1	-1	2.6	4.50	0.01	2.32E+04	34.92	2.3598	69.01	0.7072	14.52	10.87
-1	-1	2.6	6.42	15.00	3.85E+05	40.50	2.3124	60.48	0.6241	16.24	10.66
-1	-1	2.6	6.42	10.00	3.18E+05	43.11	2.3124	60.48	0.6241	16.24	10.66
-1	-1	2.6	6.42	5.00	2.29E+05	46.66	2.3124	60.48	0.6241	16.24	10.66
-1	-1	2.6	6.42	2.00	1.45E+05	50.46	2.3124	60.48	0.6241	16.24	10.66
-1	-1	2.6	6.42	1.00	1.00E+05	51.70	2.3124	60.48	0.6241	16.24	10.66
-1	-1	2.6	6.42	0.50	7.14E+04	51.60	2.3124	60.48	0.6241	16.24	10.66
-1	-1	2.6	6.42	0.20	4.58E+04	50.01	2.3124	60.48	0.6241	16.24	10.66
-1	-1	2.6	6.42	0.10	3.38E+04	49.38	2.3124	60.48	0.6241	16.24	10.66
-1	-1	2.6	6.42	0.05	2.62E+04	43.21	2.3124	60.48	0.6241	16.24	10.66
-1	-1	2.6	6.42	0.02	1.97E+04	41.62	2.3124	60.48	0.6241	16.24	10.66
-1	-1	2.6	6.42	0.01	1.80E+04	38.67	2.3124	60.48	0.6241	16.24	10.66
1	1	-1	3.44	15.00	1.55E+06	14.81	2.3975	74.35	0.7624	13.42	11.05
1	1	-1	3.44	10.00	1.46E+06	15.80	2.3975	74.35	0.7624	13.42	11.05
1	1	-1	3.44	5.00	1.29E+06	17.74	2.3975	74.35	0.7624	13.42	11.05
1	1	-1	3.44	2.00	1.07E+06	20.71	2.3975	74.35	0.7624	13.42	11.05
1	1	-1	3.44	1.00	9.12E+05	23.15	2.3975	74.35	0.7624	13.42	11.05
1	1	-1	3.44	0.50	7.74E+05	26.35	2.3975	74.35	0.7624	13.42	11.05
1	1	-1	3.44	0.20	5.80E+05	29.58	2.3975	74.35	0.7624	13.42	11.05
1	1	-1	3.44	0.10	4.50E+05	32.03	2.3975	74.35	0.7624	13.42	11.05
1	1	-1	3.44	0.05	4.01E+05	45.07	2.3975	74.35	0.7624	13.42	11.05
1	1	-1	3.44	0.02	2.62E+05	36.99	2.3975	74.35	0.7624	13.42	11.05
1	1	-1	3.44	0.01	1.97E+05	41.00	2.3975	74.35	0.7624	13.42	11.05
1	1	-1	5.88	15.00	1.37E+06	15.67	2.3369	62.31	0.6467	15.61	10.77
1	1	-1	5.88	10.00	1.28E+06	16.80	2.3369	62.31	0.6467	15.61	10.77
1	1	-1	5.88	5.00	1.12E+06	19.03	2.3369	62.31	0.6467	15.61	10.77
1	1	-1	5.88	2.00	9.21E+05	22.31	2.3369	62.31	0.6467	15.61	10.77
1	1	-1	5.88	1.00	7.75E+05	25.17	2.3369	62.31	0.6467	15.61	10.77
1	1	-1	5.88	0.50	6.37E+05	27.79	2.3369	62.31	0.6467	15.61	10.77
1	1	-1	5.88	0.20	4.77E+05	31.74	2.3369	62.31	0.6467	15.61	10.77
1	1	-1	5.88	0.10	3.74E+05	34.72	2.3369	62.31	0.6467	15.61	10.77
1	1	-1	5.88	0.05	2.80E+05	35.69	2.3369	62.31	0.6467	15.61	10.77
1	1	-1	5.88	0.02	1.98E+05	40.53	2.3369	62.31	0.6467	15.61	10.77
1	1	-1	5.88	0.01	1.46E+05	42.07	2.3369	62.31	0.6467	15.61	10.77
1	1	-1	6.09	15.00	1.38E+06	14.66	2.3318	61.45	0.6383	15.79	10.74
1	1	-1	6.09	10.00	1.30E+06	15.63	2.3318	61.45	0.6383	15.79	10.74
1	1	-1	6.09	5.00	1.15E+06	17.66	2.3318	61.45	0.6383	15.79	10.74
1	1	-1	6.09	2.00	9.55E+05	20.74	2.3318	61.45	0.6383	15.79	10.74

(Continued)

AC	GR	Temp	V_a	Freq	|E*|	phi	G_{mb}	VFA	$V_b/(V_a+V_b)$	VMA	V_b
			(%)	(Hz)	(psi)	(Degree)		(%)		(%)	(%)
1	1	-1	6.09	1.00	8.18E+05	23.77	2.3318	61.45	0.6383	15.79	10.74
1	1	-1	6.09	0.50	6.83E+05	26.77	2.3318	61.45	0.6383	15.79	10.74
1	1	-1	6.09	0.20	5.17E+05	30.67	2.3318	61.45	0.6383	15.79	10.74
1	1	-1	6.09	0.10	4.07E+05	33.54	2.3318	61.45	0.6383	15.79	10.74
1	1	-1	6.09	0.05	3.07E+05	35.74	2.3318	61.45	0.6383	15.79	10.74
1	1	-1	6.09	0.02	2.22E+05	40.24	2.3318	61.45	0.6383	15.79	10.74
1	1	-1	6.09	0.01	1.63E+05	42.25	2.3318	61.45	0.6383	15.79	10.74
1	1	-1	7.07	15.00	1.28E+06	15.84	2.3075	57.60	0.6007	16.67	10.63
1	1	-1	7.07	10.00	1.19E+06	16.93	2.3075	57.60	0.6007	16.67	10.63
1	1	-1	7.07	5.00	1.05E+06	18.99	2.3075	57.60	0.6007	16.67	10.63
1	1	-1	7.07	2.00	8.64E+05	22.17	2.3075	57.60	0.6007	16.67	10.63
1	1	-1	7.07	1.00	7.28E+05	24.72	2.3075	57.60	0.6007	16.67	10.63
1	1	-1	7.07	0.50	5.98E+05	27.26	2.3075	57.60	0.6007	16.67	10.63
1	1	-1	7.07	0.20	3.85E+05	24.52	2.3075	57.60	0.6007	16.67	10.63
1	1	-1	7.07	0.10	3.88E+05	34.24	2.3075	57.60	0.6007	16.67	10.63
1	1	-1	7.07	0.05	3.91E+05	43.96	2.3075	57.60	0.6007	16.67	10.63
1	1	-1	7.07	0.02	1.95E+05	37.77	2.3075	57.60	0.6007	16.67	10.63
1	1	-1	7.07	0.01	1.46E+05	38.49	2.3075	57.60	0.6007	16.67	10.63
1	1	0	3.44	15.00	1.26E+06	18.62	2.3975	74.35	0.7624	13.42	11.05
1	1	0	3.44	10.00	1.16E+06	19.87	2.3975	74.35	0.7624	13.42	11.05
1	1	0	3.44	5.00	9.98E+05	22.27	2.3975	74.35	0.7624	13.42	11.05
1	1	0	3.44	2.00	7.94E+05	25.70	2.3975	74.35	0.7624	13.42	11.05
1	1	0	3.44	1.00	6.50E+05	28.59	2.3975	74.35	0.7624	13.42	11.05
1	1	0	3.44	0.50	5.24E+05	31.39	2.3975	74.35	0.7624	13.42	11.05
1	1	0	3.44	0.20	3.82E+05	34.67	2.3975	74.35	0.7624	13.42	11.05
1	1	0	3.44	0.10	2.96E+05	37.05	2.3975	74.35	0.7624	13.42	11.05
1	1	0	3.44	0.05	2.06E+05	36.87	2.3975	74.35	0.7624	13.42	11.05
1	1	0	3.44	0.02	1.53E+05	40.62	2.3975	74.35	0.7624	13.42	11.05
1	1	0	3.44	0.01	1.15E+05	40.73	2.3975	74.35	0.7624	13.42	11.05
1	1	0	5.88	15.00	1.19E+06	18.71	2.3369	62.31	0.6467	15.61	10.77
1	1	0	5.88	10.00	1.09E+06	20.03	2.3369	62.31	0.6467	15.61	10.77
1	1	0	5.88	5.00	9.36E+05	22.82	2.3369	62.31	0.6467	15.61	10.77
1	1	0	5.88	2.00	7.42E+05	26.60	2.3369	62.31	0.6467	15.61	10.77
1	1	0	5.88	1.00	6.05E+05	29.75	2.3369	62.31	0.6467	15.61	10.77
1	1	0	5.88	0.50	4.83E+05	32.61	2.3369	62.31	0.6467	15.61	10.77
1	1	0	5.88	0.20	3.46E+05	36.28	2.3369	62.31	0.6467	15.61	10.77
1	1	0	5.88	0.10	2.65E+05	38.28	2.3369	62.31	0.6467	15.61	10.77
1	1	0	5.88	0.05	1.90E+05	39.23	2.3369	62.31	0.6467	15.61	10.77
1	1	0	5.88	0.02	1.34E+05	40.47	2.3369	62.31	0.6467	15.61	10.77
1	1	0	5.88	0.01	1.02E+05	41.14	2.3369	62.31	0.6467	15.61	10.77
1	1	0	6.09	15.00	1.13E+06	18.59	2.3318	61.45	0.6383	15.79	10.74
1	1	0	6.09	10.00	1.04E+06	20.02	2.3318	61.45	0.6383	15.79	10.74
1	1	0	6.09	5.00	8.86E+05	22.79	2.3318	61.45	0.6383	15.79	10.74
1	1	0	6.09	2.00	6.99E+05	26.75	2.3318	61.45	0.6383	15.79	10.74
1	1	0	6.09	1.00	5.66E+05	29.99	2.3318	61.45	0.6383	15.79	10.74
1	1	0	6.09	0.50	4.50E+05	33.13	2.3318	61.45	0.6383	15.79	10.74
1	1	0	6.09	0.20	3.21E+05	36.92	2.3318	61.45	0.6383	15.79	10.74
1	1	0	6.09	0.10	2.43E+05	39.08	2.3318	61.45	0.6383	15.79	10.74
1	1	0	6.09	0.05	1.73E+05	40.26	2.3318	61.45	0.6383	15.79	10.74
1	1	0	6.09	0.02	1.21E+05	42.27	2.3318	61.45	0.6383	15.79	10.74
1	1	0	6.09	0.01	9.02E+04	43.96	2.3318	61.45	0.6383	15.79	10.74
1	1	0	7.07	15.00	1.03E+06	19.65	2.3075	57.60	0.6007	16.67	10.63
1	1	0	7.07	10.00	9.42E+05	21.02	2.3075	57.60	0.6007	16.67	10.63
1	1	0	7.07	5.00	7.97E+05	23.67	2.3075	57.60	0.6007	16.67	10.63
1	1	0	7.07	2.00	6.23E+05	27.32	2.3075	57.60	0.6007	16.67	10.63
1	1	0	7.07	1.00	5.04E+05	30.32	2.3075	57.60	0.6007	16.67	10.63
1	1	0	7.07	0.50	4.00E+05	33.01	2.3075	57.60	0.6007	16.67	10.63
1	1	0	7.07	0.20	2.85E+05	36.39	2.3075	57.60	0.6007	16.67	10.63
1	1	0	7.07	0.10	2.21E+05	38.39	2.3075	57.60	0.6007	16.67	10.63
1	1	0	7.07	0.05	1.52E+05	38.16	2.3075	57.60	0.6007	16.67	10.63
1	1	0	7.07	0.02	1.15E+05	40.93	2.3075	57.60	0.6007	16.67	10.63
1	1	0	7.07	0.01	8.26E+04	40.26	2.3075	57.60	0.6007	16.67	10.63
1	1	1	3.44	15.00	1.03E+06	22.00	2.3975	74.35	0.7624	13.42	11.05

(Continued)

AC	GR	Temp	V_a	Freq	$\lvert E^* \rvert$	phi	G_{mb}	VFA	$V_b/(V_a+V_b)$	VMA	V_b
			(%)	(Hz)	(psi)	(Degree)		(%)		(%)	(%)
1	1	1	3.44	10.00	9.26E+05	24.00	2.3975	74.35	0.7624	13.42	11.05
1	1	1	3.44	5.00	7.68E+05	27.00	2.3975	74.35	0.7624	13.42	11.05
1	1	1	3.44	2.00	5.82E+05	31.00	2.3975	74.35	0.7624	13.42	11.05
1	1	1	3.44	1.00	4.59E+05	34.00	2.3975	74.35	0.7624	13.42	11.05
1	1	1	3.44	0.50	3.56E+05	36.00	2.3975	74.35	0.7624	13.42	11.05
1	1	1	3.44	0.20	2.48E+05	39.00	2.3975	74.35	0.7624	13.42	11.05
1	1	1	3.44	0.10	1.87E+05	41.00	2.3975	74.35	0.7624	13.42	11.05
1	1	1	3.44	0.05	1.25E+05	41.00	2.3975	74.35	0.7624	13.42	11.05
1	1	1	3.44	0.02	9.15E+04	43.00	2.3975	74.35	0.7624	13.42	11.05
1	1	1	3.44	0.01	6.86E+04	42.00	2.3975	74.35	0.7624	13.42	11.05
1	1	1	5.88	15.00	8.54E+05	24.88	2.3369	62.31	0.6467	15.61	10.77
1	1	1	5.88	10.00	7.62E+05	26.52	2.3369	62.31	0.6467	15.61	10.77
1	1	1	5.88	5.00	6.19E+05	29.67	2.3369	62.31	0.6467	15.61	10.77
1	1	1	5.88	2.00	4.58E+05	33.32	2.3369	62.31	0.6467	15.61	10.77
1	1	1	5.88	1.00	3.56E+05	35.95	2.3369	62.31	0.6467	15.61	10.77
1	1	1	5.88	0.50	2.76E+05	37.69	2.3369	62.31	0.6467	15.61	10.77
1	1	1	5.88	0.20	1.91E+05	39.01	2.3369	62.31	0.6467	15.61	10.77
1	1	1	5.88	0.10	1.46E+05	38.60	2.3369	62.31	0.6467	15.61	10.77
1	1	1	5.88	0.05	1.04E+05	36.25	2.3369	62.31	0.6467	15.61	10.77
1	1	1	5.88	0.02	8.10E+04	35.92	2.3369	62.31	0.6467	15.61	10.77
1	1	1	5.88	0.01	6.53E+04	34.25	2.3369	62.31	0.6467	15.61	10.77
1	1	1	6.09	15.00	7.86E+05	25.32	2.3318	61.45	0.6383	15.79	10.74
1	1	1	6.09	10.00	6.99E+05	27.16	2.3318	61.45	0.6383	15.79	10.74
1	1	1	6.09	5.00	5.66E+05	30.34	2.3318	61.45	0.6383	15.79	10.74
1	1	1	6.09	2.00	4.16E+05	34.30	2.3318	61.45	0.6383	15.79	10.74
1	1	1	6.09	1.00	3.21E+05	36.94	2.3318	61.45	0.6383	15.79	10.74
1	1	1	6.09	0.50	2.47E+05	38.61	2.3318	61.45	0.6383	15.79	10.74
1	1	1	6.09	0.20	1.70E+05	39.97	2.3318	61.45	0.6383	15.79	10.74
1	1	1	6.09	0.10	1.30E+05	39.69	2.3318	61.45	0.6383	15.79	10.74
1	1	1	6.09	0.05	9.09E+04	36.48	2.3318	61.45	0.6383	15.79	10.74
1	1	1	6.09	0.02	7.09E+04	37.20	2.3318	61.45	0.6383	15.79	10.74
1	1	1	6.09	0.01	5.71E+04	33.41	2.3318	61.45	0.6383	15.79	10.74
1	1	1	7.07	15.00	7.01E+05	27.00	2.3075	57.60	0.6007	16.67	10.63
1	1	1	7.07	10.00	6.21E+05	29.00	2.3075	57.60	0.6007	16.67	10.63
1	1	1	7.07	5.00	4.95E+05	32.00	2.3075	57.60	0.6007	16.67	10.63
1	1	1	7.07	2.00	3.57E+05	36.00	2.3075	57.60	0.6007	16.67	10.63
1	1	1	7.07	1.00	2.67E+05	40.00	2.3075	57.60	0.6007	16.67	10.63
1	1	1	7.07	0.50	2.01E+05	42.00	2.3075	57.60	0.6007	16.67	10.63
1	1	1	7.07	0.20	1.34E+05	44.00	2.3075	57.60	0.6007	16.67	10.63
1	1	1	7.07	0.10	9.73E+04	46.00	2.3075	57.60	0.6007	16.67	10.63
1	1	1	7.07	0.05	6.38E+04	47.00	2.3075	57.60	0.6007	16.67	10.63
1	1	1	7.07	0.02	4.44E+04	49.00	2.3075	57.60	0.6007	16.67	10.63
1	1	1	7.07	0.01	3.26E+04	48.00	2.3075	57.60	0.6007	16.67	10.63
1	1	2.4	3.44	15.00	6.73E+05	30.20	2.3975	74.35	0.7624	13.42	11.05
1	1	2.4	3.44	10.00	5.86E+05	32.03	2.3975	74.35	0.7624	13.42	11.05
1	1	2.4	3.44	5.00	4.57E+05	35.15	2.3975	74.35	0.7624	13.42	11.05
1	1	2.4	3.44	2.00	3.20E+05	38.95	2.3975	74.35	0.7624	13.42	11.05
1	1	2.4	3.44	1.00	2.37E+05	41.95	2.3975	74.35	0.7624	13.42	11.05
1	1	2.4	3.44	0.50	1.77E+05	43.56	2.3975	74.35	0.7624	13.42	11.05
1	1	2.4	3.44	0.20	1.18E+05	45.18	2.3975	74.35	0.7624	13.42	11.05
1	1	2.4	3.44	0.10	8.47E+04	44.85	2.3975	74.35	0.7624	13.42	11.05
1	1	2.4	3.44	0.05	5.85E+04	46.22	2.3975	74.35	0.7624	13.42	11.05
1	1	2.4	3.44	0.02	4.32E+04	47.52	2.3975	74.35	0.7624	13.42	11.05
1	1	2.4	3.44	0.01	3.10E+04	44.70	2.3975	74.35	0.7624	13.42	11.05
1	1	2.6	7.07	15.00	4.36E+05	34.46	2.3075	57.60	0.6007	16.67	10.63
1	1	2.6	7.07	10.00	3.72E+05	36.34	2.3075	57.60	0.6007	16.67	10.63
1	1	2.6	7.07	5.00	2.80E+05	39.37	2.3075	57.60	0.6007	16.67	10.63
1	1	2.6	7.07	2.00	1.90E+05	44.22	2.3075	57.60	0.6007	16.67	10.63
1	1	2.6	7.07	1.00	1.38E+05	45.10	2.3075	57.60	0.6007	16.67	10.63
1	1	2.6	7.07	0.50	1.00E+05	46.53	2.3075	57.60	0.6007	16.67	10.63
1	1	2.6	7.07	0.20	6.52E+04	47.67	2.3075	57.60	0.6007	16.67	10.63
1	1	2.6	7.07	0.10	4.84E+04	48.01	2.3075	57.60	0.6007	16.67	10.63
1	1	2.6	7.07	0.05	3.25E+04	46.53	2.3075	57.60	0.6007	16.67	10.63

(Continued)

AC	GR	Temp	V_a	Freq	|E*|	phi	G_{mb}	VFA	$V_b/(V_a+V_b)$	VMA	V_b
			(%)	(Hz)	(psi)	(Degree)		(%)		(%)	(%)
1	1	2.6	7.07	0.02	2.47E+04	49.35	2.3075	57.60	0.6007	16.67	10.63
1	1	2.6	7.07	0.01	1.91E+04	48.75	2.3075	57.60	0.6007	16.67	10.63
-1	1	-1	3.73	15.00	1.52E+06	16.95	2.3904	71.81	0.7253	13.22	9.84
-1	1	-1	3.73	10.00	1.41E+06	18.35	2.3904	71.81	0.7253	13.22	9.84
-1	1	-1	3.73	5.00	1.22E+06	21.11	2.3904	71.81	0.7253	13.22	9.84
-1	1	-1	3.73	2.00	9.77E+05	25.20	2.3904	71.81	0.7253	13.22	9.84
-1	1	-1	3.73	1.00	7.99E+05	28.97	2.3904	71.81	0.7253	13.22	9.84
-1	1	-1	3.73	0.50	6.07E+05	31.56	2.3904	71.81	0.7253	13.22	9.84
-1	1	-1	3.73	0.20	3.89E+05	32.33	2.3904	71.81	0.7253	13.22	9.84
-1	1	-1	3.73	0.10	2.84E+05	33.56	2.3904	71.81	0.7253	13.22	9.84
-1	1	-1	3.73	0.05	1.99E+05	34.46	2.3904	71.81	0.7253	13.22	9.84
-1	1	-1	3.73	0.02	1.55E+05	47.30	2.3904	71.81	0.7253	13.22	9.84
-1	1	-1	3.73	0.01	1.07E+05	49.70	2.3904	71.81	0.7253	13.22	9.84
-1	1	-1	7.45	15.00	1.04E+06	20.72	2.2982	55.08	0.5597	16.57	9.46
-1	1	-1	7.45	10.00	9.46E+05	22.38	2.2982	55.08	0.5597	16.57	9.46
-1	1	-1	7.45	5.00	7.94E+05	25.45	2.2982	55.08	0.5597	16.57	9.46
-1	1	-1	7.45	2.00	6.07E+05	29.97	2.2982	55.08	0.5597	16.57	9.46
-1	1	-1	7.45	1.00	4.78E+05	33.73	2.2982	55.08	0.5597	16.57	9.46
-1	1	-1	7.45	0.50	3.29E+05	30.44	2.2982	55.08	0.5597	16.57	9.46
-1	1	-1	7.45	0.20	2.19E+05	31.00	2.2982	55.08	0.5597	16.57	9.46
-1	1	-1	7.45	0.10	1.87E+05	45.03	2.2982	55.08	0.5597	16.57	9.46
-1	1	-1	7.45	0.05	8.16E+04	45.00	2.2982	55.08	0.5597	16.57	9.46
-1	1	-1	7.45	0.02	8.46E+04	47.03	2.2982	55.08	0.5597	16.57	9.46
-1	1	-1	7.45	0.01	6.54E+04	47.24	2.2982	55.08	0.5597	16.57	9.46
-1	1	-1	7.80	15.00	1.14E+06	18.29	2.2893	53.83	0.5472	16.89	9.43
-1	1	-1	7.80	10.00	1.05E+06	19.76	2.2893	53.83	0.5472	16.89	9.43
-1	1	-1	7.80	5.00	8.95E+05	22.62	2.2893	53.83	0.5472	16.89	9.43
-1	1	-1	7.80	2.00	7.09E+05	26.70	2.2893	53.83	0.5472	16.89	9.43
-1	1	-1	7.80	1.00	5.75E+05	30.21	2.2893	53.83	0.5472	16.89	9.43
-1	1	-1	7.80	0.50	4.57E+05	33.49	2.2893	53.83	0.5472	16.89	9.43
-1	1	-1	7.80	0.20	3.24E+05	37.44	2.2893	53.83	0.5472	16.89	9.43
-1	1	-1	7.80	0.10	2.46E+05	39.84	2.2893	53.83	0.5472	16.89	9.43
-1	1	-1	7.80	0.05	1.68E+05	40.92	2.2893	53.83	0.5472	16.89	9.43
-1	1	-1	7.80	0.02	1.23E+05	43.66	2.2893	53.83	0.5472	16.89	9.43
-1	1	-1	7.80	0.01	8.74E+04	40.54	2.2893	53.83	0.5472	16.89	9.43
-1	1	-1	9.27	15.00	8.50E+05	19.65	2.2499	49.44	0.5000	18.32	9.26
-1	1	-1	9.27	10.00	7.79E+05	21.05	2.2499	49.44	0.5000	18.32	9.26
-1	1	-1	9.27	5.00	6.62E+05	23.71	2.2499	49.44	0.5000	18.32	9.26
-1	1	-1	9.27	2.00	5.18E+05	27.78	2.2499	49.44	0.5000	18.32	9.26
-1	1	-1	9.27	1.00	4.17E+05	31.03	2.2499	49.44	0.5000	18.32	9.26
-1	1	-1	9.27	0.50	3.30E+05	34.01	2.2499	49.44	0.5000	18.32	9.26
-1	1	-1	9.27	0.20	2.35E+05	37.28	2.2499	49.44	0.5000	18.32	9.26
-1	1	-1	9.27	0.10	1.79E+05	38.73	2.2499	49.44	0.5000	18.32	9.26
-1	1	-1	9.27	0.05	1.29E+05	39.34	2.2499	49.44	0.5000	18.32	9.26
-1	1	-1	9.27	0.02	9.25E+04	40.85	2.2499	49.44	0.5000	18.32	9.26
-1	1	-1	9.27	0.01	6.76E+04	41.17	2.2499	49.44	0.5000	18.32	9.26
-1	1	-1	9.39	15.00	8.31E+05	20.27	2.2530	48.46	0.4970	18.21	9.28
-1	1	-1	9.39	10.00	7.58E+05	21.75	2.2530	48.46	0.4970	18.21	9.28
-1	1	-1	9.39	5.00	6.41E+05	24.65	2.2530	48.46	0.4970	18.21	9.28
-1	1	-1	9.39	2.00	4.96E+05	28.98	2.2530	48.46	0.4970	18.21	9.28
-1	1	-1	9.39	1.00	3.96E+05	32.24	2.2530	48.46	0.4970	18.21	9.28
-1	1	-1	9.39	0.50	3.11E+05	35.37	2.2530	48.46	0.4970	18.21	9.28
-1	1	-1	9.39	0.20	2.20E+05	38.71	2.2530	48.46	0.4970	18.21	9.28
-1	1	-1	9.39	0.10	1.66E+05	40.20	2.2530	48.46	0.4970	18.21	9.28
-1	1	-1	9.39	0.05	1.15E+05	40.33	2.2530	48.46	0.4970	18.21	9.28
-1	1	-1	9.39	0.02	8.49E+04	42.94	2.2530	48.46	0.4970	18.21	9.28
-1	1	-1	9.39	0.01	6.41E+04	40.34	2.2530	48.46	0.4970	18.21	9.28
-1	1	-1	9.39	15.00	7.93E+05	21.06	2.2530	48.46	0.4970	18.21	9.28
-1	1	-1	9.39	10.00	7.20E+05	22.66	2.2530	48.46	0.4970	18.21	9.28
-1	1	-1	9.39	5.00	6.04E+05	25.75	2.2530	48.46	0.4970	18.21	9.28
-1	1	-1	9.39	2.00	4.61E+05	30.27	2.2530	48.46	0.4970	18.21	9.28
-1	1	-1	9.39	1.00	3.65E+05	33.83	2.2530	48.46	0.4970	18.21	9.28
-1	1	-1	9.39	0.50	2.83E+05	37.21	2.2530	48.46	0.4970	18.21	9.28

(Continued)

AC	GR	Temp	V_a (%)	Freq (Hz)	|E*| (psi)	phi (Degree)	G_{mb}	VFA (%)	$V_b/(V_a+V_b)$	VMA (%)	V_b (%)
-1	1	-1	9.39	0.20	1.94E+05	41.51	2.2530	48.46	0.4970	18.21	9.28
-1	1	-1	9.39	0.10	1.42E+05	43.66	2.2530	48.46	0.4970	18.21	9.28
-1	1	-1	9.39	0.05	9.62E+04	46.31	2.2530	48.46	0.4970	18.21	9.28
-1	1	-1	9.39	0.02	6.52E+04	47.87	2.2530	48.46	0.4970	18.21	9.28
-1	1	-1	9.39	0.01	4.81E+04	49.63	2.2530	48.46	0.4970	18.21	9.28
-1	1	0	3.73	15.00	1.16E+06	22.96	2.3904	71.81	0.7253	13.22	9.84
-1	1	0	3.73	10.00	1.04E+06	24.92	2.3904	71.81	0.7253	13.22	9.84
-1	1	0	3.73	5.00	8.58E+05	28.67	2.3904	71.81	0.7253	13.22	9.84
-1	1	0	3.73	2.00	6.36E+05	33.94	2.3904	71.81	0.7253	13.22	9.84
-1	1	0	3.73	1.00	4.89E+05	38.20	2.3904	71.81	0.7253	13.22	9.84
-1	1	0	3.73	0.50	3.66E+05	42.04	2.3904	71.81	0.7253	13.22	9.84
-1	1	0	3.73	0.20	2.41E+05	46.16	2.3904	71.81	0.7253	13.22	9.84
-1	1	0	3.73	0.10	1.72E+05	48.66	2.3904	71.81	0.7253	13.22	9.84
-1	1	0	3.73	0.05	1.11E+05	47.64	2.3904	71.81	0.7253	13.22	9.84
-1	1	0	3.73	0.02	7.67E+04	48.54	2.3904	71.81	0.7253	13.22	9.84
-1	1	0	3.73	0.01	5.62E+04	46.87	2.3904	71.81	0.7253	13.22	9.84
-1	1	0	3.86	15.00	1.29E+06	20.00	2.3872	71.07	0.7181	13.34	9.83
-1	1	0	3.86	10.00	1.17E+06	22.00	2.3872	71.07	0.7181	13.34	9.83
-1	1	0	3.86	5.00	9.91E+05	25.00	2.3872	71.07	0.7181	13.34	9.83
-1	1	0	3.86	2.00	7.63E+05	29.00	2.3872	71.07	0.7181	13.34	9.83
-1	1	0	3.86	1.00	6.05E+05	32.00	2.3872	71.07	0.7181	13.34	9.83
-1	1	0	3.86	0.50	4.66E+05	35.00	2.3872	71.07	0.7181	13.34	9.83
-1	1	0	3.86	0.20	3.30E+05	40.00	2.3872	71.07	0.7181	13.34	9.83
-1	1	0	3.86	0.10	2.45E+05	42.00	2.3872	71.07	0.7181	13.34	9.83
-1	1	0	3.86	0.05	1.73E+05	41.00	2.3872	71.07	0.7181	13.34	9.83
-1	1	0	3.86	0.02	1.21E+05	43.00	2.3872	71.07	0.7181	13.34	9.83
-1	1	0	3.86	0.01	9.13E+04	42.00	2.3872	71.07	0.7181	13.34	9.83
-1	1	0	7.45	15.00	8.47E+05	24.95	2.2982	55.08	0.5597	16.57	9.46
-1	1	0	7.45	10.00	7.56E+05	26.82	2.2982	55.08	0.5597	16.57	9.46
-1	1	0	7.45	5.00	6.11E+05	30.34	2.2982	55.08	0.5597	16.57	9.46
-1	1	0	7.45	2.00	4.47E+05	35.21	2.2982	55.08	0.5597	16.57	9.46
-1	1	0	7.45	1.00	3.38E+05	39.41	2.2982	55.08	0.5597	16.57	9.46
-1	1	0	7.45	0.50	2.55E+05	41.66	2.2982	55.08	0.5597	16.57	9.46
-1	1	0	7.45	0.20	1.70E+05	44.22	2.2982	55.08	0.5597	16.57	9.46
-1	1	0	7.45	0.10	1.20E+05	45.05	2.2982	55.08	0.5597	16.57	9.46
-1	1	0	7.45	0.05	8.28E+04	44.47	2.2982	55.08	0.5597	16.57	9.46
-1	1	0	7.45	0.02	6.07E+04	43.52	2.2982	55.08	0.5597	16.57	9.46
-1	1	0	7.45	0.01	4.47E+04	39.44	2.2982	55.08	0.5597	16.57	9.46
-1	1	0	7.45	15.00	7.67E+05	26.00	2.2982	55.08	0.5597	16.57	9.46
-1	1	0	7.45	10.00	6.83E+05	28.00	2.2982	55.08	0.5597	16.57	9.46
-1	1	0	7.45	5.00	5.50E+05	31.00	2.2982	55.08	0.5597	16.57	9.46
-1	1	0	7.45	2.00	4.01E+05	37.00	2.2982	55.08	0.5597	16.57	9.46
-1	1	0	7.45	1.00	3.06E+05	40.00	2.2982	55.08	0.5597	16.57	9.46
-1	1	0	7.45	0.50	2.25E+05	43.00	2.2982	55.08	0.5597	16.57	9.46
-1	1	0	7.45	0.20	1.49E+05	46.00	2.2982	55.08	0.5597	16.57	9.46
-1	1	0	7.45	0.10	1.08E+05	47.00	2.2982	55.08	0.5597	16.57	9.46
-1	1	0	7.45	0.05	7.17E+04	46.00	2.2982	55.08	0.5597	16.57	9.46
-1	1	0	7.45	0.02	5.32E+04	48.00	2.2982	55.08	0.5597	16.57	9.46
-1	1	0	7.45	0.01	3.79E+04	44.00	2.2982	55.08	0.5597	16.57	9.46
-1	1	0	9.39	15.00	6.84E+05	26.41	2.2530	48.46	0.4970	18.21	9.28
-1	1	0	9.39	10.00	6.10E+05	28.40	2.2530	48.46	0.4970	18.21	9.28
-1	1	0	9.39	5.00	4.90E+05	31.89	2.2530	48.46	0.4970	18.21	9.28
-1	1	0	9.39	2.00	3.64E+05	36.47	2.2530	48.46	0.4970	18.21	9.28
-1	1	0	9.39	1.00	2.92E+05	39.87	2.2530	48.46	0.4970	18.21	9.28
-1	1	0	9.39	0.50	2.01E+05	42.29	2.2530	48.46	0.4970	18.21	9.28
-1	1	0	9.39	0.20	1.34E+05	44.37	2.2530	48.46	0.4970	18.21	9.28
-1	1	0	9.39	0.10	9.78E+04	44.46	2.2530	48.46	0.4970	18.21	9.28
-1	1	0	9.39	0.05	6.73E+04	44.03	2.2530	48.46	0.4970	18.21	9.28
-1	1	0	9.39	0.02	4.96E+04	42.81	2.2530	48.46	0.4970	18.21	9.28
-1	1	0	9.39	0.01	3.75E+04	40.07	2.2530	48.46	0.4970	18.21	9.28
-1	1	0	9.39	15.00	5.87E+05	26.99	2.2530	48.46	0.4970	18.21	9.28
-1	1	0	9.39	10.00	5.16E+05	29.09	2.2530	48.46	0.4970	18.21	9.28
-1	1	0	9.39	5.00	4.11E+05	32.52	2.2530	48.46	0.4970	18.21	9.28

(Continued)

AC	GR	Temp	V_a	Freq	|E*|	phi	G_{mb}	VFA	$V_b/(V_a+V_b)$	VMA	V_b
			(%)	(Hz)	(psi)	(Degree)		(%)		(%)	(%)
-1	1	0	9.39	2.00	2.94E+05	36.80	2.2530	48.46	0.4970	18.21	9.28
-1	1	0	9.39	1.00	2.23E+05	39.84	2.2530	48.46	0.4970	18.21	9.28
-1	1	0	9.39	0.50	1.69E+05	41.41	2.2530	48.46	0.4970	18.21	9.28
-1	1	0	9.39	0.20	1.15E+05	42.68	2.2530	48.46	0.4970	18.21	9.28
-1	1	0	9.39	0.10	8.55E+04	41.83	2.2530	48.46	0.4970	18.21	9.28
-1	1	0	9.39	0.05	6.08E+04	40.48	2.2530	48.46	0.4970	18.21	9.28
-1	1	0	9.39	0.02	4.70E+04	38.16	2.2530	48.46	0.4970	18.21	9.28
-1	1	0	9.39	0.01	3.48E+04	35.23	2.2530	48.46	0.4970	18.21	9.28
-1	1	1	3.86	15.00	9.29E+05	26.90	2.3872	71.07	0.7181	13.34	9.83
-1	1	1	3.86	10.00	8.20E+05	28.96	2.3872	71.07	0.7181	13.34	9.83
-1	1	1	3.86	5.00	6.52E+05	32.68	2.3872	71.07	0.7181	13.34	9.83
-1	1	1	3.86	2.00	4.64E+05	37.43	2.3872	71.07	0.7181	13.34	9.83
-1	1	1	3.86	1.00	3.47E+05	41.03	2.3872	71.07	0.7181	13.34	9.83
-1	1	1	3.86	0.50	2.56E+05	43.58	2.3872	71.07	0.7181	13.34	9.83
-1	1	1	3.86	0.20	1.68E+05	45.64	2.3872	71.07	0.7181	13.34	9.83
-1	1	1	3.86	0.10	1.22E+05	45.84	2.3872	71.07	0.7181	13.34	9.83
-1	1	1	3.86	0.05	8.18E+04	44.88	2.3872	71.07	0.7181	13.34	9.83
-1	1	1	3.86	0.02	5.83E+04	44.52	2.3872	71.07	0.7181	13.34	9.83
-1	1	1	3.86	0.01	4.43E+04	40.60	2.3872	71.07	0.7181	13.34	9.83
-1	1	1	7.45	15.00	5.84E+05	30.89	2.2982	55.08	0.5597	16.57	9.46
-1	1	1	7.45	10.00	5.05E+05	33.02	2.2982	55.08	0.5597	16.57	9.46
-1	1	1	7.45	5.00	3.92E+05	36.66	2.2982	55.08	0.5597	16.57	9.46
-1	1	1	7.45	2.00	2.70E+05	40.70	2.2982	55.08	0.5597	16.57	9.46
-1	1	1	7.45	1.00	1.97E+05	42.19	2.2982	55.08	0.5597	16.57	9.46
-1	1	1	7.45	0.50	1.45E+05	45.36	2.2982	55.08	0.5597	16.57	9.46
-1	1	1	7.45	0.20	9.40E+04	45.93	2.2982	55.08	0.5597	16.57	9.46
-1	1	1	7.45	0.10	6.88E+04	46.53	2.2982	55.08	0.5597	16.57	9.46
-1	1	1	7.45	0.05	5.01E+04	43.00	2.2982	55.08	0.5597	16.57	9.46
-1	1	1	7.45	0.02	3.57E+04	40.38	2.2982	55.08	0.5597	16.57	9.46
-1	1	1	7.45	0.01	2.95E+04	41.06	2.2982	55.08	0.5597	16.57	9.46
-1	1	1	9.39	15.00	6.62E+05	31.88	2.2530	48.46	0.4970	18.21	9.28
-1	1	1	9.39	10.00	5.78E+05	34.02	2.2530	48.46	0.4970	18.21	9.28
-1	1	1	9.39	5.00	4.63E+05	37.73	2.2530	48.46	0.4970	18.21	9.28
-1	1	1	9.39	2.00	3.52E+05	42.14	2.2530	48.46	0.4970	18.21	9.28
-1	1	1	9.39	1.00	2.27E+05	44.55	2.2530	48.46	0.4970	18.21	9.28
-1	1	1	9.39	0.50	1.65E+05	46.11	2.2530	48.46	0.4970	18.21	9.28
-1	1	1	9.39	0.20	1.08E+05	46.96	2.2530	48.46	0.4970	18.21	9.28
-1	1	1	9.39	0.10	7.77E+04	44.85	2.2530	48.46	0.4970	18.21	9.28
-1	1	1	9.39	0.05	5.45E+04	42.16	2.2530	48.46	0.4970	18.21	9.28
-1	1	1	9.39	0.02	4.11E+04	39.89	2.2530	48.46	0.4970	18.21	9.28
-1	1	1	9.39	0.01	3.20E+04	40.83	2.2530	48.46	0.4970	18.21	9.28
-1	1	1	9.39	15.00	4.06E+05	33.69	2.2530	48.46	0.4970	18.21	9.28
-1	1	1	9.39	10.00	3.48E+05	35.76	2.2530	48.46	0.4970	18.21	9.28
-1	1	1	9.39	5.00	2.62E+05	39.53	2.2530	48.46	0.4970	18.21	9.28
-1	1	1	9.39	2.00	1.75E+05	44.44	2.2530	48.46	0.4970	18.21	9.28
-1	1	1	9.39	1.00	1.26E+05	47.06	2.2530	48.46	0.4970	18.21	9.28
-1	1	1	9.39	0.50	8.83E+04	49.47	2.2530	48.46	0.4970	18.21	9.28
-1	1	1	9.39	0.20	5.52E+04	50.89	2.2530	48.46	0.4970	18.21	9.28
-1	1	1	9.39	0.10	3.93E+04	50.63	2.2530	48.46	0.4970	18.21	9.28
-1	1	1	9.39	0.05	2.58E+04	56.13	2.2530	48.46	0.4970	18.21	9.28
-1	1	1	9.39	0.02	1.68E+04	50.32	2.2530	48.46	0.4970	18.21	9.28
-1	1	1	9.39	0.01	1.32E+04	47.90	2.2530	48.46	0.4970	18.21	9.28
-1	1	1.6	3.73	15.00	7.00E+05	33.18	2.3904	71.81	0.7253	13.22	9.84
-1	1	1.6	3.73	10.00	6.02E+05	35.48	2.3904	71.81	0.7253	13.22	9.84
-1	1	1.6	3.73	5.00	4.56E+05	39.39	2.3904	71.81	0.7253	13.22	9.84
-1	1	1.6	3.73	2.00	3.10E+05	41.61	2.3904	71.81	0.7253	13.22	9.84
-1	1	1.6	3.73	1.00	2.21E+05	45.69	2.3904	71.81	0.7253	13.22	9.84
-1	1	1.6	3.73	0.50	1.50E+05	49.54	2.3904	71.81	0.7253	13.22	9.84
-1	1	1.6	3.73	0.20	9.25E+04	50.25	2.3904	71.81	0.7253	13.22	9.84
-1	1	1.6	3.73	0.10	6.68E+04	47.48	2.3904	71.81	0.7253	13.22	9.84
-1	1	1.6	3.73	0.05	4.57E+04	42.35	2.3904	71.81	0.7253	13.22	9.84
-1	1	1.6	3.73	0.02	3.34E+04	32.19	2.3904	71.81	0.7253	13.22	9.84
-1	1	1.6	3.73	0.01	2.80E+04	37.20	2.3904	71.81	0.7253	13.22	9.84

(Continued)

AC	GR	Temp	V_a	Freq	|E*|	phi	G_{mb}	VFA	$V_b/(V_a+V_b)$	VMA	V_b
			(%)	(Hz)	(psi)	(Degree)		(%)		(%)	(%)
-1	1	1.6	7.45	15.00	4.62E+05	35.85	2.2982	55.08	0.5597	16.57	9.46
-1	1	1.6	7.45	10.00	3.91E+05	38.08	2.2982	55.08	0.5597	16.57	9.46
-1	1	1.6	7.45	5.00	2.91E+05	41.50	2.2982	55.08	0.5597	16.57	9.46
-1	1	1.6	7.45	2.00	1.94E+05	43.14	2.2982	55.08	0.5597	16.57	9.46
-1	1	1.6	7.45	1.00	1.40E+05	46.30	2.2982	55.08	0.5597	16.57	9.46
-1	1	1.6	7.45	0.50	9.50E+04	49.92	2.2982	55.08	0.5597	16.57	9.46
-1	1	1.6	7.45	0.20	5.95E+04	49.45	2.2982	55.08	0.5597	16.57	9.46
-1	1	1.6	7.45	0.10	4.34E+04	48.32	2.2982	55.08	0.5597	16.57	9.46
-1	1	1.6	7.45	0.05	3.29E+04	43.27	2.2982	55.08	0.5597	16.57	9.46
-1	1	1.6	7.45	0.02	2.03E+04	43.04	2.2982	55.08	0.5597	16.57	9.46
-1	1	1.6	7.45	0.01	1.91E+04	38.68	2.2982	55.08	0.5597	16.57	9.46
-1	1	1.6	7.80	15.00	4.22E+05	37.60	2.2893	53.83	0.5472	16.89	9.43
-1	1	1.6	7.80	10.00	3.55E+05	39.73	2.2893	53.83	0.5472	16.89	9.43
-1	1	1.6	7.80	5.00	2.61E+05	43.11	2.2893	53.83	0.5472	16.89	9.43
-1	1	1.6	7.80	2.00	1.70E+05	46.77	2.2893	53.83	0.5472	16.89	9.43
-1	1	1.6	7.80	1.00	1.23E+05	47.71	2.2893	53.83	0.5472	16.89	9.43
-1	1	1.6	7.80	0.50	8.82E+04	48.19	2.2893	53.83	0.5472	16.89	9.43
-1	1	1.6	7.80	0.20	5.90E+04	46.42	2.2893	53.83	0.5472	16.89	9.43
-1	1	1.6	7.80	0.10	4.72E+04	43.56	2.2893	53.83	0.5472	16.89	9.43
-1	1	1.6	7.80	0.05	3.41E+04	41.79	2.2893	53.83	0.5472	16.89	9.43
-1	1	1.6	7.80	0.02	2.73E+04	34.32	2.2893	53.83	0.5472	16.89	9.43
-1	1	1.6	7.80	0.01	2.32E+04	29.66	2.2893	53.83	0.5472	16.89	9.43
-1	1	1.6	9.27	15.00	2.98E+05	38.13	2.2499	49.44	0.5000	18.32	9.26
-1	1	1.6	9.27	10.00	2.52E+05	39.79	2.2499	49.44	0.5000	18.32	9.26
-1	1	1.6	9.27	5.00	1.87E+05	42.16	2.2499	49.44	0.5000	18.32	9.26
-1	1	1.6	9.27	2.00	1.28E+05	42.13	2.2499	49.44	0.5000	18.32	9.26
-1	1	1.6	9.27	1.00	9.14E+04	45.34	2.2499	49.44	0.5000	18.32	9.26
-1	1	1.6	9.27	0.50	6.82E+04	44.61	2.2499	49.44	0.5000	18.32	9.26
-1	1	1.6	9.27	0.20	4.76E+04	42.24	2.2499	49.44	0.5000	18.32	9.26
-1	1	1.6	9.27	0.10	3.76E+04	37.82	2.2499	49.44	0.5000	18.32	9.26
-1	1	1.6	9.27	0.05	3.07E+04	34.11	2.2499	49.44	0.5000	18.32	9.26
-1	1	1.6	9.27	0.02	2.47E+04	30.04	2.2499	49.44	0.5000	18.32	9.26
-1	1	1.6	9.27	0.01	2.22E+04	25.86	2.2499	49.44	0.5000	18.32	9.26

Appendix E. Shear frequency sweep test data

Nomenclature:

AC = Asphalt content.	-1 = optimum minus 0.5% asphalt content; 1 = optimum asphalt content;
GR = Gradation.	-1 = SP 12.5-mm mix; 1 = SP19-mm mix.
RT = Replicates.	-1 = one replicate; 1 = two replicates.
Temp = Temperature.	-1 = 15°C; and 0 = 20°C, and 1 = 25°C.

AC	GR	Temp	V_a	Freq	|G*|	Phase angle	G_{mb}	VFA	$V_b/(V_a+V_b)$	VMA	V_b
			(%)	(Hz)	(psi)	(Degree)		(%)		(%)	(%)
1	-1	-1	3.61	15.00	7.65E+05	14.30	2.3818	74.55	0.7709	14.18	12.14
1	-1	-1	3.61	10.00	7.19E+05	14.46	2.3818	74.55	0.7709	14.18	12.14
1	-1	-1	3.61	5.00	6.51E+05	15.26	2.3818	74.55	0.7709	14.18	12.14
1	-1	-1	3.61	2.00	5.96E+05	21.99	2.3818	74.55	0.7709	14.18	12.14
1	-1	-1	3.61	1.00	5.40E+05	28.07	2.3818	74.55	0.7709	14.18	12.14
1	-1	-1	3.61	0.50	3.98E+05	34.62	2.3818	74.55	0.7709	14.18	12.14
1	-1	-1	3.61	0.20	1.60E+05	39.35	2.3818	74.55	0.7709	14.18	12.14
1	-1	-1	3.61	0.10	1.03E+05	43.03	2.3818	74.55	0.7709	14.18	12.14
1	-1	-1	3.61	0.05	6.42E+04	45.67	2.3818	74.55	0.7709	14.18	12.14
1	-1	-1	3.61	0.02	4.23E+04	49.37	2.3818	74.55	0.7709	14.18	12.14
1	-1	-1	3.61	0.01	2.96E+04	50.83	2.3818	74.55	0.7709	14.18	12.14
1	-1	0	3.61	15.00	5.30E+05	16.34	2.3818	74.55	0.7709	14.18	12.14
1	-1	0	3.61	10.00	4.80E+05	19.15	2.3818	74.55	0.7709	14.18	12.14
1	-1	0	3.61	5.00	4.06E+05	25.38	2.3818	74.55	0.7709	14.18	12.14
1	-1	0	3.61	2.00	3.02E+05	28.45	2.3818	74.55	0.7709	14.18	12.14
1	-1	0	3.61	1.00	1.98E+05	36.46	2.3818	74.55	0.7709	14.18	12.14
1	-1	0	3.61	0.50	1.19E+05	41.88	2.3818	74.55	0.7709	14.18	12.14
1	-1	0	3.61	0.20	6.54E+04	46.23	2.3818	74.55	0.7709	14.18	12.14
1	-1	0	3.61	0.10	4.38E+04	48.93	2.3818	74.55	0.7709	14.18	12.14
1	-1	0	3.61	0.05	2.81E+04	50.61	2.3818	74.55	0.7709	14.18	12.14
1	-1	0	3.61	0.02	1.81E+04	52.28	2.3818	74.55	0.7709	14.18	12.14
1	-1	0	3.61	0.01	1.24E+04	51.28	2.3818	74.55	0.7709	14.18	12.14
1	-1	1	3.61	15.00	3.89E+05	28.85	2.3818	74.55	0.7709	14.18	12.14
1	-1	1	3.61	10.00	3.34E+05	31.98	2.3818	74.55	0.7709	14.18	12.14
1	-1	1	3.61	5.00	2.37E+05	38.20	2.3818	74.55	0.7709	14.18	12.14
1	-1	1	3.61	2.00	1.24E+05	39.75	2.3818	74.55	0.7709	14.18	12.14
1	-1	1	3.61	1.00	9.94E+04	46.55	2.3818	74.55	0.7709	14.18	12.14
1	-1	1	3.61	0.50	6.24E+04	49.38	2.3818	74.55	0.7709	14.18	12.14
1	-1	1	3.61	0.20	3.47E+04	52.49	2.3818	74.55	0.7709	14.18	12.14
1	-1	1	3.61	0.10	2.30E+04	54.13	2.3818	74.55	0.7709	14.18	12.14
1	-1	1	3.61	0.05	1.45E+04	54.29	2.3818	74.55	0.7709	14.18	12.14
1	-1	1	3.61	0.02	9.19E+03	54.49	2.3818	74.55	0.7709	14.18	12.14
1	-1	1	3.61	0.01	6.38E+03	54.11	2.3818	74.55	0.7709	14.18	12.14
1	-1	-0.8	3.73	15.00	6.21E+05	6.28	2.3485	75.75	0.7625	15.38	11.97
1	-1	-0.8	3.73	10.00	5.90E+05	7.77	2.3485	75.75	0.7625	15.38	11.97
1	-1	-0.8	3.73	5.00	5.50E+05	11.26	2.3485	75.75	0.7625	15.38	11.97
1	-1	-0.8	3.73	2.00	4.75E+05	17.90	2.3485	75.75	0.7625	15.38	11.97
1	-1	-0.8	3.73	1.00	3.20E+05	7.44	2.3485	75.75	0.7625	15.38	11.97
1	-1	-0.8	3.73	0.50	2.35E+05	14.87	2.3485	75.75	0.7625	15.38	11.97
1	-1	-0.8	3.73	0.20	1.62E+05	29.26	2.3485	75.75	0.7625	15.38	11.97
1	-1	-0.8	3.73	0.10	1.03E+05	34.46	2.3485	75.75	0.7625	15.38	11.97
1	-1	-0.8	3.73	0.05	6.60E+04	37.60	2.3485	75.75	0.7625	15.38	11.97
1	-1	-0.8	3.73	0.02	4.71E+04	41.29	2.3485	75.75	0.7625	15.38	11.97
1	-1	-0.8	3.73	0.01	3.45E+04	42.17	2.3485	75.75	0.7625	15.38	11.97
1	-1	0	3.73	15.00	5.84E+05	11.86	2.3485	75.75	0.7625	15.38	11.97
1	-1	0	3.73	10.00	5.26E+05	15.80	2.3485	75.75	0.7625	15.38	11.97
1	-1	0	3.73	5.00	4.68E+05	20.82	2.3485	75.75	0.7625	15.38	11.97
1	-1	0	3.73	2.00	2.59E+05	25.66	2.3485	75.75	0.7625	15.38	11.97
1	-1	0	3.73	1.00	2.13E+05	30.53	2.3485	75.75	0.7625	15.38	11.97
1	-1	0	3.73	0.50	1.41E+05	38.41	2.3485	75.75	0.7625	15.38	11.97
1	-1	0	3.73	0.20	7.39E+04	42.26	2.3485	75.75	0.7625	15.38	11.97

(Continued)

AC	GR	Temp	V_a	Freq	|G*|	Phase angle	G_{mb}	VFA	$V_b/(V_a+V_b)$	VMA	V_b
			(%)	(Hz)	(psi)	(Degree)		(%)		(%)	(%)
1	-1	0	3.73	0.10	5.05E+04	44.55	2.3485	75.75	0.7625	15.38	11.97
1	-1	0	3.73	0.05	3.33E+04	45.02	2.3485	75.75	0.7625	15.38	11.97
1	-1	0	3.73	0.02	2.28E+04	46.49	2.3485	75.75	0.7625	15.38	11.97
1	-1	0	3.73	0.01	1.62E+04	46.95	2.3485	75.75	0.7625	15.38	11.97
1	-1	1	3.73	15.00	4.46E+05	20.75	2.3485	75.75	0.7625	15.38	11.97
1	-1	1	3.73	10.00	3.83E+05	25.14	2.3485	75.75	0.7625	15.38	11.97
1	-1	1	3.73	5.00	2.96E+05	31.29	2.3485	75.75	0.7625	15.38	11.97
1	-1	1	3.73	2.00	1.34E+05	35.79	2.3485	75.75	0.7625	15.38	11.97
1	-1	1	3.73	1.00	1.14E+05	39.73	2.3485	75.75	0.7625	15.38	11.97
1	-1	1	3.73	0.50	6.98E+04	43.96	2.3485	75.75	0.7625	15.38	11.97
1	-1	1	3.73	0.20	4.10E+04	47.00	2.3485	75.75	0.7625	15.38	11.97
1	-1	1	3.73	0.10	2.87E+04	47.79	2.3485	75.75	0.7625	15.38	11.97
1	-1	1	3.73	0.05	1.91E+04	47.14	2.3485	75.75	0.7625	15.38	11.97
1	-1	1	3.73	0.02	1.32E+04	43.37	2.3485	75.75	0.7625	15.38	11.97
1	-1	1	3.73	0.01	9.60E+03	45.51	2.3485	75.75	0.7625	15.38	11.97
1	-1	-0.8	3.60	15.00	7.51E+05	0.97	2.3820	74.58	0.7712	14.17	12.14
1	-1	-0.8	3.60	10.00	6.61E+05	3.00	2.3820	74.58	0.7712	14.17	12.14
1	-1	-0.8	3.60	5.00	5.80E+05	6.00	2.3820	74.58	0.7712	14.17	12.14
1	-1	-0.8	3.60	2.00	4.80E+05	10.00	2.3820	74.58	0.7712	14.17	12.14
1	-1	-0.8	3.60	1.00	4.30E+05	14.50	2.3820	74.58	0.7712	14.17	12.14
1	-1	-0.8	3.60	0.50	3.16E+05	16.78	2.3820	74.58	0.7712	14.17	12.14
1	-1	-0.8	3.60	0.20	2.50E+05	20.00	2.3820	74.58	0.7712	14.17	12.14
1	-1	-0.8	3.60	0.10	2.00E+05	25.00	2.3820	74.58	0.7712	14.17	12.14
1	-1	-0.8	3.60	0.05	1.33E+05	31.21	2.3820	74.58	0.7712	14.17	12.14
1	-1	-0.8	3.60	0.02	9.15E+04	42.41	2.3820	74.58	0.7712	14.17	12.14
1	-1	-0.8	3.60	0.01	6.41E+04	42.36	2.3820	74.58	0.7712	14.17	12.14
1	-1	0	3.60	15.00	5.42E+05	7.10	2.3820	74.58	0.7712	14.17	12.14
1	-1	0	3.60	10.00	5.02E+05	9.15	2.3820	74.58	0.7712	14.17	12.14
1	-1	0	3.60	5.00	4.42E+05	13.66	2.3820	74.58	0.7712	14.17	12.14
1	-1	0	3.60	2.00	3.16E+05	16.78	2.3820	74.58	0.7712	14.17	12.14
1	-1	0	3.60	1.00	2.62E+05	17.13	2.3820	74.58	0.7712	14.17	12.14
1	-1	0	3.60	0.50	2.25E+05	24.32	2.3820	74.58	0.7712	14.17	12.14
1	-1	0	3.60	0.20	1.33E+05	30.31	2.3820	74.58	0.7712	14.17	12.14
1	-1	0	3.60	0.10	9.31E+04	33.54	2.3820	74.58	0.7712	14.17	12.14
1	-1	0	3.60	0.05	6.18E+04	35.99	2.3820	74.58	0.7712	14.17	12.14
1	-1	0	3.60	0.02	4.45E+04	39.32	2.3820	74.58	0.7712	14.17	12.14
1	-1	0	3.60	0.01	3.31E+04	40.38	2.3820	74.58	0.7712	14.17	12.14
1	-1	1	3.60	15.00	4.18E+05	11.54	2.3820	74.58	0.7712	14.17	12.14
1	-1	1	3.60	10.00	3.85E+05	13.46	2.3820	74.58	0.7712	14.17	12.14
1	-1	1	3.60	5.00	3.27E+05	19.43	2.3820	74.58	0.7712	14.17	12.14
1	-1	1	3.60	2.00	1.92E+05	24.64	2.3820	74.58	0.7712	14.17	12.14
1	-1	1	3.60	1.00	1.71E+05	27.39	2.3820	74.58	0.7712	14.17	12.14
1	-1	1	3.60	0.50	1.22E+05	33.09	2.3820	74.58	0.7712	14.17	12.14
1	-1	1	3.60	0.20	7.12E+04	37.42	2.3820	74.58	0.7712	14.17	12.14
1	-1	1	3.60	0.10	5.07E+04	39.93	2.3820	74.58	0.7712	14.17	12.14
1	-1	1	3.60	0.05	3.45E+04	41.15	2.3820	74.58	0.7712	14.17	12.14
1	-1	1	3.60	0.02	2.42E+04	43.83	2.3820	74.58	0.7712	14.17	12.14
1	-1	1	3.60	0.01	1.78E+04	43.66	2.3820	74.58	0.7712	14.17	12.14
1	-1	-0.8	3.91	15.00	9.81E+05	7.18	2.3743	72.94	0.7558	14.45	12.10
1	-1	-0.8	3.91	10.00	9.34E+05	8.41	2.3743	72.94	0.7558	14.45	12.10
1	-1	-0.8	3.91	5.00	8.96E+05	10.84	2.3743	72.94	0.7558	14.45	12.10
1	-1	-0.8	3.91	2.00	5.45E+05	16.63	2.3743	72.94	0.7558	14.45	12.10
1	-1	-0.8	3.91	1.00	1.38E+06	16.67	2.3743	72.94	0.7558	14.45	12.10
1	-1	-0.8	3.91	0.50	1.12E+06	22.09	2.3743	72.94	0.7558	14.45	12.10
1	-1	-0.8	3.91	0.20	6.56E+05	24.67	2.3743	72.94	0.7558	14.45	12.10

(Continued)

AC	GR	Temp	V_a	Freq	|G*|	Phase angle	G_{mb}	VFA	$V_b/(V_a+V_b)$	VMA	V_b
			(%)	(Hz)	(psi)	(Degree)		(%)		(%)	(%)
1	-1	-0.8	3.91	0.10	4.40E+05	29.21	2.3743	72.94	0.7558	14.45	12.10
1	-1	-0.8	3.91	0.05	1.67E+05	26.12	2.3743	72.94	0.7558	14.45	12.10
1	-1	-0.8	3.91	0.02	1.00E+05	34.89	2.3743	72.94	0.7558	14.45	12.10
1	-1	-0.8	3.91	0.01	6.92E+04	37.75	2.3743	72.94	0.7558	14.45	12.10
1	-1	0	3.91	15.00	5.37E+05	5.44	2.3743	72.94	0.7558	14.45	12.10
1	-1	0	3.91	10.00	5.09E+05	6.52	2.3743	72.94	0.7558	14.45	12.10
1	-1	0	3.91	5.00	4.69E+05	8.46	2.3743	72.94	0.7558	14.45	12.10
1	-1	0	3.91	2.00	2.65E+05	14.10	2.3743	72.94	0.7558	14.45	12.10
1	-1	0	3.91	1.00	4.55E+05	13.92	2.3743	72.94	0.7558	14.45	12.10
1	-1	0	3.91	0.50	3.02E+05	20.39	2.3743	72.94	0.7558	14.45	12.10
1	-1	0	3.91	0.20	1.32E+05	29.70	2.3743	72.94	0.7558	14.45	12.10
1	-1	0	3.91	0.10	9.10E+04	33.14	2.3743	72.94	0.7558	14.45	12.10
1	-1	0	3.91	0.05	5.96E+04	34.67	2.3743	72.94	0.7558	14.45	12.10
1	-1	0	3.91	0.02	4.19E+04	39.20	2.3743	72.94	0.7558	14.45	12.10
1	-1	0	3.91	0.01	3.13E+04	40.93	2.3743	72.94	0.7558	14.45	12.10
1	-1	1	3.91	15.00	5.66E+05	10.11	2.3743	72.94	0.7558	14.45	12.10
1	-1	1	3.91	10.00	5.15E+05	12.50	2.3743	72.94	0.7558	14.45	12.10
1	-1	1	3.91	5.00	4.40E+05	15.09	2.3743	72.94	0.7558	14.45	12.10
1	-1	1	3.91	2.00	2.28E+05	18.28	2.3743	72.94	0.7558	14.45	12.10
1	-1	1	3.91	1.00	2.91E+05	19.87	2.3743	72.94	0.7558	14.45	12.10
1	-1	1	3.91	0.50	1.69E+05	30.83	2.3743	72.94	0.7558	14.45	12.10
1	-1	1	3.91	0.20	8.85E+04	35.82	2.3743	72.94	0.7558	14.45	12.10
1	-1	1	3.91	0.10	6.07E+04	38.22	2.3743	72.94	0.7558	14.45	12.10
1	-1	1	3.91	0.05	3.96E+04	39.95	2.3743	72.94	0.7558	14.45	12.10
1	-1	1	3.91	0.02	2.82E+04	42.82	2.3743	72.94	0.7558	14.45	12.10
1	-1	1	3.91	0.01	2.05E+04	42.71	2.3743	72.94	0.7558	14.45	12.10
1	-1	-1.2	6.00	15.00	9.18E+05	4.00	2.3226	63.22	0.6637	16.31	11.84
1	-1	-1.2	6.00	10.00	9.01E+05	5.00	2.3226	63.22	0.6637	16.31	11.84
1	-1	-1.2	6.00	5.00	7.99E+05	7.82	2.3226	63.22	0.6637	16.31	11.84
1	-1	-1.2	6.00	2.00	5.50E+05	7.98	2.3226	63.22	0.6637	16.31	11.84
1	-1	-1.2	6.00	1.00	4.70E+05	15.00	2.3226	63.22	0.6637	16.31	11.84
1	-1	-1.2	6.00	0.50	3.40E+05	16.80	2.3226	63.22	0.6637	16.31	11.84
1	-1	-1.2	6.00	0.20	2.07E+05	18.00	2.3226	63.22	0.6637	16.31	11.84
1	-1	-1.2	6.00	0.10	1.41E+05	27.36	2.3226	63.22	0.6637	16.31	11.84
1	-1	-1.2	6.00	0.05	9.06E+04	28.22	2.3226	63.22	0.6637	16.31	11.84
1	-1	-1.2	6.00	0.02	6.59E+04	33.59	2.3226	63.22	0.6637	16.31	11.84
1	-1	-1.2	6.00	0.01	5.01E+04	35.72	2.3226	63.22	0.6637	16.31	11.84
1	-1	0	6.00	15.00	5.45E+05	6.49	2.3226	63.22	0.6637	16.31	11.84
1	-1	0	6.00	10.00	5.04E+05	8.91	2.3226	63.22	0.6637	16.31	11.84
1	-1	0	6.00	5.00	4.50E+05	9.43	2.3226	63.22	0.6637	16.31	11.84
1	-1	0	6.00	2.00	3.66E+05	16.73	2.3226	63.22	0.6637	16.31	11.84
1	-1	0	6.00	1.00	2.60E+05	18.00	2.3226	63.22	0.6637	16.31	11.84
1	-1	0	6.00	0.50	2.07E+05	20.72	2.3226	63.22	0.6637	16.31	11.84
1	-1	0	6.00	0.20	1.05E+05	30.38	2.3226	63.22	0.6637	16.31	11.84
1	-1	0	6.00	0.10	7.42E+04	32.71	2.3226	63.22	0.6637	16.31	11.84
1	-1	0	6.00	0.05	5.06E+04	34.26	2.3226	63.22	0.6637	16.31	11.84
1	-1	0	6.00	0.02	3.68E+04	37.69	2.3226	63.22	0.6637	16.31	11.84
1	-1	0	6.00	0.01	2.83E+04	38.65	2.3226	63.22	0.6637	16.31	11.84
1	-1	1	6.00	15.00	3.96E+05	13.38	2.3226	63.22	0.6637	16.31	11.84
1	-1	1	6.00	10.00	3.50E+05	16.14	2.3226	63.22	0.6637	16.31	11.84
1	-1	1	6.00	5.00	2.81E+05	20.15	2.3226	63.22	0.6637	16.31	11.84
1	-1	1	6.00	2.00	2.14E+05	22.63	2.3226	63.22	0.6637	16.31	11.84
1	-1	1	6.00	1.00	1.48E+05	27.54	2.3226	63.22	0.6637	16.31	11.84
1	-1	1	6.00	0.50	9.88E+04	32.33	2.3226	63.22	0.6637	16.31	11.84
1	-1	1	6.00	0.20	6.19E+04	35.22	2.3226	63.22	0.6637	16.31	11.84

(Continued)

AC	GR	Temp	V_a (%)	Freq (Hz)	|G*| (psi)	Phase angle (Degree)	G_{mb}	VFA (%)	$V_b/(V_a+V_b)$	VMA (%)	V_b (%)
1	-1	1	6.00	0.10	4.46E+04	37.04	2.3226	63.22	0.6637	16.31	11.84
1	-1	1	6.00	0.05	3.12E+04	38.09	2.3226	63.22	0.6637	16.31	11.84
1	-1	1	6.00	0.02	2.27E+04	39.65	2.3226	63.22	0.6637	16.31	11.84
1	-1	1	6.00	0.01	1.74E+04	39.61	2.3226	63.22	0.6637	16.31	11.84
1	-1	-1	5.42	15.00	5.24E+05	5.59	2.3369	65.69	0.6873	15.80	11.91
1	-1	-1	5.42	10.00	5.07E+05	6.73	2.3369	65.69	0.6873	15.80	11.91
1	-1	-1	5.42	5.00	4.74E+05	11.05	2.3369	65.69	0.6873	15.80	11.91
1	-1	-1	5.42	2.00	3.60E+05	14.92	2.3369	65.69	0.6873	15.80	11.91
1	-1	-1	5.42	1.00	3.00E+05	19.60	2.3369	65.69	0.6873	15.80	11.91
1	-1	-1	5.42	0.50	2.00E+05	29.67	2.3369	65.69	0.6873	15.80	11.91
1	-1	-1	5.42	0.20	1.54E+05	32.73	2.3369	65.69	0.6873	15.80	11.91
1	-1	-1	5.42	0.10	9.81E+04	36.14	2.3369	65.69	0.6873	15.80	11.91
1	-1	-1	5.42	0.05	6.30E+04	38.29	2.3369	65.69	0.6873	15.80	11.91
1	-1	-1	5.42	0.02	4.46E+04	41.65	2.3369	65.69	0.6873	15.80	11.91
1	-1	-1	5.42	0.01	3.28E+04	42.19	2.3369	65.69	0.6873	15.80	11.91
1	-1	0	5.42	15.00	4.37E+05	10.57	2.3369	65.69	0.6873	15.80	11.91
1	-1	0	5.42	10.00	4.10E+05	12.63	2.3369	65.69	0.6873	15.80	11.91
1	-1	0	5.42	5.00	3.51E+05	17.85	2.3369	65.69	0.6873	15.80	11.91
1	-1	0	5.42	2.00	2.86E+05	21.19	2.3369	65.69	0.6873	15.80	11.91
1	-1	0	5.42	1.00	2.21E+05	25.92	2.3369	65.69	0.6873	15.80	11.91
1	-1	0	5.42	0.50	1.52E+05	31.51	2.3369	65.69	0.6873	15.80	11.91
1	-1	0	5.42	0.20	9.08E+04	36.29	2.3369	65.69	0.6873	15.80	11.91
1	-1	0	5.42	0.10	6.32E+04	39.30	2.3369	65.69	0.6873	15.80	11.91
1	-1	0	5.42	0.05	4.20E+04	40.99	2.3369	65.69	0.6873	15.80	11.91
1	-1	0	5.42	0.02	2.94E+04	43.38	2.3369	65.69	0.6873	15.80	11.91
1	-1	0	5.42	0.01	2.11E+04	44.45	2.3369	65.69	0.6873	15.80	11.91
1	-1	1	5.42	15.00	3.37E+05	18.58	2.3369	65.69	0.6873	15.80	11.91
1	-1	1	5.42	10.00	2.98E+05	21.94	2.3369	65.69	0.6873	15.80	11.91
1	-1	1	5.42	5.00	2.30E+05	28.76	2.3369	65.69	0.6873	15.80	11.91
1	-1	1	5.42	2.00	1.20E+05	33.70	2.3369	65.69	0.6873	15.80	11.91
1	-1	1	5.42	1.00	1.09E+05	36.62	2.3369	65.69	0.6873	15.80	11.91
1	-1	1	5.42	0.50	7.05E+04	40.59	2.3369	65.69	0.6873	15.80	11.91
1	-1	1	5.42	0.20	4.24E+04	44.39	2.3369	65.69	0.6873	15.80	11.91
1	-1	1	5.42	0.10	3.00E+04	45.68	2.3369	65.69	0.6873	15.80	11.91
1	-1	1	5.42	0.05	2.00E+04	46.42	2.3369	65.69	0.6873	15.80	11.91
1	-1	1	5.42	0.02	1.37E+04	47.06	2.3369	65.69	0.6873	15.80	11.91
1	-1	1	5.42	0.01	9.72E+03	45.74	2.3369	65.69	0.6873	15.80	11.91
1	-1	-1	6.35	15.00	7.93E+05	4.45	2.3140	61.80	0.6501	16.62	11.80
1	-1	-1	6.35	10.00	7.35E+05	4.41	2.3140	61.80	0.6501	16.62	11.80
1	-1	-1	6.35	5.00	6.54E+05	7.20	2.3140	61.80	0.6501	16.62	11.80
1	-1	-1	6.35	2.00	4.50E+05	13.00	2.3140	61.80	0.6501	16.62	11.80
1	-1	-1	6.35	1.00	3.50E+05	15.00	2.3140	61.80	0.6501	16.62	11.80
1	-1	-1	6.35	0.50	2.67E+05	18.16	2.3140	61.80	0.6501	16.62	11.80
1	-1	-1	6.35	0.20	2.30E+05	28.48	2.3140	61.80	0.6501	16.62	11.80
1	-1	-1	6.35	0.10	1.60E+05	32.00	2.3140	61.80	0.6501	16.62	11.80
1	-1	-1	6.35	0.05	1.02E+05	31.32	2.3140	61.80	0.6501	16.62	11.80
1	-1	-1	6.35	0.02	7.07E+04	35.96	2.3140	61.80	0.6501	16.62	11.80
1	-1	-1	6.35	0.01	5.05E+04	37.49	2.3140	61.80	0.6501	16.62	11.80
1	-1	0	6.35	15.00	4.96E+05	11.15	2.3140	61.80	0.6501	16.62	11.80
1	-1	0	6.35	10.00	4.58E+05	12.41	2.3140	61.80	0.6501	16.62	11.80
1	-1	0	6.35	5.00	3.83E+05	14.68	2.3140	61.80	0.6501	16.62	11.80
1	-1	0	6.35	2.00	2.67E+05	16.70	2.3140	61.80	0.6501	16.62	11.80
1	-1	0	6.35	1.00	2.39E+05	16.97	2.3140	61.80	0.6501	16.62	11.80
1	-1	0	6.35	0.50	1.78E+05	26.02	2.3140	61.80	0.6501	16.62	11.80
1	-1	0	6.35	0.20	1.13E+05	30.07	2.3140	61.80	0.6501	16.62	11.80

(Continued)

AC	GR	Temp	V_a	Freq	|G*|	Phase angle	G_{mb}	VFA	$V_b/(V_a+V_b)$	VMA	V_b
			(%)	(Hz)	(psi)	(Degree)		(%)		(%)	(%)
1	-1	0	6.35	0.10	8.17E+04	32.45	2.3140	61.80	0.6501	16.62	11.80
1	-1	0	6.35	0.05	5.54E+04	33.54	2.3140	61.80	0.6501	16.62	11.80
1	-1	0	6.35	0.02	3.92E+04	37.49	2.3140	61.80	0.6501	16.62	11.80
1	-1	0	6.35	0.01	2.90E+04	38.23	2.3140	61.80	0.6501	16.62	11.80
1	-1	1	6.35	15.00	3.29E+05	14.03	2.3140	61.80	0.6501	16.62	11.80
1	-1	1	6.35	10.00	2.94E+05	16.35	2.3140	61.80	0.6501	16.62	11.80
1	-1	1	6.35	5.00	2.43E+05	20.38	2.3140	61.80	0.6501	16.62	11.80
1	-1	1	6.35	2.00	1.88E+05	26.01	2.3140	61.80	0.6501	16.62	11.80
1	-1	1	6.35	1.00	1.32E+05	29.26	2.3140	61.80	0.6501	16.62	11.80
1	-1	1	6.35	0.50	9.01E+04	33.72	2.3140	61.80	0.6501	16.62	11.80
1	-1	1	6.35	0.20	5.69E+04	37.01	2.3140	61.80	0.6501	16.62	11.80
1	-1	1	6.35	0.10	4.09E+04	39.18	2.3140	61.80	0.6501	16.62	11.80
1	-1	1	6.35	0.05	2.88E+04	40.18	2.3140	61.80	0.6501	16.62	11.80
1	-1	1	6.35	0.02	2.04E+04	41.14	2.3140	61.80	0.6501	16.62	11.80
1	-1	1	6.35	0.01	1.52E+04	41.34	2.3140	61.80	0.6501	16.62	11.80
1	-1	-1	6.01	15.00	4.89E+05	31.91	2.3226	63.16	0.6633	16.31	11.84
1	-1	-1	6.01	10.00	4.29E+05	30.16	2.3226	63.16	0.6633	16.31	11.84
1	-1	-1	6.01	5.00	3.60E+05	28.87	2.3226	63.16	0.6633	16.31	11.84
1	-1	-1	6.01	2.00	2.60E+05	34.08	2.3226	63.16	0.6633	16.31	11.84
1	-1	-1	6.01	1.00	2.25E+05	29.69	2.3226	63.16	0.6633	16.31	11.84
1	-1	-1	6.01	0.50	1.52E+05	35.96	2.3226	63.16	0.6633	16.31	11.84
1	-1	-1	6.01	0.20	9.81E+04	42.19	2.3226	63.16	0.6633	16.31	11.84
1	-1	-1	6.01	0.10	6.93E+04	44.99	2.3226	63.16	0.6633	16.31	11.84
1	-1	-1	6.01	0.05	4.53E+04	42.27	2.3226	63.16	0.6633	16.31	11.84
1	-1	-1	6.01	0.02	3.05E+04	45.34	2.3226	63.16	0.6633	16.31	11.84
1	-1	-1	6.01	0.01	2.32E+04	46.52	2.3226	63.16	0.6633	16.31	11.84
1	-1	0	6.01	15.00	2.59E+05	30.10	2.3226	63.16	0.6633	16.31	11.84
1	-1	0	6.01	10.00	2.27E+05	30.63	2.3226	63.16	0.6633	16.31	11.84
1	-1	0	6.01	5.00	1.82E+05	32.80	2.3226	63.16	0.6633	16.31	11.84
1	-1	0	6.01	2.00	1.26E+05	38.06	2.3226	63.16	0.6633	16.31	11.84
1	-1	0	6.01	1.00	9.46E+04	40.99	2.3226	63.16	0.6633	16.31	11.84
1	-1	0	6.01	0.50	6.56E+04	45.20	2.3226	63.16	0.6633	16.31	11.84
1	-1	0	6.01	0.20	4.08E+04	50.48	2.3226	63.16	0.6633	16.31	11.84
1	-1	0	6.01	0.10	2.90E+04	53.55	2.3226	63.16	0.6633	16.31	11.84
1	-1	0	6.01	0.05	1.75E+04	51.44	2.3226	63.16	0.6633	16.31	11.84
1	-1	0	6.01	0.02	1.11E+04	53.62	2.3226	63.16	0.6633	16.31	11.84
1	-1	0	6.01	0.01	8.27E+03	54.15	2.3226	63.16	0.6633	16.31	11.84
1	-1	1	6.01	15.00	1.95E+05	14.03	2.3226	63.16	0.6633	16.31	11.84
1	-1	1	6.01	10.00	1.66E+05	16.35	2.3226	63.16	0.6633	16.31	11.84
1	-1	1	6.01	5.00	1.23E+05	20.38	2.3226	63.16	0.6633	16.31	11.84
1	-1	1	6.01	2.00	7.90E+04	26.01	2.3226	63.16	0.6633	16.31	11.84
1	-1	1	6.01	1.00	5.55E+04	29.26	2.3226	63.16	0.6633	16.31	11.84
1	-1	1	6.01	0.50	3.96E+04	33.72	2.3226	63.16	0.6633	16.31	11.84
1	-1	1	6.01	0.20	1.24E+05	37.01	2.3226	63.16	0.6633	16.31	11.84
1	-1	1	6.01	0.10	1.30E+04	39.18	2.3226	63.16	0.6633	16.31	11.84
1	-1	1	6.01	0.05	1.98E+04	40.18	2.3226	63.16	0.6633	16.31	11.84
1	-1	1	6.01	0.02	1.02E+04	41.14	2.3226	63.16	0.6633	16.31	11.84
1	-1	1	6.01	0.01	7.41E+03	41.34	2.3226	63.16	0.6633	16.31	11.84
1	-1	-1	6.23	15.00	4.89E+05	15.80	2.3170	62.27	0.6547	16.51	11.81
1	-1	-1	6.23	10.00	4.29E+05	17.88	2.3170	62.27	0.6547	16.51	11.81
1	-1	-1	6.23	5.00	3.60E+05	24.30	2.3170	62.27	0.6547	16.51	11.81
1	-1	-1	6.23	2.00	2.60E+05	26.13	2.3170	62.27	0.6547	16.51	11.81
1	-1	-1	6.23	1.00	2.25E+05	21.07	2.3170	62.27	0.6547	16.51	11.81
1	-1	-1	6.23	0.50	1.52E+05	24.25	2.3170	62.27	0.6547	16.51	11.81
1	-1	-1	6.23	0.20	9.81E+04	31.73	2.3170	62.27	0.6547	16.51	11.81

(Continued)

AC	GR	Temp	V_a	Freq	|G*|	Phase angle	G_{mb}	VFA	$V_b/(V_a+V_b)$	VMA	V_b
			(%)	(Hz)	(psi)	(Degree)		(%)		(%)	(%)
1	-1	0	6.23	15.00	4.34E+05	14.58	2.3170	62.27	0.6547	16.51	11.81
1	-1	-1	6.23	0.10	6.93E+04	36.72	2.3170	62.27	0.6547	16.51	11.81
1	-1	-1	6.23	0.05	4.53E+04	38.48	2.3170	62.27	0.6547	16.51	11.81
1	-1	-1	6.23	0.02	3.05E+04	42.84	2.3170	62.27	0.6547	16.51	11.81
1	-1	-1	6.23	0.01	2.32E+04	44.47	2.3170	62.27	0.6547	16.51	11.81
1	-1	0	6.23	10.00	4.00E+05	16.15	2.3170	62.27	0.6547	16.51	11.81
1	-1	0	6.23	5.00	3.42E+05	18.69	2.3170	62.27	0.6547	16.51	11.81
1	-1	0	6.23	2.00	2.61E+05	23.17	2.3170	62.27	0.6547	16.51	11.81
1	-1	0	6.23	1.00	2.04E+05	25.47	2.3170	62.27	0.6547	16.51	11.81
1	-1	0	6.23	0.50	1.51E+05	30.86	2.3170	62.27	0.6547	16.51	11.81
1	-1	0	6.23	0.20	8.75E+04	36.80	2.3170	62.27	0.6547	16.51	11.81
1	-1	0	6.23	0.10	6.20E+04	39.50	2.3170	62.27	0.6547	16.51	11.81
1	-1	0	6.23	0.05	4.14E+04	40.06	2.3170	62.27	0.6547	16.51	11.81
1	-1	0	6.23	0.02	2.91E+04	43.04	2.3170	62.27	0.6547	16.51	11.81
1	-1	0	6.23	0.01	2.17E+04	43.87	2.3170	62.27	0.6547	16.51	11.81
1	-1	1	6.23	15.00	3.14E+05	15.01	2.3170	62.27	0.6547	16.51	11.81
1	-1	1	6.23	10.00	2.77E+05	17.70	2.3170	62.27	0.6547	16.51	11.81
1	-1	1	6.23	5.00	2.19E+05	22.42	2.3170	62.27	0.6547	16.51	11.81
1	-1	1	6.23	2.00	1.50E+05	27.09	2.3170	62.27	0.6547	16.51	11.81
1	-1	1	6.23	1.00	1.11E+05	30.67	2.3170	62.27	0.6547	16.51	11.81
1	-1	1	6.23	0.50	7.48E+04	35.09	2.3170	62.27	0.6547	16.51	11.81
1	-1	1	6.23	0.20	7.12E+04	38.40	2.3170	62.27	0.6547	16.51	11.81
1	-1	1	6.23	0.10	3.21E+04	40.27	2.3170	62.27	0.6547	16.51	11.81
1	-1	1	6.23	0.05	2.50E+04	41.22	2.3170	62.27	0.6547	16.51	11.81
1	-1	1	6.23	0.02	1.67E+04	42.25	2.3170	62.27	0.6547	16.51	11.81
1	-1	1	6.23	0.01	1.24E+04	42.00	2.3170	62.27	0.6547	16.51	11.81
1	-1	-1.3	7.69	15.00	6.20E+05	4.58	2.2811	56.84	0.6021	17.81	11.63
1	-1	-1.3	7.69	10.00	5.99E+05	5.91	2.2811	56.84	0.6021	17.81	11.63
1	-1	-1.3	7.69	5.00	5.86E+05	8.03	2.2811	56.84	0.6021	17.81	11.63
1	-1	-1.3	7.69	2.00	3.52E+05	17.64	2.2811	56.84	0.6021	17.81	11.63
1	-1	-1.3	7.69	1.00	2.81E+05	21.90	2.2811	56.84	0.6021	17.81	11.63
1	-1	-1.3	7.69	0.50	2.08E+05	31.56	2.2811	56.84	0.6021	17.81	11.63
1	-1	-1.3	7.69	0.20	1.28E+05	37.04	2.2811	56.84	0.6021	17.81	11.63
1	-1	-1.3	7.69	0.10	7.96E+04	41.29	2.2811	56.84	0.6021	17.81	11.63
1	-1	-1.3	7.69	0.05	5.04E+04	44.62	2.2811	56.84	0.6021	17.81	11.63
1	-1	-1.3	7.69	0.02	3.45E+04	46.20	2.2811	56.84	0.6021	17.81	11.63
1	-1	-1.3	7.69	0.01	2.40E+04	48.15	2.2811	56.84	0.6021	17.81	11.63
1	-1	0	7.69	15.00	3.97E+05	17.69	2.2811	56.84	0.6021	17.81	11.63
1	-1	0	7.69	10.00	3.52E+05	20.80	2.2811	56.84	0.6021	17.81	11.63
1	-1	0	7.69	5.00	2.81E+05	27.27	2.2811	56.84	0.6021	17.81	11.63
1	-1	0	7.69	2.00	2.06E+05	34.32	2.2811	56.84	0.6021	17.81	11.63
1	-1	0	7.69	1.00	1.31E+05	38.15	2.2811	56.84	0.6021	17.81	11.63
1	-1	0	7.69	0.50	8.03E+04	42.95	2.2811	56.84	0.6021	17.81	11.63
1	-1	0	7.69	0.20	4.69E+04	47.17	2.2811	56.84	0.6021	17.81	11.63
1	-1	0	7.69	0.10	3.26E+04	48.72	2.2811	56.84	0.6021	17.81	11.63
1	-1	0	7.69	0.05	2.12E+04	49.35	2.2811	56.84	0.6021	17.81	11.63
1	-1	0	7.69	0.02	1.49E+04	50.96	2.2811	56.84	0.6021	17.81	11.63
1	-1	0	7.69	0.01	1.01E+04	47.70	2.2811	56.84	0.6021	17.81	11.63
1	-1	1	7.69	15.00	2.23E+05	24.19	2.2811	56.84	0.6021	17.81	11.63
1	-1	1	7.69	10.00	1.89E+05	27.38	2.2811	56.84	0.6021	17.81	11.63
1	-1	1	7.69	5.00	1.35E+05	33.84	2.2811	56.84	0.6021	17.81	11.63
1	-1	1	7.69	2.00	8.23E+04	40.09	2.2811	56.84	0.6021	17.81	11.63
1	-1	1	7.69	1.00	6.11E+04	43.85	2.2811	56.84	0.6021	17.81	11.63
1	-1	1	7.69	0.50	4.13E+04	47.75	2.2811	56.84	0.6021	17.81	11.63
1	-1	1	7.69	0.20	2.52E+04	50.89	2.2811	56.84	0.6021	17.81	11.63

(Continued)

AC	GR	Temp	V_a	Freq	|G*|	Phase angle	G_{mb}	VFA	$V_b/(V_a+V_b)$	VMA	V_b
			(%)	(Hz)	(psi)	(Degree)		(%)		(%)	(%)
1	-1	-1	7.07	10.00	4.11E+05	16.97	2.2962	59.04	0.6235	17.26	11.71
1	-1	1	7.69	0.10	1.73E+04	52.19	2.2811	56.84	0.6021	17.81	11.63
1	-1	1	7.69	0.05	1.10E+04	51.97	2.2811	56.84	0.6021	17.81	11.63
1	-1	1	7.69	0.02	7.19E+03	50.77	2.2811	56.84	0.6021	17.81	11.63
1	-1	1	7.69	0.01	5.41E+03	51.10	2.2811	56.84	0.6021	17.81	11.63
1	-1	-1	7.07	15.00	4.55E+05	15.35	2.2962	59.04	0.6235	17.26	11.71
1	-1	-1	7.07	5.00	3.55E+05	21.13	2.2962	59.04	0.6235	17.26	11.71
1	-1	-1	7.07	2.00	2.57E+05	26.38	2.2962	59.04	0.6235	17.26	11.71
1	-1	-1	7.07	1.00	2.43E+05	21.98	2.2962	59.04	0.6235	17.26	11.71
1	-1	-1	7.07	0.50	1.59E+05	34.60	2.2962	59.04	0.6235	17.26	11.71
1	-1	-1	7.07	0.20	1.07E+05	40.36	2.2962	59.04	0.6235	17.26	11.71
1	-1	-1	7.07	0.10	7.45E+04	52.81	2.2962	59.04	0.6235	17.26	11.71
1	-1	-1	7.07	0.05	5.06E+04	24.82	2.2962	59.04	0.6235	17.26	11.71
1	-1	-1	7.07	0.02	3.36E+04	39.11	2.2962	59.04	0.6235	17.26	11.71
1	-1	-1	7.07	0.01	2.48E+04	41.26	2.2962	59.04	0.6235	17.26	11.71
1	-1	0	7.07	15.00	2.60E+05	21.31	2.2962	59.04	0.6235	17.26	11.71
1	-1	0	7.07	10.00	2.29E+05	24.00	2.2962	59.04	0.6235	17.26	11.71
1	-1	0	7.07	5.00	1.82E+05	30.21	2.2962	59.04	0.6235	17.26	11.71
1	-1	0	7.07	2.00	1.23E+05	35.57	2.2962	59.04	0.6235	17.26	11.71
1	-1	0	7.07	1.00	9.16E+04	39.65	2.2962	59.04	0.6235	17.26	11.71
1	-1	0	7.07	0.50	6.28E+04	46.89	2.2962	59.04	0.6235	17.26	11.71
1	-1	0	7.07	0.20	3.93E+04	50.45	2.2962	59.04	0.6235	17.26	11.71
1	-1	0	7.07	0.10	2.83E+04	60.94	2.2962	59.04	0.6235	17.26	11.71
1	-1	0	7.07	0.05	1.78E+04	30.45	2.2962	59.04	0.6235	17.26	11.71
1	-1	0	7.07	0.02	1.23E+04	41.57	2.2962	59.04	0.6235	17.26	11.71
1	-1	0	7.07	0.01	9.21E+03	42.79	2.2962	59.04	0.6235	17.26	11.71
1	-1	1	7.07	15.00	1.76E+05	24.19	2.2962	59.04	0.6235	17.26	11.71
1	-1	1	7.07	10.00	1.52E+05	27.38	2.2962	59.04	0.6235	17.26	11.71
1	-1	1	7.07	5.00	1.16E+05	33.84	2.2962	59.04	0.6235	17.26	11.71
1	-1	1	7.07	2.00	7.77E+04	40.09	2.2962	59.04	0.6235	17.26	11.71
1	-1	1	7.07	1.00	5.51E+04	43.85	2.2962	59.04	0.6235	17.26	11.71
1	-1	1	7.07	0.50	3.47E+04	47.75	2.2962	59.04	0.6235	17.26	11.71
1	-1	1	7.07	0.20	2.40E+04	50.89	2.2962	59.04	0.6235	17.26	11.71
1	-1	1	7.07	0.10	1.26E+04	52.19	2.2962	59.04	0.6235	17.26	11.71
1	-1	1	7.07	0.05	2.08E+04	51.97	2.2962	59.04	0.6235	17.26	11.71
1	-1	1	7.07	0.02	9.86E+03	50.77	2.2962	59.04	0.6235	17.26	11.71
1	-1	1	7.07	0.01	8.02E+03	51.10	2.2962	59.04	0.6235	17.26	11.71
1	-1	0	7.27	15.00	2.86E+05	25.64	2.2913	58.31	0.6164	17.44	11.68
1	-1	0	7.27	10.00	2.49E+05	27.95	2.2913	58.31	0.6164	17.44	11.68
1	-1	0	7.27	5.00	1.98E+05	33.30	2.2913	58.31	0.6164	17.44	11.68
1	-1	0	7.27	2.00	1.37E+05	40.38	2.2913	58.31	0.6164	17.44	11.68
1	-1	0	7.27	1.00	1.03E+05	43.05	2.2913	58.31	0.6164	17.44	11.68
1	-1	0	7.27	0.50	6.90E+04	54.59	2.2913	58.31	0.6164	17.44	11.68
1	-1	0	7.27	0.20	4.93E+04	53.45	2.2913	58.31	0.6164	17.44	11.68
1	-1	0	7.27	0.10	3.81E+04	57.82	2.2913	58.31	0.6164	17.44	11.68
1	-1	0	7.27	0.05	1.68E+04	49.29	2.2913	58.31	0.6164	17.44	11.68
1	-1	0	7.27	0.02	1.32E+04	51.19	2.2913	58.31	0.6164	17.44	11.68
1	-1	0	7.27	0.01	1.12E+04	59.10	2.2913	58.31	0.6164	17.44	11.68
1	-1	1	7.27	15.00	2.48E+05	24.19	2.2913	58.31	0.6164	17.44	11.68
1	-1	1	7.27	10.00	2.16E+05	27.38	2.2913	58.31	0.6164	17.44	11.68
1	-1	1	7.27	5.00	1.70E+05	33.84	2.2913	58.31	0.6164	17.44	11.68
1	-1	1	7.27	2.00	1.16E+05	40.09	2.2913	58.31	0.6164	17.44	11.68
1	-1	1	7.27	1.00	8.59E+04	43.85	2.2913	58.31	0.6164	17.44	11.68
1	-1	1	7.27	0.50	6.08E+04	47.75	2.2913	58.31	0.6164	17.44	11.68
1	-1	1	7.27	0.20	3.93E+04	50.89	2.2913	58.31	0.6164	17.44	11.68

(Continued)

AC	GR	Temp	V_a	Freq	|G*|	Phase angle	G_{mb}	VFA	$V_b/(V_a+V_b)$	VMA	V_b
			(%)	(Hz)	(psi)	(Degree)		(%)		(%)	(%)
1	-1	1	7.27	0.10	2.84E+04	52.19	2.2913	58.31	0.6164	17.44	11.68
1	-1	1	7.27	0.05	2.10E+04	51.97	2.2913	58.31	0.6164	17.44	11.68
1	-1	1	7.27	0.02	1.39E+04	50.77	2.2913	58.31	0.6164	17.44	11.68
1	-1	1	7.27	0.01	1.03E+04	51.10	2.2913	58.31	0.6164	17.44	11.68
-1	-1	1	3.27	15.00	5.42E+05	25.83	2.3903	75.65	0.7712	13.42	11.01
-1	-1	1	3.27	10.00	5.01E+05	27.97	2.3903	75.65	0.7712	13.42	11.01
-1	-1	1	3.27	5.00	3.91E+05	32.94	2.3903	75.65	0.7712	13.42	11.01
-1	-1	1	3.27	2.00	2.60E+05	37.14	2.3903	75.65	0.7712	13.42	11.01
-1	-1	1	3.27	1.00	1.43E+05	43.04	2.3903	75.65	0.7712	13.42	11.01
-1	-1	1	3.27	0.50	8.43E+04	44.71	2.3903	75.65	0.7712	13.42	11.01
-1	-1	1	3.27	0.20	4.52E+04	49.06	2.3903	75.65	0.7712	13.42	11.01
-1	-1	1	3.27	0.10	3.05E+04	50.37	2.3903	75.65	0.7712	13.42	11.01
-1	-1	1	3.27	0.05	1.87E+04	48.68	2.3903	75.65	0.7712	13.42	11.01
-1	-1	1	3.27	0.02	1.26E+04	40.85	2.3903	75.65	0.7712	13.42	11.01
-1	-1	1	3.27	0.01	9.17E+03	47.25	2.3903	75.65	0.7712	13.42	11.01
-1	-1	0	3.27	15.00	6.60E+05	15.28	2.3903	75.65	0.7712	13.42	11.01
-1	-1	0	3.27	10.00	6.21E+05	17.22	2.3903	75.65	0.7712	13.42	11.01
-1	-1	0	3.27	5.00	5.53E+05	21.14	2.3903	75.65	0.7712	13.42	11.01
-1	-1	0	3.27	2.00	4.00E+05	25.69	2.3903	75.65	0.7712	13.42	11.01
-1	-1	0	3.27	1.00	3.01E+05	30.21	2.3903	75.65	0.7712	13.42	11.01
-1	-1	0	3.27	0.50	1.68E+05	37.76	2.3903	75.65	0.7712	13.42	11.01
-1	-1	0	3.27	0.20	8.27E+04	41.96	2.3903	75.65	0.7712	13.42	11.01
-1	-1	0	3.27	0.10	5.30E+04	45.76	2.3903	75.65	0.7712	13.42	11.01
-1	-1	0	3.27	0.05	3.34E+04	33.89	2.3903	75.65	0.7712	13.42	11.01
-1	-1	0	3.27	0.02	2.17E+04	40.81	2.3903	75.65	0.7712	13.42	11.01
-1	-1	0	3.27	0.01	1.53E+04	43.42	2.3903	75.65	0.7712	13.42	11.01
-1	-1	-1	3.27	15.00	7.50E+05	11.61	2.3903	75.65	0.7712	13.42	11.01
-1	-1	-1	3.27	10.00	7.20E+05	12.57	2.3903	75.65	0.7712	13.42	11.01
-1	-1	-1	3.27	5.00	6.80E+05	15.38	2.3903	75.65	0.7712	13.42	11.01
-1	-1	-1	3.27	2.00	6.00E+05	18.51	2.3903	75.65	0.7712	13.42	11.01
-1	-1	-1	3.27	1.00	5.00E+05	19.93	2.3903	75.65	0.7712	13.42	11.01
-1	-1	-1	3.27	0.50	4.50E+05	23.07	2.3903	75.65	0.7712	13.42	11.01
-1	-1	-1	3.27	0.20	2.80E+05	30.72	2.3903	75.65	0.7712	13.42	11.01
-1	-1	-1	3.27	0.10	1.36E+05	34.59	2.3903	75.65	0.7712	13.42	11.01
-1	-1	-1	3.27	0.05	7.40E+04	33.19	2.3903	75.65	0.7712	13.42	11.01
-1	-1	-1	3.27	0.02	4.81E+04	36.68	2.3903	75.65	0.7712	13.42	11.01
-1	-1	-1	3.27	0.01	3.26E+04	39.04	2.3903	75.65	0.7712	13.42	11.01
-1	-1	1	3.27	15.00	5.42E+05	22.23	2.3901	75.64	0.7711	13.42	11.01
-1	-1	1	3.27	10.00	5.01E+05	25.69	2.3901	75.64	0.7711	13.42	11.01
-1	-1	1	3.27	5.00	3.91E+05	30.64	2.3901	75.64	0.7711	13.42	11.01
-1	-1	1	3.27	2.00	2.60E+05	36.29	2.3901	75.64	0.7711	13.42	11.01
-1	-1	1	3.27	1.00	1.43E+05	44.81	2.3901	75.64	0.7711	13.42	11.01
-1	-1	1	3.27	0.50	8.43E+04	49.75	2.3901	75.64	0.7711	13.42	11.01
-1	-1	1	3.27	0.20	4.52E+04	52.36	2.3901	75.64	0.7711	13.42	11.01
-1	-1	1	3.27	0.10	3.05E+04	53.92	2.3901	75.64	0.7711	13.42	11.01
-1	-1	1	3.27	0.05	1.87E+04	54.74	2.3901	75.64	0.7711	13.42	11.01
-1	-1	1	3.27	0.02	1.26E+04	54.58	2.3901	75.64	0.7711	13.42	11.01
-1	-1	1	3.27	0.01	9.17E+03	53.50	2.3901	75.64	0.7711	13.42	11.01
-1	-1	0	3.27	15.00	6.60E+05	15.47	2.3901	75.64	0.7711	13.42	11.01
-1	-1	0	3.27	10.00	6.21E+05	17.33	2.3901	75.64	0.7711	13.42	11.01
-1	-1	0	3.27	5.00	5.53E+05	21.68	2.3901	75.64	0.7711	13.42	11.01
-1	-1	0	3.27	2.00	4.20E+05	26.87	2.3901	75.64	0.7711	13.42	11.01
-1	-1	0	3.27	1.00	3.01E+05	37.13	2.3901	75.64	0.7711	13.42	11.01
-1	-1	0	3.27	0.50	1.68E+05	42.02	2.3901	75.64	0.7711	13.42	11.01
-1	-1	0	3.27	0.20	8.27E+04	46.74	2.3901	75.64	0.7711	13.42	11.01

(Continued)

AC	GR	Temp	V_a	Freq	|G*|	Phase angle	G_{mb}	VFA	$V_b/(V_a+V_b)$	VMA	V_b
			(%)	(Hz)	(psi)	(Degree)		(%)		(%)	(%)
-1	-1	0	3.27	0.10	5.30E+04	48.98	2.3901	75.64	0.7711	13.42	11.01
-1	-1	0	3.27	0.05	3.34E+04	50.86	2.3901	75.64	0.7711	13.42	11.01
-1	-1	0	3.27	0.02	2.17E+04	52.29	2.3901	75.64	0.7711	13.42	11.01
-1	-1	0	3.27	0.01	1.53E+04	52.70	2.3901	75.64	0.7711	13.42	11.01
-1	-1	-1	3.27	15.00	7.60E+05	10.00	2.3901	75.64	0.7711	13.42	11.01
-1	-1	-1	3.27	10.00	7.30E+05	10.10	2.3901	75.64	0.7711	13.42	11.01
-1	-1	-1	3.27	5.00	7.00E+05	10.28	2.3901	75.64	0.7711	13.42	11.01
-1	-1	-1	3.27	2.00	6.30E+05	20.67	2.3901	75.64	0.7711	13.42	11.01
-1	-1	-1	3.27	1.00	5.40E+05	27.96	2.3901	75.64	0.7711	13.42	11.01
-1	-1	-1	3.27	0.50	4.50E+05	38.00	2.3901	75.64	0.7711	13.42	11.01
-1	-1	-1	3.27	0.20	3.57E+05	46.01	2.3901	75.64	0.7711	13.42	11.01
-1	-1	-1	3.27	0.10	1.36E+05	47.79	2.3901	75.64	0.7711	13.42	11.01
-1	-1	-1	3.27	0.05	7.40E+04	48.42	2.3901	75.64	0.7711	13.42	11.01
-1	-1	-1	3.27	0.02	4.81E+04	51.39	2.3901	75.64	0.7711	13.42	11.01
-1	-1	-1	3.27	0.01	3.26E+04	52.06	2.3901	75.64	0.7711	13.42	11.01
-1	-1	1	2.89	15.00	6.72E+05	21.95	2.3997	77.90	0.7928	13.08	11.06
-1	-1	1	2.89	10.00	6.18E+05	26.61	2.3997	77.90	0.7928	13.08	11.06
-1	-1	1	2.89	5.00	4.69E+05	36.52	2.3997	77.90	0.7928	13.08	11.06
-1	-1	1	2.89	2.00	3.00E+05	34.89	2.3997	77.90	0.7928	13.08	11.06
-1	-1	1	2.89	1.00	1.61E+05	46.80	2.3997	77.90	0.7928	13.08	11.06
-1	-1	1	2.89	0.50	9.43E+04	49.61	2.3997	77.90	0.7928	13.08	11.06
-1	-1	1	2.89	0.20	4.99E+04	51.18	2.3997	77.90	0.7928	13.08	11.06
-1	-1	1	2.89	0.10	3.30E+04	52.55	2.3997	77.90	0.7928	13.08	11.06
-1	-1	1	2.89	0.05	2.15E+04	53.65	2.3997	77.90	0.7928	13.08	11.06
-1	-1	1	2.89	0.02	1.37E+04	53.28	2.3997	77.90	0.7928	13.08	11.06
-1	-1	1	2.89	0.01	9.45E+03	52.36	2.3997	77.90	0.7928	13.08	11.06
-1	-1	0	2.89	15.00	6.94E+05	11.18	2.3997	77.90	0.7928	13.08	11.06
-1	-1	0	2.89	10.00	6.58E+05	11.68	2.3997	77.90	0.7928	13.08	11.06
-1	-1	0	2.89	5.00	5.79E+05	15.07	2.3997	77.90	0.7928	13.08	11.06
-1	-1	0	2.89	2.00	4.30E+05	19.79	2.3997	77.90	0.7928	13.08	11.06
-1	-1	0	2.89	1.00	3.50E+05	27.25	2.3997	77.90	0.7928	13.08	11.06
-1	-1	0	2.89	0.50	2.72E+05	32.52	2.3997	77.90	0.7928	13.08	11.06
-1	-1	0	2.89	0.20	1.34E+05	40.27	2.3997	77.90	0.7928	13.08	11.06
-1	-1	0	2.89	0.10	8.75E+04	43.08	2.3997	77.90	0.7928	13.08	11.06
-1	-1	0	2.89	0.05	5.38E+04	45.67	2.3997	77.90	0.7928	13.08	11.06
-1	-1	0	2.89	0.02	3.53E+04	48.57	2.3997	77.90	0.7928	13.08	11.06
-1	-1	0	2.89	0.01	2.45E+04	49.58	2.3997	77.90	0.7928	13.08	11.06
-1	-1	-1	2.89	15.00	8.19E+05	6.14	2.3997	77.90	0.7928	13.08	11.06
-1	-1	-1	2.89	10.00	8.06E+05	7.14	2.3997	77.90	0.7928	13.08	11.06
-1	-1	-1	2.89	5.00	7.50E+05	9.94	2.3997	77.90	0.7928	13.08	11.06
-1	-1	-1	2.89	2.00	6.36E+05	12.61	2.3997	77.90	0.7928	13.08	11.06
-1	-1	-1	2.89	1.00	4.50E+05	20.24	2.3997	77.90	0.7928	13.08	11.06
-1	-1	-1	2.89	0.50	3.50E+05	26.61	2.3997	77.90	0.7928	13.08	11.06
-1	-1	-1	2.89	0.20	2.37E+05	31.51	2.3997	77.90	0.7928	13.08	11.06
-1	-1	-1	2.89	0.10	1.48E+05	35.81	2.3997	77.90	0.7928	13.08	11.06
-1	-1	-1	2.89	0.05	8.75E+04	39.11	2.3997	77.90	0.7928	13.08	11.06
-1	-1	-1	2.89	0.02	5.92E+04	43.38	2.3997	77.90	0.7928	13.08	11.06
-1	-1	-1	2.89	0.01	4.18E+04	45.57	2.3997	77.90	0.7928	13.08	11.06
-1	-1	1	6.12	15.00	3.97E+05	28.69	2.3200	61.67	0.6359	15.97	10.69
-1	-1	1	6.12	10.00	3.61E+05	31.18	2.3200	61.67	0.6359	15.97	10.69
-1	-1	1	6.12	5.00	2.75E+05	36.20	2.3200	61.67	0.6359	15.97	10.69
-1	-1	1	6.12	2.00	1.18E+05	41.36	2.3200	61.67	0.6359	15.97	10.69
-1	-1	1	6.12	1.00	9.38E+04	46.80	2.3200	61.67	0.6359	15.97	10.69
-1	-1	1	6.12	0.50	5.60E+04	48.81	2.3200	61.67	0.6359	15.97	10.69
-1	-1	1	6.12	0.20	3.01E+04	51.51	2.3200	61.67	0.6359	15.97	10.69

(Continued)

AC	GR	Temp	V_a	Freq	|G*|	Phase angle	G_{mb}	VFA	$V_b/(V_a+V_b)$	VMA	V_b
			(%)	(Hz)	(psi)	(Degree)		(%)		(%)	(%)
-1	-1	1	6.12	0.10	2.01E+04	51.86	2.3200	61.67	0.6359	15.97	10.69
-1	-1	1	6.12	0.05	1.25E+04	48.73	2.3200	61.67	0.6359	15.97	10.69
-1	-1	1	6.12	0.02	8.36E+03	49.37	2.3200	61.67	0.6359	15.97	10.69
-1	-1	1	6.12	0.01	6.07E+03	46.07	2.3200	61.67	0.6359	15.97	10.69
-1	-1	0	6.12	15.00	6.74E+05	19.35	2.3200	61.67	0.6359	15.97	10.69
-1	-1	0	6.12	10.00	6.27E+05	20.74	2.3200	61.67	0.6359	15.97	10.69
-1	-1	0	6.12	5.00	5.43E+05	25.28	2.3200	61.67	0.6359	15.97	10.69
-1	-1	0	6.12	2.00	2.61E+05	29.47	2.3200	61.67	0.6359	15.97	10.69
-1	-1	0	6.12	1.00	2.64E+05	34.65	2.3200	61.67	0.6359	15.97	10.69
-1	-1	0	6.12	0.50	1.46E+05	36.69	2.3200	61.67	0.6359	15.97	10.69
-1	-1	0	6.12	0.20	6.69E+04	44.03	2.3200	61.67	0.6359	15.97	10.69
-1	-1	0	6.12	0.10	4.08E+04	46.86	2.3200	61.67	0.6359	15.97	10.69
-1	-1	0	6.12	0.05	3.59E+04	44.43	2.3200	61.67	0.6359	15.97	10.69
-1	-1	0	6.12	0.02	2.06E+04	46.67	2.3200	61.67	0.6359	15.97	10.69
-1	-1	0	6.12	0.01	1.27E+04	49.66	2.3200	61.67	0.6359	15.97	10.69
-1	-1	1	5.89	15.00	3.47E+05	34.00	2.3255	62.64	0.6453	15.77	10.72
-1	-1	1	5.89	10.00	2.86E+05	37.61	2.3255	62.64	0.6453	15.77	10.72
-1	-1	1	5.89	5.00	1.91E+05	44.25	2.3255	62.64	0.6453	15.77	10.72
-1	-1	1	5.89	2.00	1.02E+05	44.87	2.3255	62.64	0.6453	15.77	10.72
-1	-1	1	5.89	1.00	7.44E+04	50.57	2.3255	62.64	0.6453	15.77	10.72
-1	-1	1	5.89	0.50	4.62E+04	53.02	2.3255	62.64	0.6453	15.77	10.72
-1	-1	1	5.89	0.20	2.59E+04	55.33	2.3255	62.64	0.6453	15.77	10.72
-1	-1	1	5.89	0.10	1.71E+04	55.69	2.3255	62.64	0.6453	15.77	10.72
-1	-1	1	5.89	0.05	1.11E+04	56.15	2.3255	62.64	0.6453	15.77	10.72
-1	-1	1	5.89	0.02	6.73E+03	53.17	2.3255	62.64	0.6453	15.77	10.72
-1	-1	1	5.89	0.01	4.85E+03	50.60	2.3255	62.64	0.6453	15.77	10.72
-1	-1	0	5.89	15.00	5.72E+05	21.72	2.3255	62.64	0.6453	15.77	10.72
-1	-1	0	5.89	10.00	5.06E+05	24.45	2.3255	62.64	0.6453	15.77	10.72
-1	-1	0	5.89	5.00	4.06E+05	29.88	2.3255	62.64	0.6453	15.77	10.72
-1	-1	0	5.89	2.00	1.98E+05	33.29	2.3255	62.64	0.6453	15.77	10.72
-1	-1	0	5.89	1.00	1.74E+05	41.08	2.3255	62.64	0.6453	15.77	10.72
-1	-1	0	5.89	0.50	1.09E+05	45.45	2.3255	62.64	0.6453	15.77	10.72
-1	-1	0	5.89	0.20	5.95E+04	49.42	2.3255	62.64	0.6453	15.77	10.72
-1	-1	0	5.89	0.10	3.93E+04	51.97	2.3255	62.64	0.6453	15.77	10.72
-1	-1	0	5.89	0.05	2.47E+04	53.74	2.3255	62.64	0.6453	15.77	10.72
-1	-1	0	5.89	0.02	1.54E+04	55.50	2.3255	62.64	0.6453	15.77	10.72
-1	-1	0	5.89	0.01	1.03E+04	54.75	2.3255	62.64	0.6453	15.77	10.72
-1	-1	-1	5.89	15.00	6.90E+05	10.00	2.3255	62.64	0.6453	15.77	10.72
-1	-1	-1	5.89	10.00	6.50E+05	10.28	2.3255	62.64	0.6453	15.77	10.72
-1	-1	-1	5.89	5.00	5.50E+05	16.88	2.3255	62.64	0.6453	15.77	10.72
-1	-1	-1	5.89	2.00	3.73E+05	22.63	2.3255	62.64	0.6453	15.77	10.72
-1	-1	-1	5.89	1.00	2.25E+05	37.75	2.3255	62.64	0.6453	15.77	10.72
-1	-1	-1	5.89	0.50	2.00E+05	45.24	2.3255	62.64	0.6453	15.77	10.72
-1	-1	-1	5.89	0.20	1.24E+05	45.65	2.3255	62.64	0.6453	15.77	10.72
-1	-1	-1	5.89	0.10	7.92E+04	48.36	2.3255	62.64	0.6453	15.77	10.72
-1	-1	-1	5.89	0.05	4.87E+04	51.16	2.3255	62.64	0.6453	15.77	10.72
-1	-1	-1	5.89	0.02	3.09E+04	53.29	2.3255	62.64	0.6453	15.77	10.72
-1	-1	-1	5.89	0.01	2.05E+04	54.56	2.3255	62.64	0.6453	15.77	10.72
-1	-1	1	7.70	15.00	1.99E+05	28.32	2.2808	55.72	0.5772	17.39	10.51
-1	-1	1	7.70	10.00	1.71E+05	31.31	2.2808	55.72	0.5772	17.39	10.51
-1	-1	1	7.70	5.00	1.27E+05	36.64	2.2808	55.72	0.5772	17.39	10.51
-1	-1	1	7.70	2.00	7.95E+04	40.52	2.2808	55.72	0.5772	17.39	10.51
-1	-1	1	7.70	1.00	6.06E+04	45.28	2.2808	55.72	0.5772	17.39	10.51
-1	-1	1	7.70	0.50	3.96E+04	51.49	2.2808	55.72	0.5772	17.39	10.51
-1	-1	1	7.70	0.20	2.27E+04	55.40	2.2808	55.72	0.5772	17.39	10.51

(Continued)

AC	GR	Temp	V_a	Freq	|G*|	Phase angle	G_{mb}	VFA	$V_b/(V_a+V_b)$	VMA	V_b
			(%)	(Hz)	(psi)	(Degree)		(%)		(%)	(%)
-1	-1	1	7.70	0.10	1.48E+04	56.69	2.2808	55.72	0.5772	17.39	10.51
-1	-1	1	7.70	0.05	9.61E+03	59.04	2.2808	55.72	0.5772	17.39	10.51
-1	-1	1	7.70	0.02	5.68E+03	58.36	2.2808	55.72	0.5772	17.39	10.51
-1	-1	1	7.70	0.01	3.83E+03	56.95	2.2808	55.72	0.5772	17.39	10.51
-1	-1	0	7.70	15.00	3.24E+05	17.41	2.2808	55.72	0.5772	17.39	10.51
-1	-1	0	7.70	10.00	2.91E+05	19.67	2.2808	55.72	0.5772	17.39	10.51
-1	-1	0	7.70	5.00	2.30E+05	24.98	2.2808	55.72	0.5772	17.39	10.51
-1	-1	0	7.70	2.00	1.36E+05	29.00	2.2808	55.72	0.5772	17.39	10.51
-1	-1	0	7.70	1.00	1.24E+05	33.92	2.2808	55.72	0.5772	17.39	10.51
-1	-1	0	7.70	0.50	8.52E+04	39.08	2.2808	55.72	0.5772	17.39	10.51
-1	-1	0	7.70	0.20	5.14E+04	44.97	2.2808	55.72	0.5772	17.39	10.51
-1	-1	0	7.70	0.10	3.53E+04	47.71	2.2808	55.72	0.5772	17.39	10.51
-1	-1	0	7.70	0.05	2.26E+04	50.48	2.2808	55.72	0.5772	17.39	10.51
-1	-1	0	7.70	0.02	1.48E+04	52.14	2.2808	55.72	0.5772	17.39	10.51
-1	-1	0	7.70	0.01	1.01E+04	52.26	2.2808	55.72	0.5772	17.39	10.51
-1	-1	-1	7.70	15.00	3.72E+05	10.49	2.2808	55.72	0.5772	17.39	10.51
-1	-1	-1	7.70	10.00	3.49E+05	11.45	2.2808	55.72	0.5772	17.39	10.51
-1	-1	-1	7.70	5.00	3.08E+05	14.22	2.2808	55.72	0.5772	17.39	10.51
-1	-1	-1	7.70	2.00	1.95E+05	21.05	2.2808	55.72	0.5772	17.39	10.51
-1	-1	-1	7.70	1.00	2.04E+05	17.90	2.2808	55.72	0.5772	17.39	10.51
-1	-1	-1	7.70	0.50	1.55E+05	25.94	2.2808	55.72	0.5772	17.39	10.51
-1	-1	-1	7.70	0.20	9.80E+04	34.14	2.2808	55.72	0.5772	17.39	10.51
-1	-1	-1	7.70	0.10	6.88E+04	39.05	2.2808	55.72	0.5772	17.39	10.51
-1	-1	-1	7.70	0.05	4.50E+04	42.11	2.2808	55.72	0.5772	17.39	10.51
-1	-1	-1	7.70	0.02	3.06E+04	46.71	2.2808	55.72	0.5772	17.39	10.51
-1	-1	-1	7.70	0.01	2.16E+04	48.48	2.2808	55.72	0.5772	17.39	10.51
-1	-1	1	7.87	15.00	2.61E+05	39.76	2.2766	55.14	0.5715	17.54	10.49
-1	-1	1	7.87	10.00	2.05E+05	42.35	2.2766	55.14	0.5715	17.54	10.49
-1	-1	1	7.87	5.00	1.35E+05	47.13	2.2766	55.14	0.5715	17.54	10.49
-1	-1	1	7.87	2.00	7.47E+04	48.66	2.2766	55.14	0.5715	17.54	10.49
-1	-1	1	7.87	1.00	5.25E+04	51.71	2.2766	55.14	0.5715	17.54	10.49
-1	-1	1	7.87	0.50	3.32E+04	54.33	2.2766	55.14	0.5715	17.54	10.49
-1	-1	1	7.87	0.20	1.93E+04	55.72	2.2766	55.14	0.5715	17.54	10.49
-1	-1	1	7.87	0.10	1.28E+04	55.66	2.2766	55.14	0.5715	17.54	10.49
-1	-1	1	7.87	0.05	8.24E+03	55.62	2.2766	55.14	0.5715	17.54	10.49
-1	-1	1	7.87	0.02	5.23E+03	54.01	2.2766	55.14	0.5715	17.54	10.49
-1	-1	1	7.87	0.01	3.88E+03	51.68	2.2766	55.14	0.5715	17.54	10.49
-1	-1	0	7.87	15.00	4.71E+05	23.82	2.2766	55.14	0.5715	17.54	10.49
-1	-1	0	7.87	10.00	4.26E+05	26.89	2.2766	55.14	0.5715	17.54	10.49
-1	-1	0	7.87	5.00	3.18E+05	32.95	2.2766	55.14	0.5715	17.54	10.49
-1	-1	0	7.87	2.00	1.69E+05	35.70	2.2766	55.14	0.5715	17.54	10.49
-1	-1	0	7.87	1.00	1.39E+05	43.02	2.2766	55.14	0.5715	17.54	10.49
-1	-1	0	7.87	0.50	8.83E+04	46.70	2.2766	55.14	0.5715	17.54	10.49
-1	-1	0	7.87	0.20	4.94E+04	50.82	2.2766	55.14	0.5715	17.54	10.49
-1	-1	0	7.87	0.10	3.27E+04	52.99	2.2766	55.14	0.5715	17.54	10.49
-1	-1	0	7.87	0.05	2.04E+04	54.88	2.2766	55.14	0.5715	17.54	10.49
-1	-1	0	7.87	0.02	1.27E+04	56.49	2.2766	55.14	0.5715	17.54	10.49
-1	-1	0	7.87	0.01	8.55E+03	56.37	2.2766	55.14	0.5715	17.54	10.49
-1	-1	-1	7.87	15.00	5.03E+05	10.20	2.2766	55.14	0.5715	17.54	10.49
-1	-1	-1	7.87	10.00	4.75E+05	11.63	2.2766	55.14	0.5715	17.54	10.49
-1	-1	-1	7.87	5.00	4.17E+05	15.40	2.2766	55.14	0.5715	17.54	10.49
-1	-1	-1	7.87	2.00	3.20E+05	23.72	2.2766	55.14	0.5715	17.54	10.49
-1	-1	-1	7.87	1.00	2.61E+05	21.38	2.2766	55.14	0.5715	17.54	10.49
-1	-1	-1	7.87	0.50	1.62E+05	34.22	2.2766	55.14	0.5715	17.54	10.49
-1	-1	-1	7.87	0.20	8.79E+04	42.31	2.2766	55.14	0.5715	17.54	10.49

(Continued)

AC	GR	Temp	V_a	Freq	|G*|	Phase angle	G_{mb}	VFA	$V_b/(V_a+V_b)$	VMA	V_b
			(%)	(Hz)	(psi)	(Degree)		(%)		(%)	(%)
-1	-1	-1	7.87	0.10	5.90E+04	46.23	2.2766	55.14	0.5715	17.54	10.49
-1	-1	-1	7.87	0.05	3.69E+04	48.37	2.2766	55.14	0.5715	17.54	10.49
-1	-1	-1	7.87	0.02	2.40E+04	52.91	2.2766	55.14	0.5715	17.54	10.49
-1	-1	-1	7.87	0.01	1.63E+04	53.91	2.2766	55.14	0.5715	17.54	10.49
1	1	1.2	3.75	15.00	4.92E+05	11.50	2.3899	72.62	0.7460	13.70	11.01
1	1	1.2	3.75	10.00	4.49E+05	13.69	2.3899	72.62	0.7460	13.70	11.01
1	1	1.2	3.75	5.00	3.72E+05	18.32	2.3899	72.62	0.7460	13.70	11.01
1	1	1.2	3.75	2.00	2.03E+05	22.23	2.3899	72.62	0.7460	13.70	11.01
1	1	1.2	3.75	1.00	2.45E+05	22.81	2.3899	72.62	0.7460	13.70	11.01
1	1	1.2	3.75	0.50	1.65E+05	29.52	2.3899	72.62	0.7460	13.70	11.01
1	1	1.2	3.75	0.20	9.52E+04	34.04	2.3899	72.62	0.7460	13.70	11.01
1	1	1.2	3.75	0.10	6.66E+04	36.52	2.3899	72.62	0.7460	13.70	11.01
1	1	1.2	3.75	0.05	4.59E+04	38.07	2.3899	72.62	0.7460	13.70	11.01
1	1	1.2	3.75	0.02	3.28E+04	38.53	2.3899	72.62	0.7460	13.70	11.01
1	1	1.2	3.75	0.01	2.50E+04	39.64	2.3899	72.62	0.7460	13.70	11.01
1	1	0	3.75	15.00	6.27E+05	5.46	2.3899	72.62	0.7460	13.70	11.01
1	1	0	3.75	10.00	6.14E+05	6.73	2.3899	72.62	0.7460	13.70	11.01
1	1	0	3.75	5.00	5.67E+05	10.03	2.3899	72.62	0.7460	13.70	11.01
1	1	0	3.75	2.00	5.50E+05	12.92	2.3899	72.62	0.7460	13.70	11.01
1	1	0	3.75	1.00	4.50E+05	16.00	2.3899	72.62	0.7460	13.70	11.01
1	1	0	3.75	0.50	3.35E+05	20.00	2.3899	72.62	0.7460	13.70	11.01
1	1	0	3.75	0.20	2.91E+05	25.48	2.3899	72.62	0.7460	13.70	11.01
1	1	0	3.75	0.10	1.29E+05	31.47	2.3899	72.62	0.7460	13.70	11.01
1	1	0	3.75	0.05	8.25E+04	33.40	2.3899	72.62	0.7460	13.70	11.01
1	1	0	3.75	0.02	5.92E+04	37.93	2.3899	72.62	0.7460	13.70	11.01
1	1	0	3.75	0.01	4.51E+04	38.91	2.3899	72.62	0.7460	13.70	11.01
1	1	-1	3.75	15.00	1.46E+06	7.27	2.3899	72.62	0.7460	13.70	11.01
1	1	-1	3.75	10.00	1.43E+06	8.97	2.3899	72.62	0.7460	13.70	11.01
1	1	-1	3.75	5.00	1.33E+06	13.21	2.3899	72.62	0.7460	13.70	11.01
1	1	-1	3.75	2.00	1.05E+06	19.39	2.3899	72.62	0.7460	13.70	11.01
1	1	-1	3.75	1.00	9.17E+05	28.42	2.3899	72.62	0.7460	13.70	11.01
1	1	-1	3.75	0.50	8.50E+05	37.04	2.3899	72.62	0.7460	13.70	11.01
1	1	-1	3.75	0.20	8.00E+05	41.77	2.3899	72.62	0.7460	13.70	11.01
1	1	-1	3.75	0.10	7.50E+05	44.82	2.3899	72.62	0.7460	13.70	11.01
1	1	-1	3.75	0.05	4.57E+05	47.95	2.3899	72.62	0.7460	13.70	11.01
1	1	-1	3.75	0.02	2.59E+05	51.82	2.3899	72.62	0.7460	13.70	11.01
1	1	-1	3.75	0.01	1.60E+05	52.20	2.3899	72.62	0.7460	13.70	11.01
1	1	1	4.18	15.00	3.63E+05	22.10	2.3793	70.31	0.7240	14.08	10.96
1	1	1	4.18	10.00	3.13E+05	26.80	2.3793	70.31	0.7240	14.08	10.96
1	1	1	4.18	5.00	2.31E+05	35.83	2.3793	70.31	0.7240	14.08	10.96
1	1	1	4.18	2.00	1.08E+05	41.69	2.3793	70.31	0.7240	14.08	10.96
1	1	1	4.18	1.00	8.74E+04	45.78	2.3793	70.31	0.7240	14.08	10.96
1	1	1	4.18	0.50	5.21E+04	50.48	2.3793	70.31	0.7240	14.08	10.96
1	1	1	4.18	0.20	2.99E+04	54.02	2.3793	70.31	0.7240	14.08	10.96
1	1	1	4.18	0.10	1.98E+04	55.06	2.3793	70.31	0.7240	14.08	10.96
1	1	1	4.18	0.05	1.27E+04	55.55	2.3793	70.31	0.7240	14.08	10.96
1	1	1	4.18	0.02	8.13E+03	54.61	2.3793	70.31	0.7240	14.08	10.96
1	1	1	4.18	0.01	5.60E+03	51.68	2.3793	70.31	0.7240	14.08	10.96
1	1	0	4.18	15.00	4.84E+05	16.07	2.3793	70.31	0.7240	14.08	10.96
1	1	0	4.18	10.00	4.45E+05	19.09	2.3793	70.31	0.7240	14.08	10.96
1	1	0	4.18	5.00	3.86E+05	24.76	2.3793	70.31	0.7240	14.08	10.96
1	1	0	4.18	2.00	1.77E+05	32.00	2.3793	70.31	0.7240	14.08	10.96
1	1	0	4.18	1.00	1.82E+05	38.23	2.3793	70.31	0.7240	14.08	10.96
1	1	0	4.18	0.50	1.03E+05	44.72	2.3793	70.31	0.7240	14.08	10.96
1	1	0	4.18	0.20	5.46E+04	49.15	2.3793	70.31	0.7240	14.08	10.96

(Continued)

AC	GR	Temp	V_a (%)	Freq (Hz)	|G*| (psi)	Phase angle (Degree)	G_{mb}	VFA (%)	$V_b/(V_a+V_b)$	VMA (%)	V_b (%)
1	1	0	4.18	0.10	3.69E+04	50.98	2.3793	70.31	0.7240	14.08	10.96
1	1	0	4.18	0.05	2.35E+04	52.18	2.3793	70.31	0.7240	14.08	10.96
1	1	0	4.18	0.02	1.54E+04	51.56	2.3793	70.31	0.7240	14.08	10.96
1	1	0	4.18	0.01	1.08E+04	49.62	2.3793	70.31	0.7240	14.08	10.96
1	1	-1	4.18	15.00	7.27E+05	7.27	2.3793	70.31	0.7240	14.08	10.96
1	1	-1	4.18	10.00	7.03E+05	8.97	2.3793	70.31	0.7240	14.08	10.96
1	1	-1	4.18	5.00	6.50E+05	13.21	2.3793	70.31	0.7240	14.08	10.96
1	1	-1	4.18	2.00	5.50E+05	19.39	2.3793	70.31	0.7240	14.08	10.96
1	1	-1	4.18	1.00	4.60E+05	28.42	2.3793	70.31	0.7240	14.08	10.96
1	1	-1	4.18	0.50	3.84E+05	37.04	2.3793	70.31	0.7240	14.08	10.96
1	1	-1	4.18	0.20	1.28E+05	41.77	2.3793	70.31	0.7240	14.08	10.96
1	1	-1	4.18	0.10	7.76E+04	44.82	2.3793	70.31	0.7240	14.08	10.96
1	1	-1	4.18	0.05	4.78E+04	47.95	2.3793	70.31	0.7240	14.08	10.96
1	1	-1	4.18	0.02	3.09E+04	51.82	2.3793	70.31	0.7240	14.08	10.96
1	1	-1	4.18	0.01	2.18E+04	52.20	2.3793	70.31	0.7240	14.08	10.96
1	1	1	5.55	15.00	3.00E+05	26.97	2.3451	63.76	0.6607	15.31	10.81
1	1	1	5.55	10.00	2.53E+05	30.17	2.3451	63.76	0.6607	15.31	10.81
1	1	1	5.55	5.00	1.79E+05	36.86	2.3451	63.76	0.6607	15.31	10.81
1	1	1	5.55	2.00	9.11E+04	42.24	2.3451	63.76	0.6607	15.31	10.81
1	1	1	5.55	1.00	7.29E+04	46.53	2.3451	63.76	0.6607	15.31	10.81
1	1	1	5.55	0.50	4.60E+04	50.18	2.3451	63.76	0.6607	15.31	10.81
1	1	1	5.55	0.20	2.63E+04	53.12	2.3451	63.76	0.6607	15.31	10.81
1	1	1	5.55	0.10	1.79E+04	53.57	2.3451	63.76	0.6607	15.31	10.81
1	1	1	5.55	0.05	1.13E+04	54.67	2.3451	63.76	0.6607	15.31	10.81
1	1	1	5.55	0.02	7.25E+03	49.40	2.3451	63.76	0.6607	15.31	10.81
1	1	1	5.55	0.01	5.27E+03	49.08	2.3451	63.76	0.6607	15.31	10.81
1	1	0	5.55	15.00	4.56E+05	16.90	2.3451	63.76	0.6607	15.31	10.81
1	1	0	5.55	10.00	4.06E+05	19.18	2.3451	63.76	0.6607	15.31	10.81
1	1	0	5.55	5.00	3.19E+05	25.15	2.3451	63.76	0.6607	15.31	10.81
1	1	0	5.55	2.00	2.25E+05	29.97	2.3451	63.76	0.6607	15.31	10.81
1	1	0	5.55	1.00	1.58E+05	38.46	2.3451	63.76	0.6607	15.31	10.81
1	1	0	5.55	0.50	9.93E+04	43.66	2.3451	63.76	0.6607	15.31	10.81
1	1	0	5.55	0.20	5.45E+04	48.32	2.3451	63.76	0.6607	15.31	10.81
1	1	0	5.55	0.10	3.60E+04	51.25	2.3451	63.76	0.6607	15.31	10.81
1	1	0	5.55	0.05	2.27E+04	53.49	2.3451	63.76	0.6607	15.31	10.81
1	1	0	5.55	0.02	1.42E+04	55.13	2.3451	63.76	0.6607	15.31	10.81
1	1	0	5.55	0.01	9.40E+03	53.77	2.3451	63.76	0.6607	15.31	10.81
1	1	-1	5.55	15.00	4.92E+05	9.28	2.3451	63.76	0.6607	15.31	10.81
1	1	-1	5.55	10.00	4.55E+05	10.66	2.3451	63.76	0.6607	15.31	10.81
1	1	-1	5.55	5.00	4.23E+05	13.53	2.3451	63.76	0.6607	15.31	10.81
1	1	-1	5.55	2.00	3.50E+05	21.22	2.3451	63.76	0.6607	15.31	10.81
1	1	-1	5.55	1.00	2.89E+05	25.00	2.3451	63.76	0.6607	15.31	10.81
1	1	-1	5.55	0.50	1.91E+05	29.40	2.3451	63.76	0.6607	15.31	10.81
1	1	-1	5.55	0.20	1.00E+05	38.41	2.3451	63.76	0.6607	15.31	10.81
1	1	-1	5.55	0.10	6.70E+04	43.36	2.3451	63.76	0.6607	15.31	10.81
1	1	-1	5.55	0.05	4.37E+04	46.88	2.3451	63.76	0.6607	15.31	10.81
1	1	-1	5.55	0.02	2.88E+04	49.71	2.3451	63.76	0.6607	15.31	10.81
1	1	-1	5.55	0.01	2.16E+04	48.59	2.3451	63.76	0.6607	15.31	10.81
1	1	1	5.70	15.00	3.80E+05	19.65	2.3416	63.08	0.6543	15.44	10.79
1	1	1	5.70	10.00	3.35E+05	21.71	2.3420	63.05	0.6544	15.43	10.79
1	1	1	5.70	5.00	2.64E+05	26.80	2.3416	63.08	0.6543	15.44	10.79
1	1	1	5.70	2.00	1.80E+05	31.81	2.3417	63.07	0.6543	15.44	10.79
1	1	1	5.70	1.00	1.29E+05	36.54	2.3417	63.07	0.6543	15.44	10.79
1	1	1	5.70	0.50	8.45E+04	41.29	2.3417	63.07	0.6543	15.44	10.79
1	1	1	5.70	0.20	5.00E+04	45.32	2.3417	63.07	0.6543	15.44	10.79

(Continued)

AC	GR	Temp	V_a	Freq	|G*|	Phase angle	G_{mb}	VFA	$V_b/(V_a+V_b)$	VMA	V_b
			(%)	(Hz)	(psi)	(Degree)		(%)		(%)	(%)
1	1	1	5.70	0.10	3.42E+04	47.32	2.3417	63.07	0.6543	15.44	10.79
1	1	1	5.70	0.05	2.23E+04	48.46	2.3417	63.07	0.6543	15.44	10.79
1	1	1	5.70	0.02	1.49E+04	51.51	2.3417	63.07	0.6543	15.44	10.79
1	1	1	5.70	0.01	1.10E+04	49.14	2.3417	63.07	0.6543	15.44	10.79
1	1	0	5.70	15.00	5.46E+05	10.26	2.3417	63.07	0.6543	15.44	10.79
1	1	0	5.70	10.00	5.03E+05	11.86	2.3417	63.07	0.6543	15.44	10.79
1	1	0	5.70	5.00	4.39E+05	14.00	2.3417	63.07	0.6543	15.44	10.79
1	1	0	5.70	2.00	3.70E+05	17.21	2.3417	63.07	0.6543	15.44	10.79
1	1	0	5.70	1.00	3.14E+05	19.00	2.3417	63.07	0.6543	15.44	10.79
1	1	0	5.70	0.50	2.07E+05	25.90	2.3417	63.07	0.6543	15.44	10.79
1	1	0	5.70	0.20	1.20E+05	34.59	2.3417	63.07	0.6543	15.44	10.79
1	1	0	5.70	0.10	8.01E+04	38.27	2.3417	63.07	0.6543	15.44	10.79
1	1	0	5.70	0.05	4.98E+04	41.43	2.3417	63.07	0.6543	15.44	10.79
1	1	0	5.70	0.02	3.41E+04	45.20	2.3417	63.07	0.6543	15.44	10.79
1	1	0	5.70	0.01	2.42E+04	46.64	2.3417	63.07	0.6543	15.44	10.79
1	1	-1	5.70	15.00	6.23E+05	9.28	2.3417	63.07	0.6543	15.44	10.79
1	1	-1	5.70	10.00	5.95E+05	10.66	2.3417	63.07	0.6543	15.44	10.79
1	1	-1	5.70	5.00	5.70E+05	13.53	2.3417	63.07	0.6543	15.44	10.79
1	1	-1	5.70	2.00	4.60E+05	18.00	2.3417	63.07	0.6543	15.44	10.79
1	1	-1	5.70	1.00	4.30E+05	20.00	2.3417	63.07	0.6543	15.44	10.79
1	1	-1	5.70	0.50	3.50E+05	22.00	2.3417	63.07	0.6543	15.44	10.79
1	1	-1	5.70	0.20	2.04E+05	24.35	2.3417	63.07	0.6543	15.44	10.79
1	1	-1	5.70	0.10	1.26E+05	31.07	2.3417	63.07	0.6543	15.44	10.79
1	1	-1	5.70	0.05	7.77E+04	35.49	2.3417	63.07	0.6543	15.44	10.79
1	1	-1	5.70	0.02	5.40E+04	40.38	2.3417	63.07	0.6543	15.44	10.79
1	1	-1	5.70	0.01	3.96E+04	43.27	2.3417	63.07	0.6543	15.44	10.79
1	1	1	5.36	15.00	5.79E+05	18.24	2.3498	64.60	0.6689	15.14	10.83
1	1	1	5.36	10.00	5.05E+05	21.45	2.3498	64.60	0.6689	15.14	10.83
1	1	1	5.36	5.00	4.01E+05	25.55	2.3498	64.60	0.6689	15.14	10.83
1	1	1	5.36	2.00	2.60E+05	29.88	2.3498	64.60	0.6689	15.14	10.83
1	1	1	5.36	1.00	1.80E+05	36.73	2.3498	64.60	0.6689	15.14	10.83
1	1	1	5.36	0.50	1.12E+05	40.94	2.3498	64.60	0.6689	15.14	10.83
1	1	1	5.36	0.20	6.37E+04	43.63	2.3498	64.60	0.6689	15.14	10.83
1	1	1	5.36	0.10	4.35E+04	44.95	2.3498	64.60	0.6689	15.14	10.83
1	1	1	5.36	0.05	2.82E+04	46.60	2.3498	64.60	0.6689	15.14	10.83
1	1	1	5.36	0.02	1.87E+04	46.54	2.3498	64.60	0.6689	15.14	10.83
1	1	1	5.36	0.01	1.38E+04	47.82	2.3498	64.60	0.6689	15.14	10.83
1	1	0	5.36	15.00	6.68E+05	5.72	2.3498	64.60	0.6689	15.14	10.83
1	1	0	5.36	10.00	6.16E+05	7.48	2.3498	64.60	0.6689	15.14	10.83
1	1	0	5.36	5.00	5.52E+05	11.55	2.3498	64.60	0.6689	15.14	10.83
1	1	0	5.36	2.00	4.80E+05	15.52	2.3498	64.60	0.6689	15.14	10.83
1	1	0	5.36	1.00	3.80E+05	17.18	2.3498	64.60	0.6689	15.14	10.83
1	1	0	5.36	0.50	2.60E+05	24.50	2.3498	64.60	0.6689	15.14	10.83
1	1	0	5.36	0.20	1.28E+05	31.74	2.3498	64.60	0.6689	15.14	10.83
1	1	0	5.36	0.10	8.52E+04	36.10	2.3498	64.60	0.6689	15.14	10.83
1	1	0	5.36	0.05	5.65E+04	38.66	2.3498	64.60	0.6689	15.14	10.83
1	1	0	5.36	0.02	4.15E+04	43.29	2.3498	64.60	0.6689	15.14	10.83
1	1	0	5.36	0.01	2.96E+04	42.21	2.3498	64.60	0.6689	15.14	10.83
1	1	-1	5.36	0.20	2.03E+05	23.21	2.3498	64.60	0.6689	15.14	10.83
1	1	-1	5.36	0.10	1.35E+05	28.65	2.3498	64.60	0.6689	15.14	10.83
1	1	-1	5.36	0.05	8.87E+04	30.92	2.3498	64.60	0.6689	15.14	10.83
1	1	-1	5.36	0.02	6.46E+04	35.82	2.3498	64.60	0.6689	15.14	10.83
1	1	-1	5.36	0.01	4.98E+04	38.23	2.3498	64.60	0.6689	15.14	10.83
1	1	1	6.33	15.00	2.90E+05	24.22	2.3258	60.47	0.6287	16.01	10.72
1	1	1	6.33	10.00	2.50E+05	26.31	2.3258	60.47	0.6287	16.01	10.72

(Continued)

AC	GR	Temp	V_a (%)	Freq (Hz)	|G*| (psi)	Phase angle (Degree)	G_{mb}	VFA (%)	$V_b/(V_a+V_b)$	VMA (%)	V_b (%)
1	1	1	6.33	5.00	1.86E+05	30.65	2.3258	60.47	0.6287	16.01	10.72
1	1	1	6.33	2.00	1.08E+05	35.94	2.3258	60.47	0.6287	16.01	10.72
1	1	1	6.33	1.00	9.06E+04	37.55	2.3258	60.47	0.6287	16.01	10.72
1	1	1	6.33	0.50	6.18E+04	41.11	2.3258	60.47	0.6287	16.01	10.72
1	1	1	6.33	0.20	3.83E+04	44.76	2.3258	60.47	0.6287	16.01	10.72
1	1	1	6.33	0.10	2.71E+04	46.80	2.3258	60.47	0.6287	16.01	10.72
1	1	1	6.33	0.05	1.81E+04	48.44	2.3258	60.47	0.6287	16.01	10.72
1	1	1	6.33	0.02	1.21E+04	47.27	2.3258	60.47	0.6287	16.01	10.72
1	1	1	6.33	0.01	7.75E+03	49.52	2.3258	60.47	0.6287	16.01	10.72
1	1	0	6.33	15.00	3.70E+05	13.37	2.3258	60.47	0.6287	16.01	10.72
1	1	0	6.33	10.00	3.31E+05	15.19	2.3258	60.47	0.6287	16.01	10.72
1	1	0	6.33	5.00	2.76E+05	18.41	2.3258	60.47	0.6287	16.01	10.72
1	1	0	6.33	2.00	1.62E+05	24.41	2.3258	60.47	0.6287	16.01	10.72
1	1	0	6.33	1.00	1.64E+05	25.18	2.3258	60.47	0.6287	16.01	10.72
1	1	0	6.33	0.50	1.14E+05	31.47	2.3258	60.47	0.6287	16.01	10.72
1	1	0	6.33	0.20	7.29E+04	36.23	2.3258	60.47	0.6287	16.01	10.72
1	1	0	6.33	0.10	5.29E+04	39.18	2.3258	60.47	0.6287	16.01	10.72
1	1	0	6.33	0.05	3.61E+04	40.74	2.3258	60.47	0.6287	16.01	10.72
1	1	0	6.33	0.02	2.54E+04	45.86	2.3258	60.47	0.6287	16.01	10.72
1	1	0	6.33	0.01	1.88E+04	45.08	2.3258	60.47	0.6287	16.01	10.72
1	1	-1	6.33	15.00	4.25E+05	1.53	2.3258	60.47	0.6287	16.01	10.72
1	1	-1	6.33	10.00	3.99E+05	2.50	2.3258	60.47	0.6287	16.01	10.72
1	1	-1	6.33	5.00	3.80E+05	5.08	2.3258	60.47	0.6287	16.01	10.72
1	1	-1	6.33	2.00	2.80E+05	11.97	2.3258	60.47	0.6287	16.01	10.72
1	1	-1	6.33	1.00	2.36E+05	12.00	2.3258	60.47	0.6287	16.01	10.72
1	1	-1	6.33	0.50	1.89E+05	13.17	2.3258	60.47	0.6287	16.01	10.72
1	1	-1	6.33	0.20	1.30E+05	19.98	2.3258	60.47	0.6287	16.01	10.72
1	1	-1	6.33	0.10	9.80E+04	24.97	2.3258	60.47	0.6287	16.01	10.72
1	1	-1	6.33	0.05	6.91E+04	28.57	2.3258	60.47	0.6287	16.01	10.72
1	1	-1	6.33	0.02	5.20E+04	34.20	2.3258	60.47	0.6287	16.01	10.72
1	1	-1	6.33	0.01	4.01E+04	38.49	2.3258	60.47	0.6287	16.01	10.72
1	1	1	7.73	15.00	4.34E+05	15.16	2.2911	55.22	0.5773	17.26	10.56
1	1	1	7.73	10.00	3.99E+05	17.22	2.2911	55.22	0.5773	17.26	10.56
1	1	1	7.73	5.00	3.40E+05	20.56	2.2911	55.22	0.5773	17.26	10.56
1	1	1	7.73	2.00	2.50E+05	26.93	2.2911	55.22	0.5773	17.26	10.56
1	1	1	7.73	1.00	1.84E+05	30.83	2.2911	55.22	0.5773	17.26	10.56
1	1	1	7.73	0.50	1.18E+05	36.52	2.2911	55.22	0.5773	17.26	10.56
1	1	1	7.73	0.20	7.06E+04	40.33	2.2911	55.22	0.5773	17.26	10.56
1	1	1	7.73	0.10	4.97E+04	42.02	2.2911	55.22	0.5773	17.26	10.56
1	1	1	7.73	0.05	3.27E+04	43.17	2.2911	55.22	0.5773	17.26	10.56
1	1	1	7.73	0.02	2.26E+04	45.77	2.2911	55.22	0.5773	17.26	10.56
1	1	1	7.73	0.01	1.64E+04	46.65	2.2911	55.22	0.5773	17.26	10.56
1	1	0	7.73	15.00	4.92E+05	8.95	2.2911	55.22	0.5773	17.26	10.56
1	1	0	7.73	10.00	4.58E+05	10.57	2.2911	55.22	0.5773	17.26	10.56
1	1	0	7.73	5.00	4.00E+05	13.51	2.2911	55.22	0.5773	17.26	10.56
1	1	0	7.73	2.00	3.00E+05	17.80	2.2911	55.22	0.5773	17.26	10.56
1	1	0	7.73	1.00	2.70E+05	19.05	2.2911	55.22	0.5773	17.26	10.56
1	1	0	7.73	0.50	1.86E+05	26.96	2.2911	55.22	0.5773	17.26	10.56
1	1	0	7.73	0.20	1.11E+05	32.72	2.2911	55.22	0.5773	17.26	10.56
1	1	0	7.73	0.10	7.89E+04	35.92	2.2911	55.22	0.5773	17.26	10.56
1	1	0	7.73	0.05	5.26E+04	38.00	2.2911	55.22	0.5773	17.26	10.56
1	1	0	7.73	0.02	3.78E+04	41.59	2.2911	55.22	0.5773	17.26	10.56
1	1	0	7.73	0.01	2.80E+04	43.11	2.2911	55.22	0.5773	17.26	10.56
1	1	-1	7.73	15.00	5.51E+05	2.41	2.2911	55.22	0.5773	17.26	10.56
1	1	-1	7.73	10.00	5.22E+05	3.53	2.2911	55.22	0.5773	17.26	10.56

(Continued)

AC	GR	Temp	V_a	Freq	|G*|	Phase angle	G_{mb}	VFA	$V_b/(V_a+V_b)$	VMA	V_b
			(%)	(Hz)	(psi)	(Degree)		(%)		(%)	(%)
1	1	-1	7.73	5.00	5.00E+05	5.66	2.2911	55.22	0.5773	17.26	10.56
1	1	-1	7.73	2.00	4.00E+05	11.38	2.2911	55.22	0.5773	17.26	10.56
1	1	-1	7.73	1.00	3.60E+05	13.00	2.2911	55.22	0.5773	17.26	10.56
1	1	-1	7.73	0.50	3.26E+05	14.00	2.2911	55.22	0.5773	17.26	10.56
1	1	-1	7.73	0.20	2.12E+05	20.07	2.2911	55.22	0.5773	17.26	10.56
1	1	-1	7.73	0.10	1.49E+05	25.26	2.2911	55.22	0.5773	17.26	10.56
1	1	-1	7.73	0.05	9.67E+04	28.31	2.2911	55.22	0.5773	17.26	10.56
1	1	-1	7.73	0.02	6.98E+04	34.14	2.2911	55.22	0.5773	17.26	10.56
1	1	-1	7.73	0.01	5.28E+04	36.63	2.2911	55.22	0.5773	17.26	10.56
-1	1	1	3.75	15.00	5.56E+05	17.87	2.3898	71.67	0.7240	13.25	9.84
-1	1	1	3.75	10.00	5.18E+05	21.06	2.3898	71.67	0.7240	13.25	9.84
-1	1	1	3.75	5.00	4.34E+05	25.78	2.3898	71.67	0.7240	13.25	9.84
-1	1	1	3.75	2.00	3.00E+05	30.48	2.3898	71.67	0.7240	13.25	9.84
-1	1	1	3.75	1.00	2.01E+05	38.92	2.3898	71.67	0.7240	13.25	9.84
-1	1	1	3.75	0.50	1.13E+05	47.36	2.3898	71.67	0.7240	13.25	9.84
-1	1	1	3.75	0.20	5.88E+04	49.94	2.3898	71.67	0.7240	13.25	9.84
-1	1	1	3.75	0.10	3.84E+04	51.93	2.3898	71.67	0.7240	13.25	9.84
-1	1	1	3.75	0.05	2.48E+04	52.87	2.3898	71.67	0.7240	13.25	9.84
-1	1	1	3.75	0.02	1.63E+04	53.78	2.3898	71.67	0.7240	13.25	9.84
-1	1	1	3.75	0.01	1.13E+04	53.58	2.3898	71.67	0.7240	13.25	9.84
-1	1	0	3.75	15.00	7.09E+05	10.00	2.3898	71.67	0.7240	13.25	9.84
-1	1	0	3.75	10.00	6.96E+05	11.46	2.3898	71.67	0.7240	13.25	9.84
-1	1	0	3.75	5.00	6.26E+05	15.05	2.3898	71.67	0.7240	13.25	9.84
-1	1	0	3.75	2.00	6.00E+05	19.79	2.3898	71.67	0.7240	13.25	9.84
-1	1	0	3.75	1.00	5.48E+05	28.45	2.3898	71.67	0.7240	13.25	9.84
-1	1	0	3.75	0.50	3.86E+05	36.46	2.3898	71.67	0.7240	13.25	9.84
-1	1	0	3.75	0.20	1.53E+05	42.75	2.3898	71.67	0.7240	13.25	9.84
-1	1	0	3.75	0.10	9.54E+04	45.13	2.3898	71.67	0.7240	13.25	9.84
-1	1	0	3.75	0.05	5.76E+04	47.20	2.3898	71.67	0.7240	13.25	9.84
-1	1	0	3.75	0.02	3.87E+04	49.63	2.3898	71.67	0.7240	13.25	9.84
-1	1	0	3.75	0.01	2.78E+04	50.12	2.3898	71.67	0.7240	13.25	9.84
-1	1	-1	3.75	15.00	1.02E+06	6.26	2.3898	71.67	0.7240	13.25	9.84
-1	1	-1	3.75	10.00	9.93E+05	7.00	2.3898	71.67	0.7240	13.25	9.84
-1	1	-1	3.75	5.00	9.10E+05	8.00	2.3898	71.67	0.7240	13.25	9.84
-1	1	-1	3.75	2.00	8.30E+05	16.88	2.3898	71.67	0.7240	13.25	9.84
-1	1	-1	3.75	1.00	7.90E+05	18.04	2.3898	71.67	0.7240	13.25	9.84
-1	1	-1	3.75	0.50	7.23E+05	34.76	2.3898	71.67	0.7240	13.25	9.84
-1	1	-1	3.75	0.20	4.80E+05	55.18	2.3898	71.67	0.7240	13.25	9.84
-1	1	-1	3.75	0.10	1.38E+05	49.15	2.3898	71.67	0.7240	13.25	9.84
-1	1	-1	3.75	0.05	7.68E+04	50.60	2.3898	71.67	0.7240	13.25	9.84
-1	1	-1	3.75	0.02	4.93E+04	53.20	2.3898	71.67	0.7240	13.25	9.84
-1	1	-1	3.75	0.01	3.31E+04	54.62	2.3898	71.67	0.7240	13.25	9.84
-1	1	1	4.19	15.00	4.98E+05	25.54	2.3790	69.29	0.7005	13.64	9.80
-1	1	1	4.19	10.00	4.31E+05	29.40	2.3790	69.29	0.7005	13.64	9.80
-1	1	1	4.19	5.00	3.19E+05	37.24	2.3790	69.29	0.7005	13.64	9.80
-1	1	1	4.19	2.00	1.58E+05	38.95	2.3790	69.29	0.7005	13.64	9.80
-1	1	1	4.19	1.00	1.22E+05	48.75	2.3790	69.29	0.7005	13.64	9.80
-1	1	1	4.19	0.50	7.50E+04	51.08	2.3790	69.29	0.7005	13.64	9.80
-1	1	1	4.19	0.20	4.05E+04	52.84	2.3790	69.29	0.7005	13.64	9.80
-1	1	1	4.19	0.10	2.68E+04	53.77	2.3790	69.29	0.7005	13.64	9.80
-1	1	1	4.19	0.05	1.74E+04	53.94	2.3790	69.29	0.7005	13.64	9.80
-1	1	1	4.19	0.02	1.10E+04	53.20	2.3790	69.29	0.7005	13.64	9.80
-1	1	1	4.19	0.01	7.69E+03	51.67	2.3790	69.29	0.7005	13.64	9.80
-1	1	0	4.19	15.00	8.52E+05	11.59	2.3790	69.29	0.7005	13.64	9.80
-1	1	0	4.19	10.00	8.22E+05	12.40	2.3790	69.29	0.7005	13.64	9.80

(Continued)

AC	GR	Temp	V_a	Freq	|G*|	Phase angle	G_{mb}	VFA	$V_b/(V_a+V_b)$	VMA	V_b
			(%)	(Hz)	(psi)	(Degree)		(%)		(%)	(%)
-1	1	0	4.19	5.00	7.99E+05	15.75	2.3790	69.29	0.7005	13.64	9.80
-1	1	0	4.19	2.00	4.00E+05	25.41	2.3790	69.29	0.7005	13.64	9.80
-1	1	0	4.19	1.00	3.00E+05	40.60	2.3790	69.29	0.7005	13.64	9.80
-1	1	0	4.19	0.50	2.34E+05	43.08	2.3790	69.29	0.7005	13.64	9.80
-1	1	0	4.19	0.20	9.89E+04	46.98	2.3790	69.29	0.7005	13.64	9.80
-1	1	0	4.19	0.10	6.36E+04	49.04	2.3790	69.29	0.7005	13.64	9.80
-1	1	0	4.19	0.05	3.94E+04	50.94	2.3790	69.29	0.7005	13.64	9.80
-1	1	0	4.19	0.02	2.55E+04	52.59	2.3790	69.29	0.7005	13.64	9.80
-1	1	0	4.19	0.01	1.78E+04	52.37	2.3790	69.29	0.7005	13.64	9.80
-1	1	-1	4.19	15.00	1.11E+06	6.26	2.3790	69.29	0.7005	13.64	9.80
-1	1	-1	4.19	10.00	1.19E+06	7.00	2.3790	69.29	0.7005	13.64	9.80
-1	1	-1	4.19	5.00	9.50E+05	8.00	2.3790	69.29	0.7005	13.64	9.80
-1	1	-1	4.19	2.00	7.50E+05	10.76	2.3790	69.29	0.7005	13.64	9.80
-1	1	-1	4.19	1.00	6.00E+05	30.67	2.3790	69.29	0.7005	13.64	9.80
-1	1	-1	4.19	0.50	3.80E+05	44.54	2.3790	69.29	0.7005	13.64	9.80
-1	1	-1	4.19	0.20	2.50E+05	53.71	2.3790	69.29	0.7005	13.64	9.80
-1	1	-1	4.19	0.10	1.52E+05	46.33	2.3790	69.29	0.7005	13.64	9.80
-1	1	-1	4.19	0.05	8.61E+04	47.58	2.3790	69.29	0.7005	13.64	9.80
-1	1	-1	4.19	0.02	5.44E+04	50.20	2.3790	69.29	0.7005	13.64	9.80
-1	1	-1	4.19	0.01	3.74E+04	51.14	2.3790	69.29	0.7005	13.64	9.80
-1	1	1	5.56	15.00	2.64E+05	13.89	2.3450	62.63	0.6347	14.87	9.66
-1	1	1	5.56	10.00	2.41E+05	16.40	2.3450	62.63	0.6347	14.87	9.66
-1	1	1	5.56	5.00	1.95E+05	22.13	2.3450	62.63	0.6347	14.87	9.66
-1	1	1	5.56	2.00	1.37E+05	26.44	2.3450	62.63	0.6347	14.87	9.66
-1	1	1	5.56	1.00	1.10E+05	29.56	2.3450	62.63	0.6347	14.87	9.66
-1	1	1	5.56	0.50	7.90E+04	34.69	2.3450	62.63	0.6347	14.87	9.66
-1	1	1	5.56	0.20	4.85E+04	40.07	2.3450	62.63	0.6347	14.87	9.66
-1	1	1	5.56	0.10	3.46E+04	42.61	2.3450	62.63	0.6347	14.87	9.66
-1	1	1	5.56	0.05	2.35E+04	44.72	2.3450	62.63	0.6347	14.87	9.66
-1	1	1	5.56	0.02	1.66E+04	45.84	2.3450	62.63	0.6347	14.87	9.66
-1	1	1	5.56	0.01	1.23E+04	45.13	2.3450	62.63	0.6347	14.87	9.66
-1	1	0	5.56	15.00	3.24E+05	8.22	2.3450	62.63	0.6347	14.87	9.66
-1	1	0	5.56	10.00	3.05E+05	10.36	2.3450	62.63	0.6347	14.87	9.66
-1	1	0	5.56	5.00	2.63E+05	14.40	2.3450	62.63	0.6347	14.87	9.66
-1	1	0	5.56	2.00	2.20E+05	19.55	2.3450	62.63	0.6347	14.87	9.66
-1	1	0	5.56	1.00	1.67E+05	21.00	2.3450	62.63	0.6347	14.87	9.66
-1	1	0	5.56	0.50	1.25E+05	27.73	2.3450	62.63	0.6347	14.87	9.66
-1	1	0	5.56	0.20	7.95E+04	34.93	2.3450	62.63	0.6347	14.87	9.66
-1	1	0	5.56	0.10	5.62E+04	37.81	2.3450	62.63	0.6347	14.87	9.66
-1	1	0	5.56	0.05	3.69E+04	41.67	2.3450	62.63	0.6347	14.87	9.66
-1	1	0	5.56	0.02	2.67E+04	43.00	2.3450	62.63	0.6347	14.87	9.66
-1	1	0	5.56	0.01	1.96E+04	45.49	2.3450	62.63	0.6347	14.87	9.66
-1	1	-1	5.56	15.00	5.24E+05	5.51	2.3450	62.63	0.6347	14.87	9.66
-1	1	-1	5.56	10.00	5.04E+05	6.15	2.3450	62.63	0.6347	14.87	9.66
-1	1	-1	5.56	5.00	4.47E+05	9.09	2.3450	62.63	0.6347	14.87	9.66
-1	1	-1	5.56	2.00	4.00E+05	12.37	2.3450	62.63	0.6347	14.87	9.66
-1	1	-1	5.56	1.00	3.53E+05	13.00	2.3450	62.63	0.6347	14.87	9.66
-1	1	-1	5.56	0.50	2.98E+05	14.02	2.3450	62.63	0.6347	14.87	9.66
-1	1	-1	5.56	0.20	1.72E+05	27.02	2.3450	62.63	0.6347	14.87	9.66
-1	1	-1	5.56	0.10	1.20E+05	30.89	2.3450	62.63	0.6347	14.87	9.66
-1	1	-1	5.56	0.05	7.88E+04	31.72	2.3450	62.63	0.6347	14.87	9.66
-1	1	-1	5.56	0.02	5.61E+04	37.55	2.3450	62.63	0.6347	14.87	9.66
-1	1	-1	5.56	0.01	4.17E+04	38.98	2.3450	62.63	0.6347	14.87	9.66
-1	1	1	5.76	15.00	4.19E+05	23.01	2.3399	61.73	0.6257	15.06	9.63
-1	1	1	5.76	10.00	3.63E+05	25.96	2.3399	61.73	0.6257	15.06	9.63

(Continued)

AC	GR	Temp	V_a	Freq	|G*|	Phase angle	G_{mb}	VFA	$V_b/(V_a+V_b)$	VMA	V_b
			(%)	(Hz)	(psi)	(Degree)		(%)		(%)	(%)
-1	1	1	5.76	5.00	2.69E+05	31.89	2.3399	61.73	0.6257	15.06	9.63
-1	1	1	5.76	2.00	1.67E+05	33.37	2.3399	61.73	0.6257	15.06	9.63
-1	1	1	5.76	1.00	1.22E+05	42.48	2.3399	61.73	0.6257	15.06	9.63
-1	1	1	5.76	0.50	7.94E+04	45.47	2.3399	61.73	0.6257	15.06	9.63
-1	1	1	5.76	0.20	4.47E+04	47.66	2.3399	61.73	0.6257	15.06	9.63
-1	1	1	5.76	0.10	3.02E+04	48.90	2.3399	61.73	0.6257	15.06	9.63
-1	1	1	5.76	0.05	1.97E+04	50.30	2.3399	61.73	0.6257	15.06	9.63
-1	1	1	5.76	0.02	1.32E+04	50.69	2.3399	61.73	0.6257	15.06	9.63
-1	1	1	5.76	0.01	9.15E+03	50.72	2.3399	61.73	0.6257	15.06	9.63
-1	1	0	5.76	15.00	6.07E+05	12.23	2.3399	61.73	0.6257	15.06	9.63
-1	1	0	5.76	10.00	5.53E+05	14.49	2.3399	61.73	0.6257	15.06	9.63
-1	1	0	5.76	5.00	4.69E+05	18.82	2.3399	61.73	0.6257	15.06	9.63
-1	1	0	5.76	2.00	3.67E+05	23.91	2.3399	61.73	0.6257	15.06	9.63
-1	1	0	5.76	1.00	2.65E+05	29.09	2.3399	61.73	0.6257	15.06	9.63
-1	1	0	5.76	0.50	1.59E+05	38.00	2.3399	61.73	0.6257	15.06	9.63
-1	1	0	5.76	0.20	8.80E+04	42.34	2.3399	61.73	0.6257	15.06	9.63
-1	1	0	5.76	0.10	5.86E+04	44.29	2.3399	61.73	0.6257	15.06	9.63
-1	1	0	5.76	0.05	3.76E+04	45.91	2.3399	61.73	0.6257	15.06	9.63
-1	1	0	5.76	0.02	2.49E+04	47.68	2.3399	61.73	0.6257	15.06	9.63
-1	1	0	5.76	0.01	1.79E+04	48.79	2.3399	61.73	0.6257	15.06	9.63
-1	1	-1	5.76	15.00	7.46E+05	2.03	2.3399	61.73	0.6257	15.06	9.63
-1	1	-1	5.76	10.00	7.20E+05	2.00	2.3399	61.73	0.6257	15.06	9.63
-1	1	-1	5.76	5.00	5.95E+05	3.66	2.3399	61.73	0.6257	15.06	9.63
-1	1	-1	5.76	2.00	4.95E+05	11.40	2.3399	61.73	0.6257	15.06	9.63
-1	1	-1	5.76	1.00	3.95E+05	18.20	2.3399	61.73	0.6257	15.06	9.63
-1	1	-1	5.76	0.50	2.95E+05	27.03	2.3399	61.73	0.6257	15.06	9.63
-1	1	-1	5.76	0.20	2.42E+05	30.50	2.3399	61.73	0.6257	15.06	9.63
-1	1	-1	5.76	0.10	1.41E+05	35.68	2.3399	61.73	0.6257	15.06	9.63
-1	1	-1	5.76	0.05	8.40E+04	38.11	2.3399	61.73	0.6257	15.06	9.63
-1	1	-1	5.76	0.02	5.69E+04	42.22	2.3399	61.73	0.6257	15.06	9.63
-1	1	-1	5.76	0.01	4.10E+04	43.43	2.3399	61.73	0.6257	15.06	9.63
-1	1	1	8.05	15.00	2.24E+05	24.79	2.2832	52.99	0.5388	17.12	9.40
-1	1	1	8.05	10.00	1.94E+05	28.49	2.2832	52.99	0.5388	17.12	9.40
-1	1	1	8.05	5.00	1.41E+05	35.18	2.2832	52.99	0.5388	17.12	9.40
-1	1	1	8.05	2.00	8.58E+04	41.54	2.2832	52.99	0.5388	17.12	9.40
-1	1	1	8.05	1.00	6.28E+04	44.98	2.2832	52.99	0.5388	17.12	9.40
-1	1	1	8.05	0.50	4.18E+04	48.83	2.2832	52.99	0.5388	17.12	9.40
-1	1	1	8.05	0.20	2.47E+04	51.75	2.2832	52.99	0.5388	17.12	9.40
-1	1	1	8.05	0.10	1.67E+04	53.58	2.2832	52.99	0.5388	17.12	9.40
-1	1	1	8.05	0.05	9.97E+03	58.40	2.2832	52.99	0.5388	17.12	9.40
-1	1	1	8.05	0.02	6.97E+03	52.26	2.2832	52.99	0.5388	17.12	9.40
-1	1	1	8.05	0.01	4.75E+03	51.57	2.2832	52.99	0.5388	17.12	9.40
-1	1	0	8.05	15.00	3.11E+05	16.87	2.2832	52.99	0.5388	17.12	9.40
-1	1	0	8.05	10.00	2.82E+05	19.22	2.2832	52.99	0.5388	17.12	9.40
-1	1	0	8.05	5.00	2.27E+05	25.67	2.2832	52.99	0.5388	17.12	9.40
-1	1	0	8.05	2.00	1.31E+05	30.71	2.2832	52.99	0.5388	17.12	9.40
-1	1	0	8.05	1.00	1.19E+05	35.27	2.2832	52.99	0.5388	17.12	9.40
-1	1	0	8.05	0.50	8.02E+04	39.52	2.2832	52.99	0.5388	17.12	9.40
-1	1	0	8.05	0.20	4.76E+04	44.00	2.2832	52.99	0.5388	17.12	9.40
-1	1	0	8.05	0.10	3.30E+04	46.68	2.2832	52.99	0.5388	17.12	9.40
-1	1	0	8.05	0.05	2.15E+04	47.96	2.2832	52.99	0.5388	17.12	9.40
-1	1	0	8.05	0.02	1.43E+04	49.27	2.2832	52.99	0.5388	17.12	9.40
-1	1	0	8.05	0.01	9.89E+03	49.84	2.2832	52.99	0.5388	17.12	9.40
-1	1	-1	8.05	15.00	4.25E+05	11.70	2.2832	52.99	0.5388	17.12	9.40
-1	1	-1	8.05	10.00	3.94E+05	13.46	2.2832	52.99	0.5388	17.12	9.40

(Continued)

AC	GR	Temp	V_a (%)	Freq (Hz)	|G*| (psi)	Phase angle (Degree)	G_{mb}	VFA (%)	$V_b/(V_a+V_b)$	VMA (%)	V_b (%)
-1	1	-1	8.05	5.00	3.29E+05	18.69	2.2832	52.99	0.5388	17.12	9.40
-1	1	-1	8.05	2.00	2.16E+05	20.67	2.2832	52.99	0.5388	17.12	9.40
-1	1	-1	8.05	1.00	2.01E+05	27.75	2.2832	52.99	0.5388	17.12	9.40
-1	1	-1	8.05	0.50	1.49E+05	32.70	2.2832	52.99	0.5388	17.12	9.40
-1	1	-1	8.05	0.20	9.38E+04	37.57	2.2832	52.99	0.5388	17.12	9.40
-1	1	-1	8.05	0.10	6.41E+04	40.74	2.2832	52.99	0.5388	17.12	9.40
-1	1	-1	8.05	0.05	4.17E+04	41.90	2.2832	52.99	0.5388	17.12	9.40
-1	1	-1	8.05	0.02	2.80E+04	46.33	2.2832	52.99	0.5388	17.12	9.40
-1	1	-1	8.05	0.01	1.94E+04	47.07	2.2832	52.99	0.5388	17.12	9.40
-1	1	1	8.07	15.00	2.52E+05	31.52	2.2827	52.92	0.5381	17.14	9.40
-1	1	1	8.07	10.00	2.06E+05	34.87	2.2827	52.92	0.5381	17.14	9.40
-1	1	1	8.07	5.00	1.39E+05	40.32	2.2827	52.92	0.5381	17.14	9.40
-1	1	1	8.07	2.00	7.75E+04	43.84	2.2827	52.92	0.5381	17.14	9.40
-1	1	1	8.07	1.00	5.66E+04	46.49	2.2827	52.92	0.5381	17.14	9.40
-1	1	1	8.07	0.50	3.70E+04	49.64	2.2827	52.92	0.5381	17.14	9.40
-1	1	1	8.07	0.20	2.21E+04	52.07	2.2827	52.92	0.5381	17.14	9.40
-1	1	1	8.07	0.10	1.51E+04	52.68	2.2827	52.92	0.5381	17.14	9.40
-1	1	1	8.07	0.05	9.70E+03	53.22	2.2827	52.92	0.5381	17.14	9.40
-1	1	1	8.07	0.02	6.35E+03	52.67	2.2827	52.92	0.5381	17.14	9.40
-1	1	1	8.07	0.01	4.30E+03	52.06	2.2827	52.92	0.5381	17.14	9.40
-1	1	0	8.07	15.00	4.75E+05	16.72	2.2827	52.92	0.5381	17.14	9.40
-1	1	0	8.07	10.00	4.33E+05	20.23	2.2827	52.92	0.5381	17.14	9.40
-1	1	0	8.07	5.00	3.29E+05	26.81	2.2827	52.92	0.5381	17.14	9.40
-1	1	0	8.07	2.00	2.30E+05	31.21	2.2827	52.92	0.5381	17.14	9.40
-1	1	0	8.07	1.00	1.48E+05	39.62	2.2827	52.92	0.5381	17.14	9.40
-1	1	0	8.07	0.50	9.39E+04	44.27	2.2827	52.92	0.5381	17.14	9.40
-1	1	0	8.07	0.20	5.14E+04	47.50	2.2827	52.92	0.5381	17.14	9.40
-1	1	0	8.07	0.10	3.39E+04	49.22	2.2827	52.92	0.5381	17.14	9.40
-1	1	0	8.07	0.05	2.19E+04	51.29	2.2827	52.92	0.5381	17.14	9.40
-1	1	0	8.07	0.02	1.40E+04	52.86	2.2827	52.92	0.5381	17.14	9.40
-1	1	0	8.07	0.01	9.62E+03	52.93	2.2827	52.92	0.5381	17.14	9.40
-1	1	-1	8.07	15.00	6.30E+05	7.12	2.2827	52.92	0.5381	17.14	9.40
-1	1	-1	8.07	10.00	6.02E+05	9.07	2.2827	52.92	0.5381	17.14	9.40
-1	1	-1	8.07	5.00	5.27E+05	12.30	2.2827	52.92	0.5381	17.14	9.40
-1	1	-1	8.07	2.00	3.80E+05	21.72	2.2827	52.92	0.5381	17.14	9.40
-1	1	-1	8.07	1.00	3.14E+05	27.67	2.2827	52.92	0.5381	17.14	9.40
-1	1	-1	8.07	0.50	1.98E+05	31.36	2.2827	52.92	0.5381	17.14	9.40
-1	1	-1	8.07	0.20	9.12E+04	40.43	2.2827	52.92	0.5381	17.14	9.40
-1	1	-1	8.07	0.10	5.84E+04	44.05	2.2827	52.92	0.5381	17.14	9.40
-1	1	-1	8.07	0.05	3.74E+04	46.20	2.2827	52.92	0.5381	17.14	9.40
-1	1	-1	8.07	0.02	2.48E+04	49.29	2.2827	52.92	0.5381	17.14	9.40
-1	1	-1	8.07	0.01	1.75E+04	50.36	2.2827	52.92	0.5381	17.14	9.40

Appendix F. Shear frequency sweep test results, field cores

Nomenclature:

AC = Asphalt content.	-1 = optimum minus 0.5% asphalt content; 1 = optimum asphalt content;
GR = Gradation.	-1 = SP 12.5-mm mix; 1 = SP19-mm mix.
RT = Replicates.	-1 = one replicate; 1 = two replicates.
Temp = Temperature.	-1 = 15°C; and 0 = 20°C, and 1 = 25°C.

GR	Temp	V_a (%)	Freq (Hz)	$\|G^*\|$ (psi)	ϕ (degree)	GR	Temp	V_a (%)	Freq (Hz)	$\|G^*\|$ (psi)	ϕ (degree)
-1	-1	7.7	15	3.07E+05	20.15	-1	1	7.84	5	1.08E+05	31.37
-1	-1	7.7	10	2.81E+05	20.98	-1	1	7.84	2	7.38E+04	33.95
-1	-1	7.7	5	2.30E+05	23.54	-1	1	7.84	1	5.61E+04	37.73
-1	-1	7.7	2	1.76E+05	26.60	-1	1	7.84	0.5	3.95E+04	39.10
-1	-1	7.7	1	1.39E+05	31.34	-1	1	7.84	0.2	2.53E+04	42.56
-1	-1	7.7	0.5	1.04E+05	33.43	-1	1	7.84	0.1	1.83E+04	43.79
-1	-1	7.7	0.2	7.28E+04	34.82	-1	1	7.84	0.05	1.27E+04	42.54
-1	-1	7.7	0.1	5.62E+04	36.00	-1	1	7.84	0.02	9.08E+03	41.51
-1	-1	7.7	0.05	4.04E+04	36.32	-1	1	7.84	0.01	7.36E+03	39.36
-1	-1	7.7	0.02	2.95E+04	38.67	-1	-1	7.89	15	3.46E+05	16.04
-1	-1	7.7	0.01	2.23E+04	38.79	-1	-1	7.89	10	3.20E+05	16.68
-1	0	7.7	15	1.77E+05	24.07	-1	-1	7.89	5	2.69E+05	19.64
-1	0	7.7	10	1.58E+05	25.51	-1	-1	7.89	2	2.13E+05	21.66
-1	0	7.7	5	1.28E+05	28.51	-1	-1	7.89	1	1.75E+05	26.44
-1	0	7.7	2	9.40E+04	32.82	-1	-1	7.89	0.5	1.38E+05	29.31
-1	0	7.7	1	7.24E+04	35.91	-1	-1	7.89	0.2	9.97E+04	31.89
-1	0	7.7	0.5	5.43E+04	38.82	-1	-1	7.89	0.1	7.73E+04	33.85
-1	0	7.7	0.2	3.64E+04	40.87	-1	-1	7.89	0.05	5.55E+04	34.55
-1	0	7.7	0.1	2.69E+04	40.57	-1	-1	7.89	0.02	4.02E+04	37.35
-1	0	7.7	0.05	1.88E+04	40.14	-1	-1	7.89	0.01	2.99E+04	37.99
-1	0	7.7	0.02	1.38E+04	39.93	-1	0	7.89	15	1.92E+05	24.20
-1	0	7.7	0.01	1.05E+04	39.16	-1	0	7.89	10	1.72E+05	25.57
-1	1	7.7	15	1.81E+05	28.03	-1	0	7.89	5	1.38E+05	28.52
-1	1	7.7	10	1.57E+05	29.66	-1	0	7.89	2	1.02E+05	32.46
-1	1	7.7	5	1.18E+05	32.99	-1	0	7.89	1	7.78E+04	35.25
-1	1	7.7	2	8.43E+04	36.09	-1	0	7.89	0.5	5.87E+04	37.70
-1	1	7.7	1	6.01E+04	40.52	-1	0	7.89	0.2	3.99E+04	40.09
-1	1	7.7	0.5	4.36E+04	40.92	-1	0	7.89	0.1	2.95E+04	40.81
-1	1	7.7	0.2	2.78E+04	43.21	-1	0	7.89	0.05	2.09E+04	40.77
-1	1	7.7	0.1	1.97E+04	44.13	-1	0	7.89	0.02	1.51E+04	41.67
-1	1	7.7	0.05	1.31E+04	44.20	-1	0	7.89	0.01	1.16E+04	41.63
-1	1	7.7	0.02	9.44E+03	44.23	-1	1	7.89	15	2.17E+05	25.68
-1	1	7.7	0.01	6.10E+03	41.96	-1	1	7.89	10	1.89E+05	27.65
-1	-1	7.84	15	3.45E+05	17.48	-1	1	7.89	5	1.43E+05	31.92
-1	-1	7.84	10	3.17E+05	18.43	-1	1	7.89	2	9.38E+04	34.77
-1	-1	7.84	5	2.61E+05	21.05	-1	1	7.89	1	7.26E+04	38.48
-1	-1	7.84	2	2.01E+05	23.71	-1	1	7.89	0.5	5.15E+04	41.64
-1	-1	7.84	1	1.66E+05	28.31	-1	1	7.89	0.2	3.12E+04	44.45
-1	-1	7.84	0.5	1.26E+05	30.86	-1	1	7.89	0.1	2.16E+04	46.28
-1	-1	7.84	0.2	8.79E+04	33.80	-1	1	7.89	0.05	1.45E+04	46.64
-1	-1	7.84	0.1	6.71E+04	35.77	-1	1	7.89	0.02	9.89E+03	46.26
-1	-1	7.84	0.05	4.76E+04	36.99	-1	1	7.89	0.01	7.26E+03	43.55
-1	-1	7.84	0.02	3.40E+04	38.66	-1	-1	8.1	15	3.64E+05	15.59
-1	-1	7.84	0.01	2.53E+04	38.48	-1	-1	8.1	10	3.37E+05	16.03
-1	0	7.84	15	1.87E+05	26.84	-1	-1	8.1	5	2.85E+05	18.34
-1	0	7.84	10	1.65E+05	28.30	-1	-1	8.1	2	2.34E+05	21.46
-1	0	7.84	5	1.30E+05	31.14	-1	-1	8.1	1	1.88E+05	24.50
-1	0	7.84	2	9.54E+04	34.46	-1	-1	8.1	0.5	1.51E+05	27.30
-1	0	7.84	1	7.06E+04	37.22	-1	-1	8.1	0.2	1.12E+05	30.23
-1	0	7.84	0.5	5.32E+04	39.18	-1	-1	8.1	0.1	8.80E+04	32.62
-1	0	7.84	0.2	3.64E+04	41.18	-1	-1	8.1	0.05	6.43E+04	34.23
-1	0	7.84	0.1	2.71E+04	41.77	-1	-1	8.1	0.02	4.62E+04	37.84
-1	0	7.84	0.05	1.94E+04	41.29	-1	-1	8.1	0.01	3.34E+04	40.17
-1	0	7.84	0.02	1.39E+04	41.15	-1	0	8.1	15	1.98E+05	23.81
-1	0	7.84	0.01	1.09E+04	41.90	-1	0	8.1	10	1.79E+05	25.02
-1	1	7.84	15	1.60E+05	26.57	-1	0	8.1	5	1.46E+05	27.26
-1	1	7.84	10	1.40E+05	27.81	-1	0	8.1	2	1.09E+05	31.28

GR	Temp	V_a (%)	Freq (Hz)	$\|G^*\|$ (psi)	ϕ (degree)	GR	Temp	V_a (%)	Freq (Hz)	$\|G^*\|$ (psi)	ϕ (degree)
-1	0	8.1	1	8.54E+04	33.39	1	0	7.27	5	1.91E+05	25.91
-1	0	8.1	0.5	6.55E+04	36.02	1	0	7.27	2	1.45E+05	30.44
-1	0	8.1	0.2	4.49E+04	39.39	1	0	7.27	1	1.12E+05	34.60
-1	0	8.1	0.1	3.36E+04	40.20	1	0	7.27	0.5	8.43E+04	38.10
-1	0	8.1	0.05	2.37E+04	39.22	1	0	7.27	0.2	5.62E+04	41.81
-1	0	8.1	0.02	1.66E+04	44.54	1	0	7.27	0.1	4.04E+04	42.21
-1	0	8.1	0.01	1.23E+04	42.33	1	0	7.27	0.05	2.74E+04	44.70
-1	1	8.1	15	2.29E+05	23.45	1	0	7.27	0.02	1.89E+04	45.66
-1	1	8.1	10	2.03E+05	24.01	1	0	7.27	0.01	1.40E+04	45.18
-1	1	8.1	5	1.59E+05	28.39	1	1	7.27	15	2.42E+05	25.51
-1	1	8.1	2	1.12E+05	32.19	1	1	7.27	10	2.10E+05	27.48
-1	1	8.1	1	8.67E+04	36.32	1	1	7.27	5	1.59E+05	31.96
-1	1	8.1	0.5	6.27E+04	39.76	1	1	7.27	2	1.10E+05	36.89
-1	1	8.1	0.2	3.77E+04	43.55	1	1	7.27	1	8.09E+04	40.74
-1	1	8.1	0.1	2.53E+04	46.21	1	1	7.27	0.5	5.74E+04	44.63
-1	1	8.1	0.05	1.66E+04	46.69	1	1	7.27	0.2	3.45E+04	49.07
-1	1	8.1	0.02	1.15E+04	47.60	1	1	7.27	0.1	2.27E+04	50.33
-1	1	8.1	0.01	8.37E+03	46.16	1	1	7.27	0.05	1.46E+04	50.64
1	-1	7.92	15	4.04E+05	17.37	1	1	7.27	0.02	9.79E+03	48.14
1	-1	7.92	10	3.71E+05	18.06	1	1	7.27	0.01	7.29E+03	46.33
1	-1	7.92	5	3.16E+05	20.65	1	-1	7.42	15	4.80E+05	16.00
1	-1	7.92	2	2.51E+05	25.68	1	-1	7.42	10	4.60E+05	16.40
1	-1	7.92	1	2.09E+05	28.34	1	-1	7.42	5	4.29E+05	16.73
1	-1	7.92	0.5	1.56E+05	32.79	1	-1	7.42	2	3.16E+05	22.24
1	-1	7.92	0.2	1.07E+05	37.05	1	-1	7.42	1	4.10E+05	18.29
1	-1	7.92	0.1	8.02E+04	40.04	1	-1	7.42	0.5	3.17E+05	20.19
1	-1	7.92	0.05	5.40E+04	41.92	1	-1	7.42	0.2	1.57E+05	32.22
1	-1	7.92	0.02	3.71E+04	45.30	1	-1	7.42	0.1	1.18E+05	35.83
1	-1	7.92	0.01	2.62E+04	45.90	1	-1	7.42	0.05	8.31E+04	38.16
1	0	7.92	15	2.29E+05	24.47	1	-1	7.42	0.02	6.03E+04	41.68
1	0	7.92	10	2.07E+05	26.23	1	-1	7.42	0.01	3.70E+04	50.05
1	0	7.92	5	1.66E+05	29.87	1	0	7.42	15	2.98E+05	22.51
1	0	7.92	2	1.19E+05	35.19	1	0	7.42	10	2.71E+05	23.62
1	0	7.92	1	8.90E+04	39.13	1	0	7.42	5	2.25E+05	26.38
1	0	7.92	0.5	6.46E+04	42.36	1	0	7.42	2	1.68E+05	31.14
1	0	7.92	0.2	4.16E+04	45.66	1	0	7.42	1	1.31E+05	35.27
1	0	7.92	0.1	2.94E+04	44.55	1	0	7.42	0.5	9.75E+04	38.48
1	0	7.92	0.05	1.97E+04	47.72	1	0	7.42	0.2	6.50E+04	42.00
1	0	7.92	0.02	1.34E+04	47.41	1	0	7.42	0.1	4.72E+04	43.75
1	0	7.92	0.01	9.84E+03	45.98	1	0	7.42	0.05	3.21E+04	43.80
1	1	7.92	15	2.69E+05	28.49	1	0	7.42	0.02	2.28E+04	44.25
1	1	7.92	10	2.29E+05	30.39	1	0	7.42	0.01	1.72E+04	42.18
1	1	7.92	5	1.69E+05	34.88	1	1	7.42	15	2.91E+05	24
1	1	7.92	2	1.16E+05	38.75	1	1	7.42	10	2.55E+05	26
1	1	7.92	1	8.08E+04	43.62	1	1	7.42	5	1.95E+05	31
1	1	7.92	0.5	5.60E+04	46.73	1	1	7.42	2	1.38E+05	35
1	1	7.92	0.2	3.35E+04	50.02	1	1	7.42	1	9.89E+04	40
1	1	7.92	0.1	2.21E+04	51.22	1	1	7.42	0.5	7.03E+04	44
1	1	7.92	0.05	1.39E+04	50.37	1	1	7.42	0.2	4.28E+04	50
1	1	7.92	0.02	9.28E+03	49.23	1	1	7.42	0.1	2.83E+04	51
1	1	7.92	0.01	6.84E+03	45.82	1	1	7.42	0.05	1.73E+04	51
1	-1	7.27	15	4.61E+05	17.88	1	1	7.42	0.02	1.17E+04	49
1	-1	7.27	10	4.20E+05	18.62	1	1	7.42	0.01	8.53E+03	48
1	-1	7.27	5	3.59E+05	20.44	1	-1	7.51	15	4.43E+05	15.90
1	-1	7.27	2	2.97E+05	24.00	1	-1	7.51	10	4.05E+05	16.68
1	-1	7.27	1	2.49E+05	27.45	1	-1	7.51	5	3.46E+05	18.90
1	-1	7.27	0.5	1.90E+05	30.81	1	-1	7.51	2	2.81E+05	23.09
1	-1	7.27	0.2	1.32E+05	33.70	1	-1	7.51	1	2.32E+05	27.00
1	-1	7.27	0.1	1.02E+05	35.04	1	-1	7.51	0.5	1.77E+05	31.21
1	-1	7.27	0.05	7.36E+04	36.30	1	-1	7.51	0.2	1.22E+05	35.08
1	-1	7.27	0.02	5.44E+04	38.36	1	-1	7.51	0.1	9.33E+04	37.66
1	-1	7.27	0.01	4.14E+04	38.39	1	-1	7.51	0.05	6.54E+04	39.20
1	0	7.27	15	2.51E+05	21.67	1	-1	7.51	0.02	4.62E+04	42.27

1	0	7.27	10	2.29E+05	22.78	1	-1	7.51	0.01	3.33E+04	42.95
GR	Temp	V_a (%)	Freq (Hz)	$\lvert G^* \rvert$ (psi)	ϕ (degree)	GR	Temp	V_a (%)	Freq (Hz)	$\lvert G^* \rvert$ (psi)	ϕ (degree)
1	0	7.51	15	2.88E+05	19.50	1	-1	7.19	0.2	1.18E+05	42.15
1	0	7.51	10	2.64E+05	20.88	1	-1	7.19	0.1	8.51E+04	44.66
1	0	7.51	5	2.21E+05	24.16	1	-1	7.19	0.05	5.66E+04	46.90
1	0	7.51	2	1.68E+05	28.39	1	-1	7.19	0.02	3.78E+04	49.26
1	0	7.51	1	1.32E+05	33.22	1	-1	7.19	0.01	2.62E+04	49.72
1	0	7.51	0.5	1.01E+05	37.24	1	0	7.19	15	2.02E+05	21.95
1	0	7.51	0.2	6.66E+04	41.36	1	0	7.19	10	1.83E+05	23.59
1	0	7.51	0.1	4.81E+04	43.72	1	0	7.19	5	1.50E+05	26.94
1	0	7.51	0.05	3.20E+04	45.00	1	0	7.19	2	1.11E+05	31.65
1	0	7.51	0.02	2.20E+04	47.33	1	0	7.19	1	8.55E+04	35.86
1	0	7.51	0.01	1.60E+04	48.39	1	0	7.19	0.5	6.37E+04	39.06
1	1	7.51	15	2.87E+05	24	1	0	7.19	0.2	4.24E+04	42.21
1	1	7.51	10	2.49E+05	26	1	0	7.19	0.1	3.18E+04	43.28
1	1	7.51	5	1.93E+05	30	1	0	7.19	0.05	2.08E+04	46.37
1	1	7.51	2	1.37E+05	34	1	0	7.19	0.02	1.45E+04	45.88
1	1	7.51	1	1.01E+05	40	1	0	7.19	0.01	1.06E+04	46.71
1	1	7.51	0.5	7.13E+04	44	1	1	7.19	15	3.32E+05	32.63
1	1	7.51	0.2	4.37E+04	48	1	1	7.19	10	2.82E+05	34.53
1	1	7.51	0.1	2.93E+04	49	1	1	7.19	5	2.03E+05	38.99
1	1	7.51	0.05	1.85E+04	51	1	1	7.19	2	1.23E+05	44.57
1	1	7.51	0.02	1.21E+04	50	1	1	7.19	1	8.54E+04	48.75
1	1	7.51	0.01	8.77E+03	48	1	1	7.19	0.5	5.56E+04	51.46
1	-1	7.19	15	6.42E+05	23.22	1	1	7.19	0.2	3.22E+04	53.97
1	-1	7.19	10	5.79E+05	22.95	1	1	7.19	0.1	2.09E+04	53.89
1	-1	7.19	5	4.98E+05	25.35	1	1	7.19	0.05	1.32E+04	53.62
1	-1	7.19	2	3.34E+05	30.81	1	1	7.19	0.02	8.62E+03	51.75
1	-1	7.19	1	3.26E+05	33.32	1	1	7.19	0.01	6.21E+03	48.32
1	-1	7.19	0.5	2.12E+05	39.08						