ARIZONA DEPARTMENT OF TRANSPORTATION

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CHEMICAL AND PHYSICAL PROPERTIES OF ASPHALT- RUBBER MIXTURES — PHASE III

VOLUME 4

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16. Abstract

Eight asphalt-rubber samples which were sampled from commercial field-produced asphalt-rubber mixtures used in the Buckeye-Liberty test project in Arizona were tested using absolute viscosity, Schweyer Rheometer, force-ductility, softening point, and low temperature fracture procedures. Mixtures were produced by two major suppliers of asphalt-rubber. Properties of the field produced asphalt-rubbers are compared. Additionally, properties of the field-produced mixtures are compared to those of comparable asphalt-rubber mixtures produced in the laboratory using the Torque-Fork.

Results indicate that differences exist in field-produced asphalt-rubbers. Diluent additions to asphalt-rubber mixtures produced by one supplier tended to soften the mixtures. Increased reaction time tended to soften mixtures produced by the second supplier. Differences were noted in characteristics of mixtures produced by the two suppliers.

Properties of three different asphalt-rubber mixtures produced in the laboratory were compared to properties of comparable field produced mixtures. Results indicate that laboratory mixtures which are mixed and reacted in the Torque-Fork are significantly stiffer than field-produced materials.

17. Key Words	18. Distribution Statement
Asphalt-Rubber, Torque-Fork, Low Temperature Fracture, Buckeye Liberty Test Section, Force-ductility, Schweyer Rheometer	No restrictions. Available to the public through the NTIS, Springfield, Virginia 22161

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Unclassified	Unclassified	91	

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1.0 EXPERIMENT DESCRIPTION

1.1 The objectives of this experiment are:

A. To evaluate physical properties of field-mixed samples of asphalt-rubber.

B. To compare physical properties of field and lab mixed asphalt-rubbers composed of the same rubber and asphalt.

1.2 Field-mixed samples of asphalt-rubber which were tested in this study were obtained from the Arizona Department of Transportation Buckeye-Liberty asphalt-rubber test section project which was constructed from October to December of 1978.

1.2.1 Eight samples of asphalt-rubbers used in this project were sampled by ADOT and supplied to Western Technologies, Inc. for testing.

1.2.2 Asphalt-rubber materials sampled and tested were produced by two major asphalt-rubber commercial suppliers. Several production and formulation modifications were used with some of the asphalt-rubbers.

1.3 Field-mixing of the asphalt-rubber materials studied was accomplished in mixing trucks or tanks which are used in commercial asphalt-rubber production.

1.4 Laboratory mixed asphalt-rubber materials were mixed using a standard mixing procedure in the Arizona Torque-Fork as described in the project Summary Report (1).

1.5 Material properties assessed in this study are:

- Absolute viscosity at 140F (60C)
- Ring and Ball softening point
- Stress, strain, and creep compliance properties at 39.2F (4C) using Force-Ductility
- Apparent viscosity and shear rate sensitivity by the Schweyer Rheometer at 39.2F (4C)
- Low Temperature Fracture.

Details of testing procedures are contained in the project Summary Report (1).

1.6 Testing results for lab-mixed materials were obtained from other portions of this project which are reported in Volume I, "Effects of Rubber Type, Concentration and Asphalt," and Volume III, "Effects of Diluent."

2.0 FIELD-MIXED ASPHALT-RUBBER MIXTURES

2.1 Asphalt-rubber mixtures which were tested in the field-mixed portion of this study were obtained from two of the major suppliers of asphalt-rubber designated in this report as Supplier Nos. 1 and 2. Mixtures tested included the standard asphalt-rubber formulations used by these suppliers and several modified mixtures in which either components or production method varied.

2.2 Rubber. Three different rubber types were used in the field-mixed asphalt-rubber samples.

2.2.1 Rubber used by Supplier No. 1 was obtained from Atlos Rubber Reclaiming of Los Angeles, California. Two Atlos rubber products were used - TPO44 and TPO27. Descriptions of these products are contained in the project Summary Report (1). Gradations of TPO44 and TPO27 samples obtained from rubber shipments which were used in the field mixtures are tabulated in Table 1 and plotted in Figure 1.

2.2.2 Rubber used by Supplier No. 2 was designated as GT274 and was obtained from U.S. Rubber Reclaiming of Vicksburg, Mississippi.

2.2.2.1 Description of the rubber is contained in the project Summary Report (1). Gradations of GT274 samples obtained from rubber shipments which were used in the field produced mixtures are tabulated in Table 2 and plotted in Figure 2.

2.3 Asphalt. Four different asphalts were used in the field-mixed asphalt-rubber samples.

2.3.1 Three different grades of asphalt were used by Supplier No. 1 - AR1000, AR4000, and AR8000. Each of these three asphalts was refined from Edgington crude.

*Note: Numbers in parenthesis refer to references listed on page 41.

2.3.1.1 Penetration, softening point, absolute viscosity, and kinematic viscosity tests were performed on the AR1000 and AR4000 asphalt cements. Test results for the AR1000 and AR4000 asphalts are tabulated in Table 3. The AR8000 was not tested because a sample was not available for testing.

2.3.1.2 Rostler compositional analysis (2) of the Edgington AR1000 and AR4000 were performed by Arizona Refining Company of Phoenix, Arizona. Results are tabulated in Table 4.

2.3.2 Supplier No. 2 utilized one asphalt cement, an AR4000 produced from Powerene crude, in production of field-mixed asphalt-rubber mixtures.

2.3.2.1 Physical properties of two samples of the unaged Powerene AR4000 are tabulated in Table 5.

2.3.2.2 Rostler compositional analysis (2) of the Powerene AR4000 samples were performed by Arizona Refining Company. Results are tabulated in Table 6.

2.4 Diluent. One of the field-mixed asphalt-rubber mixtures produced by Supplier No. 1 contained 4 percent kerosene diluent by weight of asphalt-rubber mixture.

2.5 Extender Oil. All of the field-mixed asphalt-rubber mixtures produced by Supplier No. 2 which were tested contained 2.0 percent extender oil by weight of asphalt cement.

2.5.1 Rostler compositional analysis (2) of the extender oil was performed by Arizona Refining Company. Results are also tabulated in Table 6.

TABLE 1

GRADATIONS OF SAMPLES OF ATLOS TPO44
AND TPO27 RUBBERS USED IN FIELD
PRODUCTION OF ASPHALT-RUBBER MIXTURES
PRODUCED BY SUPPLIER NO. 1

	TPO44			TPO27				
Sieve Size	1	2	Average	1	2	3	4	Average
#10	100	99	100	100	100	100	100	100
#16	95	58	77	99	99	98	90	97
#30	17	6	12	82	93	86	73	84
#50	3	4	4	28	52	50	50	45
#100	3	4	4	12	22	22	23	20
#200	3	4	4	7	11	10	10	10

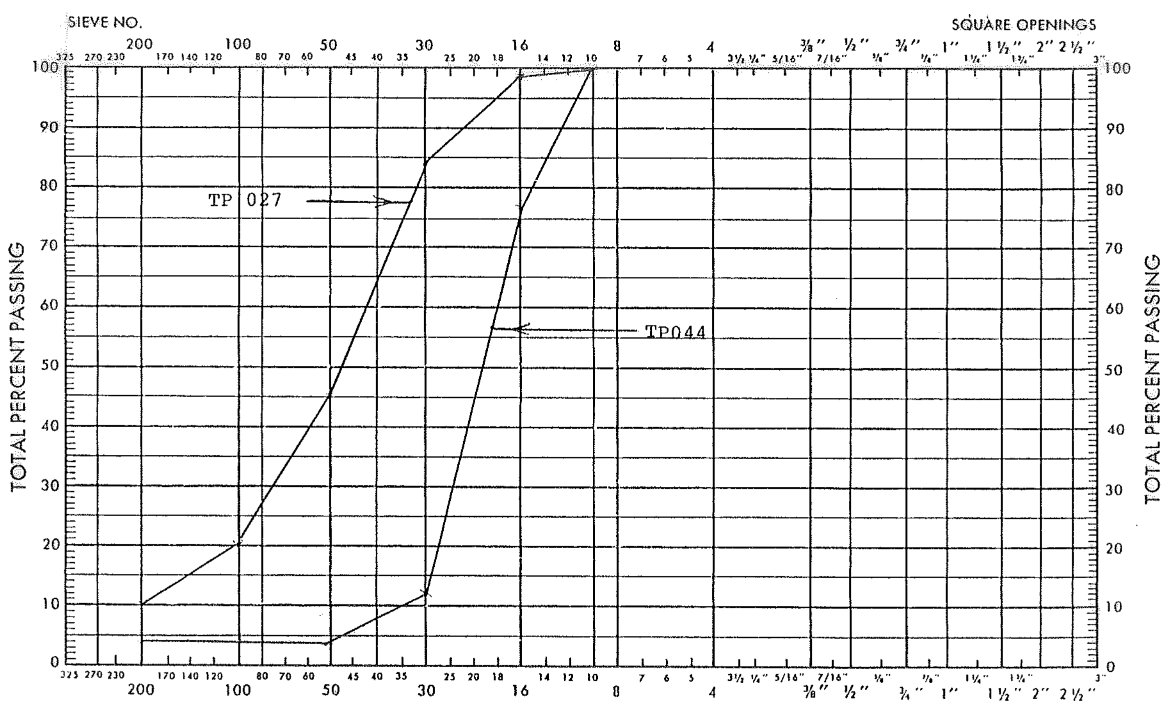

Figure 1   Gradation of TPO44 and TPO27 Used In Field Asphalt-Rubber Mixtures Produced by Supplier No. 1

TABLE 2

GRADATIONS OF FIVE SAMPLES OF U.S. RUBBER RECLAIMING GT274 RUBBER USED IN FIELD PRODUCTION OF ASPHALT-RUBBER MIXTURES PRODUCED BY SUPPLIER NO. 2

Sieve Size	% Passing 1	2	3	4	5	Average
#10	100	100	100	100	100	100
#16	94	95	97	96	96	96
#30	79	79	87	79	79	81
#50	33	30	36	31	31	32
#100	16	13	17	13	13	14
#200	10	8	11	7	7	9

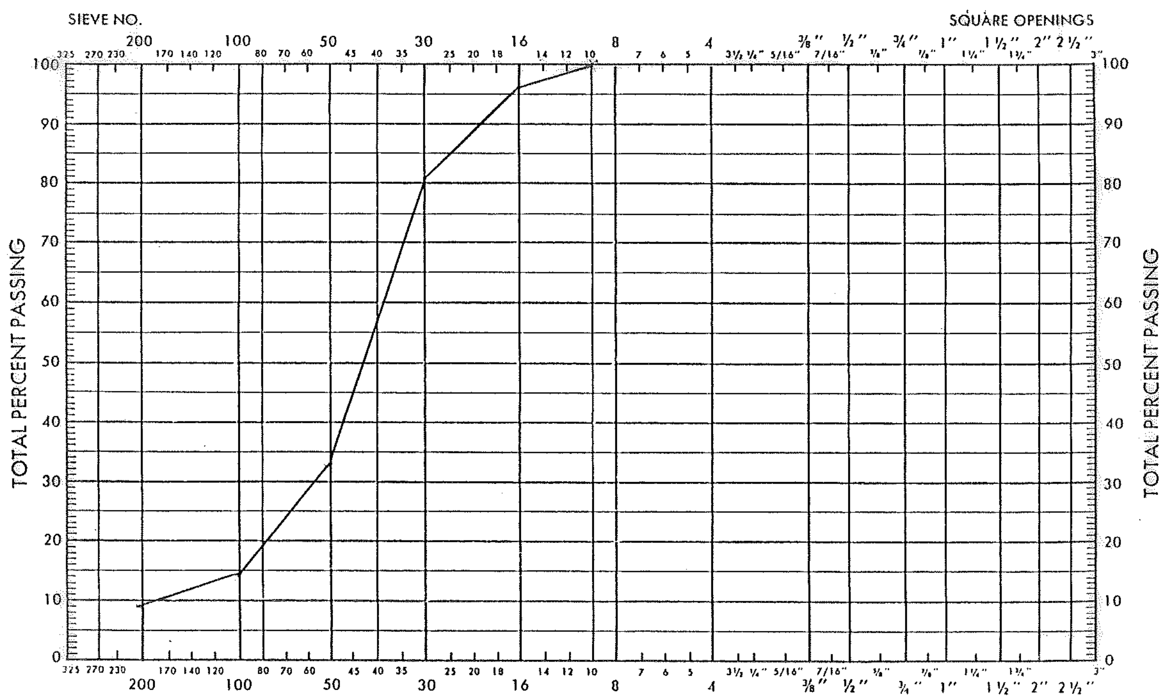

Figure 2 Gradation of GT274 Used In Field Asphalt-Rubber Mixtures Produced by Supplier No. 2

TABLE 3

PHYSICAL PROPERTIES OF UNAGED
EDGINGTON AR1000 AND AR4000 ASPHALT CEMENTS
USED BY SUPPLIER NO. 1 IN
FIELD-PRODUCED ASPHALT-RUBBER MIXTURES

Property	AR1000	AR4000
Penetration, 100g, 5 sec, 77F; 1/10 mm	135	49
Penetration, 200g, 60 sec, 39.2F; 1/10 mm	46	13
Softening Point; ^{o}C	40.0	49.0
Absolute Viscosity, 140F, 30 cm Hg; Poise	658	2253
Kinematic Viscosity, 275F; cSt	162	281

TABLE 4

ROSTLER COMPOSITIONAL ANALYSIS OF
EDGINGTON AR1000 AND AR4000
ASPHALT CEMENTS USED BY
SUPPLIER NO. 1

Fraction	% by weight AR1000	% by weight AR4000
Asphaltenes, A	13.1	16.8
Nitrogen Bases, N	37.8	37.6
First Acidifins, A_1	11.6	12.6
Second Acidifins, A_2	24.2	22.6
Parafins, P	13.3	10.4
Rostler Parameter[1]	1.32	1.52
Gotolski Parameter[2]	2.79	2.68

Note: [1]Rostler Parameter $= \frac{N + A_1}{P + A_2}$

[2]Gotolski Parameter $= \frac{A_1 + A_2 + N}{A + P}$

TABLE 5

PHYSICAL PROPERTIES OF UNAGED POWERENE
AR4000 ASPHALT CEMENT
USED BY SUPPLIER NO. 2 IN
FIELD-PRODUCED ASPHALT-RUBBER MIXTURES

Property	Sample 1	Sample 2
Penetration, 100g, 5 sec, 77F; 1/10 mm	66	60
Penetration, 200g, 60 sec, 39.2F; 1/10 mm	18	18
Softening Point; °F	46.0	48.5
Absolute Viscosity, 140F, 30 cm Hg; Poise	1456	1601
Kinematic Viscosity, 275F; cSt	229	272

TABLE 6

ROSTLER COMPOSITIONAL ANALYSIS OF
POWERENE AR4000 AND EXTENDER OIL
USED BY SUPPLIER NO. 2

	% by weight		
	Powerene AR4000		
Fraction	Sample 1	Sample 2	Extender Oil
Asphaltenes, A	12.8	18.0	2.2
Nitrogen Bases, N	39.9	37.6	19.6
First Acidifins, A_1	13.3	10.9	10.4
Second Acidifins, A_2	23.1	22.6	53.9
Parafins, P	10.9	11.3	13.9
Rostler Parameter[1]	1.56	1.43	0.44
Gotolski Parameter[2]	3.22	2.43	5.21

*Note: [1]Rostler Parameter $= \dfrac{N + A_1}{P + A_2}$

[2]Gotolski Parameter $= \dfrac{A_1 + A_2 + N}{A + P}$

2.6 Field-Mixed Asphalt-Rubber Mixture Formulations

2.6.1 Asphalt-rubber mixtures which were tested from Supplier No. 1 were formulated and designated as follows:

Constituent	Sample Designation			
	302	8NC	11A	3A
Asphalt Type	AR4000	AR1000	AR8000	AR1000
Asphalt Source	Edgington	Edgington	Edgington	Edgington
Rubber Type	TPO27	TPO44	TPO27	TPO44
% Rubber (Mix Basis)	20	25	20	25
% Diluent (Mix Basis)	0	0	0	4
Reaction Time, hr.	2.5	1.5	2.2	6.5

2.6.2 Asphalt-rubber mixtures which were tested from Supplier No. 2 were formulated and designated as follows:

Constituent	Sample Designation			
	4A*	2A*	403	101
Asphalt Type	AR4000	AR4000	AR4000	AR4000
Asphalt Source	Powerene	Powerene	Powerene	Powerene
Rubber Type	GT274	GT274	GT274	GT274
% Rubber (Mix Basis)	20	20	20	20
% Extender Oil (Mix Basis)	1.6	1.6	1.6	1.6
Reaction Time, hr.	4	4	24	166

*Note: Samples 2A and 4A are composed of the same constituents and were reacted for the same time but are from different production runs.

2.7 Field-Mixing Procedure

2.7.1 Asphalt-rubber mixtures produced by Supplier No. 1 were mixed as follows:

- Heat asphalt to 375F in a 4000 gallon insulated mixing tank on the mix truck,
- Add appropriate amount of rubber within 40 minutes with tank mix auger in operation,
- Continue mixing asphalt and rubber for the appropriate reaction time, and
- Add diluent with mix tank auger operating approximately 30 minutes prior to asphalt-rubber application.

2.7.2 Asphalt-rubber mixtures produced by Supplier No. 2 were mixed as follows:

- Heat asphalt to 400F in a twin propeller mix tank,
- Add appropriate amount of rubber to the 400F asphalt, with propellers operating, over a period of 30 minutes, and
- Continue mixing asphalt and rubber for the appropriate reaction time.

2.8 Samples of the field produced asphalt-rubber materials were obtained from the mix tanks and stored in 1 quart containers.

2.9 Following sampling, asphalt-rubber samples were stored in a freezer at less than 32F until tested. To prepare for testing, samples were removed from the freezer and then heated to 275F on a hotplate while constantly being stirred. When the material reached 275F, it was ready for specimen fabrication.

3.0 LAB-MIXED ASPHALT-RUBBER MIXTURES

3.1 The second objective of this experiment is to compare several physical properties of the field-mixed asphalt-rubber mixtures to lab-mixed asphalt-rubber mixtures composed of the same constituents. Six of the eight asphalt-rubber formulations obtained from the Buckeye-Liberty test project were also mixed and tested in the laboratory with results reported in other volumes of this investigation. Therefore, comparisons can be made between the properties of the field-mixed and lab-mixed materials to determine the effects of type of mixing, and to determine if the lab-mixing procedure results in asphalt-rubber mixtures with characteristics comparable to commercial field produced mixtures.

3.2 Buckeye-Liberty (field-mixed) asphalt-rubber formulations which were also mixed and tested in the laboratory are:

- 8NC (25% TPO44 rubber and Edgington AR1000)
- 3A (25% TPO44 rubber, Edgington AR1000, and 4% kerosene)
- 4A, 2A, 403, 101 (these are the same formulations except for reaction time and are composed of 20% GT274 rubber, Powerene AR4000, and 2% extender oil)

3.3 Materials (asphalt, rubber, diluent, and extender oil) which were used in the production of lab-mixed asphalt-rubber mixtures were of the same type and from the same suppliers as used with the field-mixed asphalt-rubbers. However, materials for the field and lab-produced mixtures were obtained from different lots.

3.4 Rubber

3.4.1 Properties of Atlos TPO44 and U.S. Rubber Reclaiming GT274 rubbers used in the lab mixtures are contained in the project Summary Report (1). Both TPO44 and GT274 used in the lab were slightly coarser than the rubbers used in the field produced mixtures.

3.5 Asphalt

3.5.1 Physical and chemical properties of Edgington AR1000 and Powerene AR4000 asphalts used in lab-mixed asphalt rubbers are contained in the project Summary Report (1). Physical properties of the asphalts used in lab and field mixtures are similar.

3.5.2 Chemical composition of Edgington AR1000 asphalts used in the lab and field mixtures are similar except that large differences exist in amounts of nitrogen bases and first acidifins. Rostler and Gotolski parameters are similar. Composition of Powerene AR4000 as- phalts used in the lab and field mixtures differ more than for the Edgington AR1000. Rostler parameters are comparable, but the Gotolski para- meters for the asphalt used in field mixtures is lower than for asphalt used in the lab. It is noted that the above comparisons are between data in Tables 5 and 6 from this volume and data in the project Summary Report (1).

3.5.3 Composition of Califlux GP extender oil used in lab-mixed asphalt rubbers is contained in the project Summary Report (1). Extender oil used in field mixtures has a lower Rostler parameter and higher Gotolski parameter than the Califlux GP used in lab mixtures.

4.0 DATA ANALYSIS

4.1 Data obtained for the field-mixed asphalt-rubber mixtures were analyzed using one-way analysis of variance (ANOVA) techniques. The experiment was designed as a completely randomized fixed factorial model with two replications per cell.

4.1.1 The experimental test matrix is present in Figure 3.

4.1.2 The fixed factor model is:

$$Y_{ij} = \mu + M_i + \varepsilon_{ij}$$

in which:

Y_{ij} = Response variable
μ = Effect of overall mean
M_i = Effect of mixture
ε_{ij} = Experimental error

4.1.3 Degrees of freedom for the analysis are as follows:

Source	Degrees of Freedom
M_i	7
Error	8
Total	15

4.2 For the comparison between laboratory and field-mixed materials, mixtures which had the same formulations were compared using one-way ANOVA techniques.

4.2.1 For Supplier No. 1, mixtures 3A and 8NC were duplicated in the lab. Comparable laboratory mixtures, however, were tested after curing, 1, 4, 24, and 168 hours at 140F. Therefore, test results for field-produced mixtures 3A (4% diluent) and 8NC (0% diluent) were compared in separate analyses to results of appropriate lab mixtures at the 5 cure times using one-way ANOVA. Details of the curing procedure used in lab mixtures are contained in Volume III, "Effects of Diluent," of this report.

4.2.1.1 The data analysis matrix for these comparisons is presented in Figure 4. This analysis matrix is used for each of the two comparisons (0% diluent, and 4% diluent).

MIXTURE

302	8NC	11A	3A	4A	2A	403	101
____ ____	____ ____	____ ____	____ ____	____ ____	____ ____	____ ____	____ ____

Figure 3 Data analysis Matrix, Field-Mixtures

MIXTURE

FIELD*	L-0	L-1	L-4	L-24	L-168
____ ____	____ ____	____ ____	____ ____	____ ____	____ ____

Figure 4 Data Analysis Matrix, Field-Lab Comparison, Supplier No. 1
*Note: Field mix is either 8NC or 3A.

MIXTURE

LAB	4A	2A	403	101
____ ____	____ ____	____ ____	____ ____	____ ____

Figure 5 Data Analysis Matrix, Field-Lab Comparison, Supplier No. 2

4.2.1.2 The fixed factor model for these analyses is:

$$Y_{ij} = \mu + M_i + \varepsilon_{ij}$$

in which:

Y_{ij} = Response variable
μ = Effect of overall mean
M_i = Effect of mixture
ε_{ij} = Experimental error

4.2.1.3 Degrees of freedom for this analysis are:

Source	Degrees of Freedom
M_i	5
Error	6
Total	11

4.2.2 All mixtures produced by Supplier No. 2 were of the same component formulation but differed only by reacton time. Therefore, field-produced mixtures 4A, 2A, 403, and 101 were compared to the lab produced mixture of the same formulation (20 percent GT274 rubber, AR4000 Powerene asphalt, and 2.0 percent extender oil). Therefore, test results for the lab-produced mixture were compared to results for the 4 field-produced mixtures with different reaction times using one-way ANOVA.

4.2.2.1 The data analysis matrix for this comparison is presented in Figure 5.

4.2.2.2 The fixed factor model for this analysis is:

$$Y_{ij} = \mu + M_i + \varepsilon_{ij}$$

in which:

Y_{ij} = Response variable
μ = Effect of overall mean
M_i = Effect of mixture
ε_{ij} = Experimental error

4.2.2.3 Degrees of freedom for this analysis are:

Source	Degrees of Freedom
M_i	4
Error	5
Total	9

4.3 Prior to performing analyses listed in sections 4.1 and 4.2, homogeneity of variance was tested by the Foster and Burr q-test (3). Appropriate data transformations were used when necessary to comply with variance homogeneity constraints required for analysis of variance.

4.3.1 If mixture type was found to be significant, means were ranked using the Newman-Keuls multiple range test (4).

5.0 FIELD-MIXED ASPHALT-RUBBER TEST RESULTS AND DISCUSSION

5.1 Absolute Viscosity

5.1.1 Measured vacuum capillary absolute viscosity results at 140F (60C) are tabulated in Appendix A in Table A-1. Each value tabulated in Table A-1 is the average of viscosity values obtained from several bulbs of one viscometer. Two viscosity tests were performed for each matrix cell replication.

5.1.2 Analyzed absolute viscosity data is tabulated in Table A-2. Each value in Table A-2 is the mean of two values in Table A-1.

5.1.3 The ANOVA summary for absolute viscosity is tabulated in Table A-3.

5.1.3.1 Mixture type significantly affected test results at the 0.01 level.

5.1.4 Newman-Keuls ranking indicates that mixtures 302, 11A and 8NC were not different and had the highest viscosity (36,537 poise average), that mixtures 11A, 8NC, and 4A were not different (26,008 poise average), that mixtures 8NC, 4A, 2A, 3A, and 403 were not different (12,493 poise average), and that mixture 101 had the lowest viscosity (1615 poise).

5.1.4.1 For Supplier No. 1 mixtures, the diluent addition did not significantly affect absolute viscosity.

5.1.4.2 For Supplier No. 2 mixtures, increased reaction time (166 hours) significantly lowered absolute viscosity.

5.2 Schweyer Rheometer Constant, G-tube

5.2.1 Measured and analyzed rheometer constants using the G-tube are tabulated in Appendix A in Table A-4 and the ANOVA summary in Table A-5.

5.2.1.1 Mixture type was not a significant effect at the 0.05 level.

5.2.2 Average shear suceptibility constant was 0.59 indicating that the field-produced mixtures exhibit pseudoplastic behavior when tested in the G-tube.

5.3 Schweyer Rheometer Constant, F-tube

5.3.1 Measured and analyzed rheometer constants using the F-tube are tabulated in Appendix C in Table A-6 and the ANOVA summary in Table A-7.

5.3.1.1 Mixture type was not a significant effect at the 0.05 level.

5.3.2 Average shear susceptibility constant was 0.97 indicating that field-produced mixtures are very close to being Newtonian in behavior when tested in the F-tube.

5.4 Schweyer Rheometer Apparent Viscosity ($\eta_{0.05}$) at 39.2F (4C), G-tube

5.4.1 Measured and analyzed viscosity data using the G-tube is tabulated in Appendix C in Table A-8 and the ANOVA summary is tabulated in Table A-9.

5.4.1.1 Mixture type is a significant effect at the 0.01 level.

5.4.2 Newman-Keuls ranking shows that mixtures 101 and 11A are not different and have the highest viscosity (260 x 10^6 Pa-s average), that mixtures 11A, 4A, 302, 8NC and 403 are not different (60.7 x 10^6 Pa-s average), and that mixtures 302, 8NC, 403, 2A, and 3A are not different (19.0 x 10^6 Pa-s average) and have the lowest viscosity.

5.4.2.1 For Supplier No. 1 mixtures, diluent addition did not significantly affect apparent viscosity.

5.4.2.2 For Supplier No. 2 mixtures, increased reaction time (166 hours) resulted in the highest apparent viscosity.

5.5 Schweyer Rheometer Apparent Viscosity ($\eta_{0.05}$) at 39.2F (4C), F-tube

5.5.1 Measured viscosity data in the F-tube are tabulated in Appendix C in Table A-10.

5.5.2 In order to provide for variance homogeneity, log transformations of the data were required prior to analysis. Log transformed data are tabulated in Table A-11 and the ANOVA summary in Table A-12.

5.5.2.1 Mixture is a significant effect at the 0.05 level but not the 0.01.

5.5.3 Newman-Keuls ranking shows that viscosity in the F-tube of mixtures 11A, 101, 302, 2A, 4A, and 403 are not different (2903 x 10^6 Pa-s average), that mixtures 101, 302, 2A, 4A, 403, and 8NC are not different (651 x 10^6 Pa-s average), and that mixtures 8NC and 3A are not different (47.4 x 10^6 Pa-s average) and have the lowest viscosity.

5.5.3.1 For Supplier No. 1 mixtures, diluent addition did not significantly influence apparent viscosity in the F-tube.

5.5.3.2 For Supplier No. 2 mixtures, increased reaction time did not significantly influence results.

5.6 Force-Ductility Engineering Stress at Failure at 39.2F (4C)

5.6.1 Calculated engineering stress at failure data are tabulated in Appendix A in Table A-13 and analyzed data in Table A-14. Each entry in Table A-14 is the average of either 2 or 3 values in Table A-13.

5.6.2 The ANOVA summary for enginering stress at failure data is tabulated in Table A-15.

5.6.2.1 Mixture is a significant effect at the 0.01 level.

5.6.3 Newman-Keuls ranking shows that mixture 11A has the highest engineering stress at failure (217.5 psi) and that mixture 302 has the second highest result (150.4 psi). Mixtures 2A, 101, and 3A are not different and have the lowest result (15.5 psi average). Mixtures 4A, 8NC, and 403 are not different (59.0 psi average) and mixtures 403, 2A, and 101 are not different (26.8 psi average).

5.6.3.1 For Supplier No. 1 mixtures, the diluent addition significantly lowered engineering stress at failure.

5.6.3.2 For Supplier No. 2 mixtures, increased reaction time (166 hours) resulted in lower engineering stress at failure than for 4 or 24 hour reaction times.

5.7 Force-Ductility Engineering Strain at Failure at 39.2F (4C)

5.7.1 Measured engineering strain at failure results are tabulated in Appendix A in Table A-16. Analyzed data are tabulated in Table A-17. Each entry in Table A-17 is the average of 2 or 3 values from Table A-16. The ANOVA summary for engineering strain at failure is tabulated in Table A-18.

5.7.1.1 Mixture type was a significant effect at the 0.01 level.

5.7.2 Newman-Keuls ranking shows that mixtures 2A, 101, and 403 were not different and had the highest engineering strain at failure (12.4 mm/mm average) that mixtures 403 and 4A were not different (9.9 mm/mm average), that mixtures 4A and 302 were not different (8.0 mm/mm average), that mixtures 302, 3A, and 11A were not different (6.21 mm/mm average), and that mixtures 3A, 11A, and 8NC were not different and had the lowest engineering strain at failure (5.5 mm/mm average). Mixtures produced by Supplier No. 1 had lower engineering strains at failure than those produced by Supplier No. 2.

5.7.2.1 For Supplier No. 1 mixtures, diluent addition did not significantly affect engineering strain at failure.

5.7.2.2 For Supplier No. 2 mixtures, reaction time did not significantly affect engineering strain at failure.

5.8 True Stress at Failure at 39.2F (4C)

5.8.1 Calculated true stress at failure results are tabulated in Appendix A in Table A-19. Analyzed data are contained in Table A-20. Each entry in Table A-20 is the average of 2 or 3 values from Table A-19. The ANOVA summary for true stress at failure is tabulated in Table A-21.

5.8.1.1 Mixture type was a significant effect at the 0.01 level.

5.8.2 Newman-Keuls ranking shows that mixtures 11A and 302 were not different and had the highest true stress at failure (1289 psi average), that mixtures 4A, 403 and 8NC were not different (511 psi average), that mixtures 403, 8NC, and 2A were not different (398 psi average), that mixtures 8NC, 2A, and 101 were not different (302 psi average), and that mixtures 101 and 3A were not different and had the lowest true stress at failure (115 psi average).

5.8.2.1 For Supplier No. 1 mixtures, diluent addition resulted in significantly lower true stress at failure.

5.8.2.2 For Supplier No. 2 mixtures, increased reaction time (166 hours) resulted in lowered true stress at failure.

5.9 Force-Ductility True Strain at Failure at 39.2F (4C)

5.9.1 Measured true strain at failure results are tabulated in Appendix A in Table A-22. Analyzed data are contained in Table A-23. Each entry in Table A-23 is the average of 2 or 3 values from Table A-22. The ANOVA summary for true strain at failure is tabulated in Table A-24.

5.9.1.1 Mixture is a significant effect at the 0.01 level.

5.9.2 Newman-Keuls analysis shows that mixtures 2A, 101, and 403 are not different (2.60 mm/mm average) and have the highest true strain at failure. Mixtures 11A and 8NC are not different (1.81 mm/mm average) and have the lowest true strain at failure. Mixtures 403 and 4A are not different (2.02 mm/mm average), and mixtures 3A and 11A are not different (1.93 mm/mm average).

5.9.2.1 For Supplier No. 1 mixtures, diluent addition significantly increased true strain at failure.

5.9.2.2 For Supplier No. 2 mixtures, reaction time did not significantly influence results.

5.10 Force-Ductility Engineering Creep Compliance at Failure at 39.2F (4C)

5.10.1 Calculated engineering creep compliance at failure data are tabulated in Appendix A in Table A-25. Analyzed data are tabulated in Table A-26. Each entry in Table A-26 is the average of 2 or 3 results from Table A-25. The ANOVA summary for engineering creep compliance at failure is tabulated in Table A-27.

5.10.1.1 Mixture is a significant effect at the 0.01 level.

5.10.2 Newman-Keuls ranking shows that mixtures 101, 3A, and 2A were not significantly different (0.905 psi^{-1} average) and have the highest engineering creep compliance at failure. Mixtures 3A, 2A, and 403 are not significantly different (.5975 psi^{-1} average), mixtures 2A, 403, 4A, and 8NC are not different (.2632 psi^{-1} average), and mixtures 403, 4A, 8NC, 302, and 11A are not different (.1102 psi^{-1} average) and have the lowest engineering creep compliance at failure.

5.10.2.1 For Supplier No. 1 mixtures, diluent addition significantly increases engineering creep compliance at failure.

5.10 2.2 For Supplier No. 2 mixtures, reaction time significantly increased engineering creep compliance at failure when compared to the 24 hour reaction time.

5.11 Force-Ductility True Creep Compliance at Failure at 39.2F (4C)

5.11.1 Calculated true creep compliance at failure data are tabulated in Appendix A in Table A-28 and reduced data in Table A-29. Each entry in Table A-29 is the average of 2 or 3 values from Table A-28.

5.11.2 In order to satisfy variance homogeneity requirements, log transformation of the data were required. Log transformed data are tabulated in Table A-30. The ANOVA summary for true creep compliance at failure is tabulated in Table A-31.

5.11.2.1 Mixture was a significant influence at the 0.01 level.

5.11.3 Newman-Keuls ranking shows that mixtures 3A and 101 are not different and have the highest true creep compliance at failure (0.030 psi^{-1} average). Mixtures 101 and 2A are not different (.012 psi^{-1} average), mixtures 2A, 403, and 8NC are not different (.006 psi^{-1} average), mixtures 403, 8NC, and 4A are not different (.005 psi^{-1} average), and mixtures 302 and 11A are not different and have the lowest true creep compliance at failure (.002 psi^{-1} average).

5.11.3.1 For Supplier No. 1 mixtures, diluent addition significantly increased true creep compliance at failure.

5.11.3.2 For Supplier No. 2 mixtures, the 166 hour reaction time significantly increased true creep compliance at failure when compared to the 24 hour reaction time.

5.12 Ring and Ball Softening Point

5.12.1 Measured and analyzed softening point data are tabulated in Appendix C in Table A-32. The ANOVA summary for softening point is tabulated in Table A-33.

5.12.1.1 Mixture is a significant effect at the 0.01 level.

5.12.2 Newman-Keuls ranking shows that mixture 8NC has the highest softening point (72.8 C), that mixtures 11A and 302 are not different (63.4 C average), and that mixtures 3A, 403, 2A, and 101 are not different (49.7 C average).

5.12.2.1 For Supplier No. 1 mixtures, diluent addition significantly lowers softening point.

5.12.2.2 For Supplier No. 2 mixtures, reaction time did not significantly influence results.

5.13 Low Temperature Fracture

5.13.1 Low temperature fracture results are as follows:

Sample	Fracture Temperature (F)
302	39
8NC	27
11A	Not tested
3A	33
4A	36
2A	45
403	36
101	72

5.13.2 One-way ANOVA performed on data collapsed by supplier shows that no significant difference exists in fracture temperature of the mixtures tested with respect to supplier.

5.13.3 For mixtures produced by Supplier No. 2, mixture 101 has a much higher fracture temperature (72F) than the other mixtures (39F average). This difference may be related to the longer reaction time (166 hours) used in production of mixture 101.

6.0 COMPARISON OF PROPERTIES OF LAB AND FIELD-MIXED ASPHALT-RUBBERS

6.1 Absolute Viscosity at 140F (60C)

6.1.1 Absolute viscosity of Supplier No. 1 mixtures could not be compared as shown in Section 4.2.1 due to lack of data. However, for Supplier No. 1 mixtures without diluent, one comparison can be made. The field-mix had a 23,739 poise average and the lab-mix with no cure time had a 68,561 poise average. One-way ANOVA shows that there is no significant difference at the 0.05 level between results.

6.1.2 Measured and analyzed absolute viscosity data for mixtures produced by Supplier No. 2 are tabulated in Appendix B in Table B-1 and the ANOVA summary in Table B-2.

7.1.2.1 Mixture is a significant effect at the 0.01 level.

7.1.3 Newman-Keuls ranking of data shows that the lab produced mixture (58,226 poise) has higher absolute viscosity than all of the field mixtures produced by Supplier No. 2 (8388 poise average) which were not significantly different.

6.2 Schweyer Rheometer Constant, G-tube

6.2.1 Measured and analyzed rheometer constants using the G-tube are tabulated in Appendix B in Tables B-3 and B-5 for Supplier No. 1 and Table B-7 for Supplier No. 2. ANOVA summaries are tabulated in Tables B-4, B-6, and B-8 respectively.

6.2.1.1 Mixture was not significant at the 0.05 level for mixtures produced by either supplier.

6.3 Schweyer Rheometer Constant, F-tube

6.3.1 Measured and analyzed rheometer constants using the F-tube are tabulated in Appendix D in Tables B-9 and B-11 for mixtures produced by Supplier No. 1 and and in Table B-13 for Supplier No. 2. ANOVA summaries are tabulated in Tables B-10, B-12, and B-14 respectively.

6.3.1.1 Mixture was not significant at the 0.05 level for mixtures produced by either supplier.

6.4 Schweyer Rheometer Apparent Viscosity ($\eta_{0.05}$) at 39.2F (4C), G-tube

6.4.1 Measured and analyzed viscosity data in the G-tube are tabulated in Appendix B in Tables B-15 and B-17 for asphalt-rubber mixtures produced by Supplier No. 1 and in Table B-19 for Supplier No. 2. ANOVA summaries are tabulated in Tables B-16, B-18, and B-20 respectively.

6.4.1.1 Mixture was not significant at the 0.05 level for mixtures produced by Supplier No. 1 but was significant at the 0.01 level for Supplier No. 2.

6.4.2 Newman-Keuls ranking of data for Supplier No. 2 shows that mixture 101 had the highest viscosity (345 x 10^6 Pa-s) and that the lab produced mixture was not different from field mixtures 4A, 403, and 2A (30.1 x 10^6 Pa-s average).

6.5 Schweyer Rheometer Apparent Viscosity ($\eta_{0.05}$) at 39.2F (4C), F-tube

6.5.1 Measured apparent viscosities in the F-tube are tabulated in Appendix B in Tables B-21 and B-23 for Supplier No. 1 and in Table B-26 for Supplier No. 2. Supplier No. 1 mixture which contained 4 percent diluent required log transformations to meet variance homogeneity requirements. ANOVA summaries for apparent viscosity in the F-tube are tabulated in Tables B-22, B-25, and B-27 respectively.

6.5.1.1 Mixture was a significant effect at the 0.01 level for Supplier No. 1 mixture with 4 percent diluent but was not significant at the 0.05 level for Supplier No. 1 mixture with 0 percent diluent or for Supplier No. 2 mixtures.

6.5.2 Newman-Keuls ranking of data for Supplier No. 1 mixture containing 4 percent diluent shows that mixture L-168 has the highest viscosity (134×10^6 Pa-s), that mixtures L-0, L-1, L-4, and L-24 were not different (18.9×10^6 Pa-s average), and that the field-produced mixture (3A) has the lowest viscosity (1.9×10^6 Pa-s).

6.6 Force-Ductility Engineering Stress at Failure at 39.2F (4C)

6.6.1 Measured and analyzed engineering stress at failure data are tabulated in Appendix B in Tables B-28, B-30, and B-32. ANOVA summaries are tabulated in Tables B-29, B-31, and B-33 respectively.

6.6.1.1 Mixture is a significant effect at the 0.01 level for Supplier No. 1 mixture containing 4 percent diluent and for Supplier No. 2 mixtures. Mixture was significant at the 0.05 level but not at the 0.01 level for Supplier No. 1 mixture containing 0 percent diluent.

6.6.2 Newman-Keuls ranking shows that for Supplier No. 1 mixture with 0 percent diluent, the lab produced mixtures were not different (132.2 psi average) and had higher engineering stresses at failure than the field-produced mixture (66.3 psi).

6.6.3 Newman-Keuls ranking shows that for Supplier No. 1 mixture with 4 percent diluent, mixture L-168 has the highest engineering stress at failure (90.5 psi), that mixtures L-4, L-24, L-1, and L-0 are not different (35.7 psi average) and that the field-produced mixture (3A) has the lowest engineering stress at failure (7.8 psi).

6.6.4 Newman-Keuls ranking shows that for Supplier No. 2, the lab produced mixture has the highest engineering stress at failure (118.4 psi), that mixtures 4A and 403 were not different (55.4 psi average) and that mixtures 2A and 101 were not different and have the lowest engineering stress at failure (19.4 psi average).

6.7 Force Ductility Engineering Strain at Failure at 39.2F (4C)

6.7.1 Measured and analyzed engineering strain at failure data are tabulated in Appendix B in Tables B-34, B-36, and B-38. ANOVA summaries are tabulated in Tables B-35, B-37, and B-39 respectively.

6.7.1.1 Mixture is not a significant effect at the 0.05 level for Supplier No. 1 mixture containing 0 percent diluent. Mixtures are significant at the 0.01 level for Supplier No. 1 mixture containing 4 percent diluent and for Supplier No. 2 mixtures.

6.7.2 Newman-Keuls ranking shows that for Supplier No. 1 mixture containing 4 percent diluent, the field-produced mixture (3A) has the highest engineering strain at failure (6.3 mm/mm), and that the lab produced mixtures were not different (3.4 mm/mm average) and have lower engineering strains at failure than the field produced mixture.

6.7.3 Newman-Keuls ranking shows that for Supplier No 2., mixtures 2A, 101, and 403 were not different and have the highest engineering strain at failure (12.4 mm/mm average), that mixtures 403 and 4A were not different (9.9 mm/mm average), and that the lab produced mixture has the lowest engineering strain at failure (7.6 mm/mm).

6.8 Force-Ductility True Stress at Failure at 39.2F (4C)

6.8.1 Calculated and analyzed true stress at failure data are tabulated in Appendix B in Tables B-40, B-42, and B-44. ANOVA summaries are tabulated in Tables B-41, B-43, and B-45 respectively.

6.8.1.1 Mixture is a significant effect at the 0.01 level for Supplier No. 1 mixture containing 4 percent diluent and for Supplier No. 2 mixtures. Mixture is not significant at the 0.05 level for Supplier No. 1 mixture containing 0 percent diluent.

6.8.2 Newman-Keuls ranking shows that for Supplier No. 1 mixture containing 4 percent diluent, mixture L-168 have the highest true stress at failure (416.7 psi), that mixtures L-4, L-24, L-1, and L-0 were not different (155.6 psi average) and that mixture L-0 and the field produced mixture were not different (91.6 psi average) and have the lowest true stress at failure.

6.8.3 Newman-Keuls ranking shows that for Supplier No. 2, the lab produced mixture and mixture 4A were not different (854.0 psi average) and have the highest true stress at failure, that mixtures 4A and 403 were not different (577.1 psi average), and that mixtures 403, 2A, and 101 were not different (330.2 psi average) and have the lowest true stress at failure.

6.9 Force-Ductility True Strain at Failure at 39.2F (4C)

6.9.1 Measured and analyzed true strain at failure data are tabulated in Appendix B in Tables B-46, B-48, and B-50. ANOVA summaries are tabulated in Tables B-47, B-49, and B-51 respectively.

6.9.1.1 Mixture was a significant effect at the 0.01 level for Supplier No. 1 mixtures containing 4 percent diluent and for Supplier No. 2 mixtures. Mixture was not significant at the 0.05 level for Supplier No. 1 mixture containing 0 percent diluent.

6.9.2 Newman-Keuls ranking shows that for Supplier No. 1 mixture containing 4 percent diluent, the field-produced mixture (3A) have the highest true strain at failure (1.98 mm/mm) and that the lab produced mixtures were not different (1.47 mm/mm average) and have the lowest true strain at failure.

6.9.3 Newman-Keuls ranking shows that for Supplier No. 2, mixtures 2A, 101, and 403 are not different and have the highest true strain at failure (2.60 mm/mm average), that mixtures 403 and 4A are not different (2.39 mm/mm average), and that the lab mixture has the lowest true strain at failure (2.15 mm/mm average).

6.10 Force-Ductility Engineering Creep Compliance at Failure at 39.2F (4C)

6.10.1 Measured engineering creep compliance data are tabulated in Appendix B in Tables B-52, B-54, and B-57. Data for Supplier No. 1 mixture containing 4 percent diluent required log transformations to comply with variance homogeneity requirements. ANOVA summaries are tabulated in Tables B-53, B-56, and B-58 respectively.

6.10.1.1 Mixture was a significant effect at the 0.01 level for Supplier No. 1 and No. 2 mixtures.

6.10.2 Newman-Keuls ranking shows that for Supplier No. 1 mixture containing 0 percent diluent, the field-produced mixture (8NC) has the highest engineering creep compliance at failure (0.0715 psi^{-1}), that mixtures L-24, L-4, and L-1 are not different (.0291 psi^{-1} average), and that mixtures L-4, L-1, L-168, and L-0 are not different (.0251 psi^{-1} average) and have the lowest result.

6.10.3 Newman-Keuls ranking shows that for Supplier No. 1 mixture containing 4 percent diluent, the field-produced mixture (3A) has the highest engineering creep compliance at failure (.9879 psi^{-1}) and that lab-produced mixtures were not different (0.0884 psi^{-1} average) and have the lowest result.

6.10.4 Newman-Keuls ranking shows that for Supplier No. 2, mixture 101 has the highest engineering creep compliance at failure (1.18 psi^{-1}), that mixtures 2A and 403 are not different (.415 psi^{-1} average) and that the lab produced mixture and mixtures 4A and 403 are not different and have the lowest engineering creep compliance at failure (.158 psi^{-1} average).

6.11 Force-Ductility True Creep Compliance at Failure at 39.2F (4C)

6.11.1 Measured and analyzed true creep compliance at failure data are tabulated in Appendix B in Tables B-59, B-61, and B-63. ANOVA summaries are tabulated in Tables B-60, B-62, and B-64 respectively.

6.11.1.1 Mixture was significant at the 0.01 level for Supplier No. 2, not significant at the 0.05 level for Supplier No. 1 mixture containing 4 percent diluent, and significant at the 0.05 level but not at the 0.01 level for Supplier No. 1 mixture containing 0 percent diluent.

6.11.2 Newman-Keuls ranking shows that for Supplier No. 1 mixture containing 0 percent diluent, the field-produced mixture (8NC) and mixture L-1 were not different and have the highest true creep compliance at failure (.0042 psi^{-1} average), that L-1, L-24, and L-4 were not different (0.0030 psi^{-1} average), and that mixtures L-24, L-4, L-168, and L-0 are not different (0.0025 psi^{-1} average) and have the lowest true creep compliance at failure.

6.11.3 Newman-Keuls ranking shows that for Supplier No. 2, mixture 101 has the highest true creep compliance at failure (.0159 psi^{-1}), that mixtures 2A and 403 are not different (.0069 psi^{-1} average), and that mixtures 4A and the lab produced mixture were not different and have the lowest true creep compliance at failure (.0030 psi^{-1} average).

6.12 Ring and Ball Softening Point

6.12.1 Measured and analyzed softening points for Supplier No. 1 are tabulated in Appendix B in Tables B-65 and B-67. ANOVA summaries are tabulated in Tables B-66 and B-67 respectively.

6.12.1.1 Mixture is significant at the 0.01 level for mixtures containing 4 percent diluent and significant at the 0.05 level but not at the 0.01 for mixtures containing 0 percent diluent.

6.12.2 Newman-Keuls ranking shows that for mixture containing 0 percent diluent, mixtures L-0 and L-168 are not different and have the highest softening point (81.5 C average) and that the field-produced mixture is not different from mixtures L-168, L-24, L-4, and L-1 (72.7 C average).

6.12.3 Newman-Keuls ranking shows that for the mixture containing 4 percent diluent, mixtures L-168, L-4, L-24, and L-0 and were not different and have the highest softening point (67.2 C average) and that the field-produced mixture (3A) has the lowest softening point (51.3 C).

6.12.4 Data was not available for comparison of Supplier No. 2 mixtures.

7.0 CONCLUSIONS

7.1 Field-Produced Mixtures

A summary of one-way ANOVA results for field-produced mixtures is tabulated in Table 7. This table indicates if significant differences exist between the field-produced mixtures. Significant differences exist in the absolute viscosity, Schweyer apparent viscosity in the G-tube, force-ductility engineering stress, strain, compliance at failure, and true stress, strain and compliance at failure, and ring and ball softening point. Schweyer shear susceptibility constants and apparent viscosity in the F-tube were not significantly different.

7.1.1 The addition of diluent to Supplier No. 1 mixtures significantly influenced engineering stress and creep compliance at failure, true stress and creep compliance at failure, and softening point. The addition of diluent softened the mixture as indicated by all tests.

7.1.2 Increased reaction (166 hours) of the Supplier No. 2 mixture significantly influenced absolute viscosity, Schweyer apparent viscosity, engineering stress and creep compliance at failure and true stress and creep compliance at failure. Increased reaction time softened the mixtures as indicated by all tests except the Schweyer apparent viscosity which indicates a stiffer mix.

7.1.3 Supplier No. 1 mixtures tended to have higher absolute viscosities, engineering and true stresses at failure, and softening points than Supplier No. 2 mixtures.

Additionally, Supplier No. 1 mixtures tended to have lower engineering and true strains at failure and lower engineering creep compliance at failure than Supplier No. 2 mixtures.

7.1.4 Low temperature fracture test results for asphalt-rubber mixtures tested vary from a low of 27F to a high of 72F. Data appear to vary by supplier and mixture.

TABLE 7

SUMMARY OF SIGNIFICANCE FOR
FIELD-PRODUCED MIXTURES

Absolute Viscosity	Y*
SCHWEYER RHEOMETER (39.2F)	
Constant (C), G-tube	-
Constant (C), F-tube	-
Apparent Viscosity, G-tube	Y
Apparent Viscosity, F-tube	-
FORCE-DUCTILITY (39.2F)	
Engineering Stress at Failure	Y
Engineering Strain at Failure	Y
True Stress at Failure	Y
True Strain at Failure	Y
Engineering Creep Compliance	Y
True Creep Compliance	Y
Softening Point	Y

*Note: Y signifies significant at the 0.05 level
- signifies not significant at the 0.05 level

8.2 Comparison of Lab-and-Field-Produced Mixtures

8.2.1 Table 8 is a summary of ANOVA and Newman-Keuls results for the comparison between lab and field mixtures produced by Supplier No. 1.

8.2.1.1 For mixtures containing 0 percent diluent, engineering stress at failure is lower for the field-produced mixtures than for lab produced mixtures, engineering and true creep compliances are higher for the field-produced mixture, and other tests, results are the same. These results indicate that the field-produced mixture is softer and not as stiff as the lab produced mixtures.

8.2.1.2 For mixtures containing 4 percent diluent, apparent viscosity, engineering and true stress at failure, and softening point are lower for the field-produced mixture than for lab produced mixtures. Engineering and true strains at failure, and engineering creep compliance at failure are higher for field-mixtures than for the lab. For other tests, results are not different. These results indicate that the field-produced mixtures are softer and not as stiff as lab produced mixtures.

8.2.2 Table 9 is a summary of ANOVA and Newman-Keuls results for the comparison between the lab and field mixtures produced by Supplier No. 2.

8.2.2.1 Absolute viscosity, engineering stress at failure and true stress at failure for the lab produced mixture are higher than for field-produced mixtures. Engineering and true strains at failure, and engineering and true creep compliances at failure are lower for the lab mixture than for the field mixtures. Schweyer Rheometer test results are not different. These results indicate that field-produced mixtures are softer and not as stiff as the lab produced mixtures.

TABLE 8
COMPARISON OF LAB-AND-FIELD-PRODUCED MIXTURES,
SUPPLIER NO. 1

	0% Diluent			4% Diluent		
	Higher	Lower	Same	Higher	Lower	Same
Schweyer Rheometer (39.2F)						
Constant (C), G-tube			X[1]			X
Constant (C), F-tube			X			X
App.Viscosity,G-tube			X			X
App.Viscosity,F-tube			X		X	
Force-Ductility						
Eng.Stress at Failure		X			X	
Eng.Strain at Failure			X	X		
True Stress at Failure			X		X	
True Strain at Failue			X	X		
Eng. Creep Compliance	X			X		
True Creep Compliance	X[3]				X[2]	
Softening Point		X		X		

Notes:

1 X signifies if the field-produced mixture test result is higher, lower, or the same as for the lab produced mixtures.

2 Result is the same as for lab mixture with no cure.

3 Result is the same as for lab mixture with 1 hour cure.

TABLE 9
COMPARISON OF LAB-AND-FIELD-PRODUCED MIXTURES, SUPPLIER NO. 2

	Higher	Lower	Same
Absolute Viscosity	X[1]		
Schweyer Rheometer (39.2F)			
Constant (C), G-tube			X
Constant (C), F-tube			X
App.Viscosity,G-tube			X
App.Viscosity,F-tube			X
Force-Ductility			
Eng.Stress at Failure	X		
Eng.Strain at Failure		X	
True Stress at Failure	X[2]		
True Strain at Failue		X	
Eng. Creep Compliance		X[3]	
True Creep Compliance		X[4]	

NOTES:
1 X signifies if the lab produced mixture test result is higher, lower, or the same as for the field-produced mixtures.

2 Result is the same as for field mixture 4A.

3 Result is the same as for field mixture 4A and 403.

4 Result is the same as for field mixture 4A.

References

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4. Burr, I. W., Applied Statistical Methods, Academic Press, Inc., New York, 1974.

APPENDIX A

FIELD-MIXED ASPHALT-RUBBER TEST DATA AND ANALYSIS

Table A-1 Absolute Viscosity, Poise (Measured Data)

DATA / Replication	302	8NC	11A	3A	4A	2A	403	101
1	57977	21709	52250	4244	20511	10187	5345	1620
1	46967	21907	50210	4294	21202	7358	7266	1638
2	41663	23841	29295	13480	11202	11416	7307	1644
2	41855	27501	23278	5140	9191	10548	6227	1560
$\bar{X}$	47115	23739	38758	6790	15526	9877	6536	1615
s	7646	2686	14633	4479	6215	1757	938	38.4
CV	16.2	11.3	37.8	66.0	40.0	17.8	14.4	2.4

Table A-2 Absolute Viscosity, Poise (Analyzed Data)

Mixture	302	8NC	11A	3A	4A	2A	403	101
DATA	52472	21808	51230	4269	20856	8772	6302	1629
DATA	41759	25671	26286	9310	10196	10982	6767	1602
$\bar{X}$	47115	23739	38758	6789	15526	9877	6534	1615
s	9492	3423	22100	4466	9445	1958	412	23.9
CV	20.1	14.4	57.0	65.8	60.8	19.8	6.3	1.5

Table A-3 One-Way ANOVA Summary, Absolute Viscosity

Source	df	SS	MS	F	F.05	F.01
Mixture	7	3.8096-E09	5.442-E08	9.72	3.50	6.18
Error	8	4.4802-E08	5.6002-E7			
Total	15	4.2576-E09				

Table A-4 Schweyer Rheometer Constant (C), G-tube, (Measured and Analyzed Data)

MIXTURE	302	8NC	11A	3A	4A	2A	403	101
DATA	.53	.70	.55	.58	.52	.54	.37	.88
	.39	.56	.66	.24	1.00	.42	.63	.80
$\bar{X}$	.46	.63	.61	.41	.76	.48	.50	.84
s	.12	.12	.10	.30	.43	.11	.23	.07
CV	27.0	19.7	16.1	73.5	56.0	22.2	46.1	8.4

Table A-5 One-Way ANOVA Summary, Schweyer Rheometer Constant (C), G-tube

Source	df	SS	MS	F	$F_{.05}$	$F_{.01}$
Mixture	7	.325	.046	1.53	3.50	6.18
Error	8	.243	.030			
Total	15	.568				

Table A-6 Schweyer Rheometer Constant (C), F-tube, (Measured and Analyzed Data)

MIXTURE	302	8NC	11A	3A	4A	2A	403	101
DATA	.78	.90	.51	.61	.89	1.60	.93	1.50
	.71	1.10	1.70	.45	1.00	1.00	.94	.80
$\bar{X}$	.75	1.00	1.10	.53	.95	1.30	.94	1.15
s	.06	.18	1.05	.14	.10	.53	.01	.62
CV	8.3	17.7	95.4	26.8	10.3	40.9	1.0	53.9

Table A-7 One-Way ANOVA Summary, Schweyer Rheometer Constant (C), F-tube

Source	df	SS	MS	F	F.05	F.01
Mixture	7	.812	.116	.79	3.50	6.18
Error	8	1.174	.147			
Total	15	1.987				

Table A-8 Schweyer Rheometer, Apparent Viscosity, $\eta_{0.05}$, 10^6 Pa-s, G-tube, (Measured and Analyzed Data)

MIXTURE	302	8NC	11A	3A	4A	2A	403	101
DATA	45	12	110	1.5	21	19	7	270
	22	18	240	3.0	110	7.2	22	420
$\bar{X}$	33.5	15.0	175	2.3	65.5	13.1	14.7	345
s	20.4	5.3	115	1.3	78.9	10.5	12.9	132.9
CV	60.8	35.4	65.8	59.1	120.4	79.8	88.0	38.5

Table A-9 One-Way ANOVA Summary, Schweyer Rheometer, Apparent Viscosity

Source	df	SS	MS	F	$F_{.05}$	$F_{.01}$
Mixture	7	2.011-E05	28731	9.53	3.50	6.18
Error	8	2.412-E04	3015			
Total	15	2.252-E05				

Table A-10 Schweyer Rheometer, Apparent Viscosity, $\eta_{0.05}$, 10^6 Pa-s, F-tube, (Measured Data)

MIXTURE	302	8NC	11A	3A	4A	2A	403	101
DATA	380	16	210	2.0	190	800	150	4600
	410	170	27000	1.7	260	120	170	540
$\bar{X}$	395	93	13605	1.85	225	460	160	2570
s	26.6	136.4	23736	.27	62.0	602.5	17.7	3597.2
CV	6.7	146.7	174.5	14.4	27.6	131.0	11.1	140.0

Table A-11 Log Schweyer Rheometer, Apparent Viscosity, $\eta_{0.05}$, 10^6 Pa-s, F-tube (Analyzed Data)

MIXTURE	302	8NC	11A	3A	4A	2A	403	101
DATA	2.580	1.204	2.322	.301	2.279	2.903	2.170	3.663
	2.613	2.230	4.431	.230	2.415	2.079	2.230	2.732
$\bar{X}$	2.597	1.717	3.377	.266	2.347	2.491	2.203	3.198
s	.029	.909	1.869	.063	.120	.730	.048	.825
CV	1.1	52.9	55.3	23.7	5.1	29.3	2.2	25.8

Table A-12 One-Way ANOVA Summary, Log Apparent Viscosity, F-tube

Source	df	SS	MS	F	F.05	F.01
Mixture	7	13.15	1.88	4.25	3.50	6.18
Error	8	3.54	.44			
Total	15	16.69				

Table A-13 Engineering Stress at Failure, psi (Calculated Data)

	Replication	302	8NC	11A	3A	4A	2A	403	101
DATA	1	144.3	68.4	247.1	6.21	43.2	32.9	37.9	8.7
		146.5	58.9	226.0	4.0	54.5	30.2	43.0	18.3
		–	67.8	222.1	–	45.6	34.8	44.7	–
	2	149.6	63.0	216.1	8.7	88.8	22.0	44.4	9.9
		158.9	72.6	199.5	10.5	86.2	17.5	44.5	12.9
		157.4	67.2	194.1	11.9	94.6	–	35.9	–
$\bar{X}$		151.3	66.3	217.5	8.3	68.8	27.5	41.7	12.5
s		6.5	4.8	19.2	3.2	23.5	7.4	3.8	4.3
CV		4.3	7.2	8.8	38.7	34.2	27.0	9.2	34.4

Table A-14 Engineering Stress at Failure, psi (Analyzed Data)

Mixture	302	8NC	11A	3A	4A	2A	403	101
DATA	145.4	65.0	231.7	5.1	47.8	32.6	41.9	13.5
	155.3	67.6	203.2	10.4	89.9	19.8	41.6	11.4
$\bar{X}$	150.4	66.3	217.5	7.8	68.9	26.2	41.8	12.5
s	8.8	2.3	25.3	4.7	37.3	11.3	.3	1.9
CV	5.8	3.5	11.6	60.6	54.2	43.3	.6	14.9

Table A-15 One-Way ANOVA Summary, Engineering Stress at Failure

Source	df	SS	MS	F	F.05	F.01
Mixture	7	75990.6	10855.8	60.2	3.50	6.18
Error	8	1442.9	180.4			
Total	15	77433.5				

Table A-16 Engineering Strain at Failure, mm/mm (Measured Data)

DATA	REPLICATION	302	8NC	11A	3A	4A	2A	403	101
	1	6.66	4.28	5.94	7.04	9.78	10.96	10.10	14.29
		6.20	4.30	4.58	6.45	8.60	12.82	9.67	10.83
		-	5.92	5.52	-	10.60	12.63	11.16	-
	2	6.76	4.54	5.44	5.96	9.00	14.00	11.55	13.70
		7.33	5.06	5.76	5.84	9.39	15.00	10.27	14.38
		7.72	4.29	5.98	5.45	7.85	-	11.06	-
$\bar{X}$		6.93	4.73	5.54	6.15	9.20	13.08	10.64	13.30
s		.60	.66	.52	.61	.95	1.53	.73	1.67
CV		8.6	13.8	9.3	10.0	10.4	11.7	6.8	12.6

Table A-17 Engineering Strain at Failure, mm/mm (Analyzed Data)

MIXTURE	302	8NC	11A	3A	4A	2A	403	101
DATA	6.43	4.83	5.35	6.75	9.66	12.14	10.31	12.56
	7.27	4.63	5.73	5.75	8.75	14.50	10.96	14.04
$\bar{X}$	6.85	4.73	5.54	6.25	9.21	13.32	10.64	13.30
s	.74	.18	.34	.89	.81	2.09	.58	1.31
CV	10.9	3.8	6.1	14.2	8.8	15.7	5.4	9.86

Table A-18 One-Way ANOVA Summary, Engineering Strain at Failure

Source	df	SS	MS	F	F.05	F.01
Mixture	7	163.34	23.33	34.25	3.50	6.18
Error	8	5.45	.68			
Total	15	168.79				

Table A-19 True Stress at Failure, psi
(Calculated Data)

DATA (Replication \ Mixture)		302	8NC	11A	3A	4A	2A	403	101
DATA	1	1105.7	312.4	1629.8	42.9	503.5	401.6	387.6	143.4
		1055.0	300.0	1170.8	27.3	459.5	417.7	431.9	222.2
		-	441.8	1440.8	-	539.6	413.6	526.7	-
	2	1207.4	348.9	1371.6	60.6	818.1	337.3	535.2	142.7
		1297.1	496.7	1375.7	82.5	860.7	256.9	459.7	188.2
		1385.7	366.4	1354.9	88.6	787.7	-	433.2	-
$\bar{X}$		1210.2	377.7	1390.6	60.4	661.5	365.4	462.4	174.1
s		135.4	76.8	148.3	25.9	179.3	68.8	57.9	38.5
CV		11.2	20.3	10.7	42.9	27.1	18.8	12.5	22.1

Table A-20 True Stress at Failure, psi
(Analyzed Data)

Mixture	302	8NC	11A	3A	4A	2A	403	101
DATA	1080.4	351.4	1413.8	35.1	500.9	410.0	448.7	182.8
	1296.7	404.0	1367.4	77.2	882.4	297.1	476.0	165.4
$\bar{X}$	1188.6	377.7	1390.6	56.2	691.7	354.0	462.4	174.1
s	191.6	46.6	41.1	37.3	338.0	101.0	24.2	15.4
CV	16.1	12.3	3.0	66.4	48.9	28.5	5.2	8.9

Table A-21 One-Way ANOVA Summary,
True Stress at Failure

Source	df	SS	MS	F	$F_{.05}$	$F_{.01}$
Mixture	7	3.169-E06	452710	34.00	3.50	6.18
Error	8	1.065-E05	13315			
Total	15	3.275-E06				

Table A-22 True Strain at Failure, mm/mm (Measured Data)

DATA (Replication)	302	8NC	11A	3A	4A	2A	403	101
1	2.04 1.97 –	1.66 1.67 1.93	1.94 1.72 1.87	2.08 2.01 –	2.38 2.26 2.45	2.50 2.63 2.63	2.41 2.37 2.50	2.73 2.47 –
2	2.05 2.12 2.17	1.71 1.80 1.67	1.86 1.91 1.94	1.94 1.92 1.86	2.30 2.34 2.18	2.71 2.77 –	2.53 2.42 2.49	2.69 2.73 –
$\bar{X}$ s CV	2.07 .08 3.7	1.74 .11 6.1	1.87 .08 4.4	1.96 .09 4.3	2.32 .09 4.1	2.65 .10 3.8	2.45 .06 2.5	2.66 .13 4.7

Table A-23 True Strain at Failure, mm/mm (Analyzed Data)

Mixture	302	8NC	11A	3A	4A	2A	403	101
DATA	2.00 2.11	1.75 1.73	1.84 1.90	2.05 1.91	2.36 2.27	2.59 2.74	2.43 2.48	2.60 2.71
$\bar{X}$ s CV	2.06 .10 4.7	1.74 .02 1.0	1.87 .05 2.8	1.98 .12 6.3	2.32 .08 3.4	2.67 .13 5.0	2.46 .04 1.8	2.66 .10 3.7

Table A-24 One-Way ANOVA Summary, True Strain at Failure

Source	df	SS	MS	F	F.05	F.01
Mixture	7	1.778	.254	50.24	3.50	6.18
Error	8	.040	.005			
Total	15	1.819				

Table A-25 Engineering Creep Compliance at Failure, psi^{-1} (Calculated Data)

Data	Replication	302	8NC	11A	3A	4A	2A	403	101
DATA	1	.0461 .0423 –	.0627 .0730 .0873	.0240 .0185 .0249	1.1282 1.6329 –	.2267 .1579 .2324	.3330 .4244 .4349	.2605 .2249 .2575	1.6335 .5908 –
	2	.0452 .0461 .0490	.0721 .0697 .0639	.0252 .0289 .0308	.6849 .5543 .3965	.1014 .1089 .0829	.6352 .8566 –	.2600 .2306 .3078	1.3822 1.1123 –
$\bar{X}$		.0457	.0715	.0254	.8794	.1517	.5368	.2579	1.1797
s		.0024	.0088	.0043	.5016	.0652	.2101	.0297	.4466
CV		5.2	12.4	16.8	57.0	43.0	39.1	11.1	37.9

Table A-26 Engineering Creep Compliance at Failure, psi^{-1} (Analyzed Data)

Mixture	302	8NC	11A	3A	4A	2A	403	101
DATA	.0422 .0468	.0743 .0686	.0225 .0283	1.3806 .5952	.2057 .0977	.3974 .7459	.2496 .2661	1.1122 1.2473
$\bar{X}$	.0445	.0715	.0254	.9629	.1517	.5717	.2579	1.1798
s	.0041	.0051	.0051	.7402	.0957	.3088	.0146	.1197
CV	9.2	7.1	20.2	76.9	63.1	54.0	5.7	10.1

Table A-27 One-Way ANOVA Summary, Engineering Creep Compliance at Failure

Source	df	SS	MS	F	$F_{.05}$	$F_{.01}$
Mixture	7	2.8772	.4110	8.56	3.50	6.18
Error	8	.3843	.0480			
Total	15	3.2615				

Table A-28 True Creep Compliance at Failure, psi^{-1} (Calculated Data)

DATA / Replication	302	8NC	11A	3A	4A	2A	403	101
1	.0018	.0053	.0012	.0486	.0047	.0088	.0062	.0190
	.0019	.0056	.0014	.0736	.0049	.0063	.0055	.0111
	–	.0049	.0013	–	.0045	.0064	.0047	–
2	.0017	.0049	.0014	.0320	.0028	.0080	.0047	.0188
	.0016	.0036	.0014	.0233	.0027	.0108	.0053	.0145
	.0016	.0045	.0014	.0210	.0028	–	.0057	–
$\bar{X}$	.0017	.0048	.0014	.0397	.0037	.0081	.0054	.0159
s	.0001	.0007	.0001	.0218	.0011	.0019	.0006	.0038
CV	7.6	14.6	6.2	55.0	28.6	23.1	10.9	23.9

Table A-29 True Creep Compliance at Failure, psi^{-1} (Reduced Data)

	302	8NC	11A	3A	4A	2A	403	101
DATA	.0018	.0053	.0013	.0611	.0047	.0072	.0055	.0150
	.0016	.0043	.0014	.0254	.0028	.0094	.0052	.0167
$\bar{X}$	.0017	.0048	.0014	.0433	.0038	.0083	.0054	.0159
s	.0002	.0009	.0001	.0316	.0017	.0019	.0003	.0015
CV	10.4	18.5	6.6	73.1	44.9	23.5	5.0	9.5

Table A-30 Log 1000 x True Creep Compliance at Failure, psi^{-1} (Analyzed Data)

MIXTURE	302	8NC	11A	3A	4A	2A	403	101
DATA	.255	.724	.114	1.786	.672	.857	.740	1.176
	.204	.633	.146	1.405	.447	.973	.716	1.223
$\bar{X}$	.230	.679	.130	1.590	.560	.915	.728	1.200
s	.045	.081	.028	.338	.199	.103	.021	.042
CV	19.7	11.9	21.8	21.2	35.6	11.2	2.9	3.5

Table A-31 One-Way ANOVA Summary, Log 1000 x True Creep Compliance at Failure

Source	df	SS	MS	F	F.05	F.01
Mixture	7	3.282	.469	33.5	3.50	6.18
Error	8	.112	.014			
Total	15	3.394				

Table A-32 Ring-and-Ball Softening Point, °C (Measured and Analyzed)

MIXTURE	302	8NC	11A	3A	4A	2A	403	101
DATA	62.0 63.5	74.5 71.0	64.0 64.0	49.0 53.5	55.5 56.5	50.0 48.5	50.0 50.5	48.0 48.0
$\bar{X}$	62.8	72.8	64.0	51.3	56.0	49.3	50.3	48.0
s	1.33	3.10	0.0	3.99	.89	1.33	.44	0.0
CV	2.1	4.3	0.0	7.8	1.6	2.7	.9	0.0

Table A-33 One-Way ANOVA Summary, Softening Point, °C

Source	df	SS	MS	F	F.05	F.01
Mixture	7	1100.86	157.27	65.78	3.50	6.18
Error	8	19.13	2.39			
Total	15	1119.98				

APPENDIX B

COMPARISON OF PROPERTIES OF LAB AND FIELD-MIXED ASPHALT-RUBBERS, TEST DATA AND ANALYSIS

Table B-1 Field-Lab Comparison, Supplier No. 2, Absolute Viscosity, Poise

MIXTURE	LAB	4A	2A	403	101
DATA	55519	20856	8772	6302	1629
	61013	10196	10982	6767	1602
$\bar{X}$	58226	15526	9877	6534	1615
s	4868	9495	1958	412	23.9
CV	8.4	60.8	19.8	6.3	1.5

Table B-2 One-Way ANOVA Summary, Absolute Viscosity, Poise

Source	df	SS	MS	F	F.05	F.01
Mixture	4	4.185-E09	1.046-E09	70.26	5.19	11.4
Error	5	7.446-E07	1.489-E07			
Total	9	4.260-E09				

Table B-3 Field-Lab Comparison, Supplier No. 1, 0% Diluent, Schweyer Rheometer Constant (C), G-tube

MIXTURE	8NC	L-0	L-1	L-4	L-24	L-168
DATA	.70	.26	.50	.61	.70	.22
	.56	.31	.78	.51	.51	.53
$\bar{X}$	.63	.29	.64	.59	.61	.38
s	.12	.04	.25	.04	.17	.28
CV	19.7	15.5	38.8	6.0	27.8	73.2

Table B-4 One-Way ANOVA Summary, 0% Diluent, Schweyer Rheometer Constant (C), G-tube

Source	df	SS	MS	F	F.05	F.01
Mixture	5	.230	.046	2.35	4.39	8.75
Error	6	.117	.020			
Total	11	.347				

Table B-5 Field-Lab Comparison, Supplier No. 1, 4% Diluent, Schweyer Rheometer Constant (C), G-tube

MIXTURE	3A	L-0	L-1	L-4	L-24	L-168
DATA	.55	.74	.86	.69	.71	.62
	.24	.80	.37	.64	.79	.56
$\bar{X}$	.41	.77	.62	.69	.75	.59
s	.30	.05	.43	0	.07	.05
CV	73.5	6.90	70.60	0	9.45	9.01

Table B-6 One-Way ANOVA Summary, 4% Diluent, Schweyer Rheometer Constant (C), G-tube

Source	df	SS	MS	F	F.05	F.01
Mixture	5	.17	.03	1.14	4.39	8.75
Error	6	.18	.03			
Total	11	.36				

Table B-7 Field-Lab Comparison, Supplier No. 2, Schweyer Rheometer Constant (C), G-tube

MIXTURE	LAB	4A	2A	403	101
DATA	.44	.52	.54	.37	.88
	.41	1.00	.42	.63	.80
$\bar{X}$	.43	.76	.48	.50	.84
s	.03	.43	.11	.23	.07
CV	6.3	56.0	22.2	46.1	8.4

Table B-8 One-Way ANOVA Summary, Schweyer Rheometer Constant (C), G-tube

Source	df	SS	MS	F	F.05	F.01
Mixture	4	.2764	.0691	2.16	5.19	11.4
Error	5	.1600	.0320			
Total	9	.4364				

Table B-9 Field-Lab Comparison, Supplier No. 1, 0% Diluent, Schweyer Rheometer Constant (C), F-tube

MIXTURE	8NC	L-0	L-1	L-4	L-24	L-168
DATA	.90	.20	.95	1.2	1.0	.28
	1.10	.85	.98	.86	.72	.72
$\bar{X}$	1.00	.53	.97	1.03	.86	.50
s	.18	.58	.03	.30	.25	.39
cv	17.7	109.7	2.8	29.3	28.9	78.0

Table B-10 One-Way ANOVA Summary, 0% Diluent, Schweyer Rheometer Constant (C), F-tube

Source	df	SS	MS	F	F.05	F.01
Mixture	5	.577	.115	1.63	4.39	8.75
Error	6	.426	.071			
Total	11	1.002				

Table B-11 Field-Lab Comparison, Supplier No. 1, 4% Diluent, Schweyer Rheometer Constant (C), F-tube

MIXTURE	3A	L-0	L-1	L-4	L-24	L-168
DATA	.61	.69	.84	.91	.86	.94
	.45	.96	.95	1.0	.94	.72
$\bar{X}$	.530	.825	.895	.955	.9000	.8300
s	.14	.24	.10	.08	.07	.19
CV	26.75	29.00	10.89	8.35	7.88	23.48

Table B-12 One-Way ANOVA Summary, 4% Diluent, Schweyer Rheometer Constant (C), F-tube

Source	df	SS	MS	F	F.05	F.01
Mixture	5	.23	.05	3.17	4.39	8.75
Error	6	.09	.01			
Total	11	.32				

Table B-13 Field-Lab Comparison, Supplier No. 2, Schweyer Rheometer Constant (C), F-tube

MIXTURE	LAB	4A	2A	403	101
DATA	.90	.89	1.60	.93	1.50
	1.7	1.00	1.00	.94	.80
$\bar{X}$	1.30	.95	1.30	.94	1.15
s	.71	.10	.53	.01	.62
CV	54.5	10.3	40.9	1.0	53.9

Table B-14 One-Way ANOVA Summary, Schweyer Rheometer Constant (C), F-tube

Source	df	SS	MS	F	$F_{.05}$	$F_{.01}$
Mixture	4	.261	.065	.43	5.19	11.4
Error	5	.751	.150			
Total	9	1.012				

Table B-15 Field-Lab Comparison, Supplier No. 1, 0% Diluent, $\eta_{0.05}$, 10^6 Pa-s, G-tube

	MIXTURE: 8NC	L-0	L-1	L-4	L-24	L-168
DATA	12	5.0	15.0	45.0	77.0	12.0
	18	13.0	69.0	64.0	30.0	47.0
$\bar{X}$	15.0	9.0	42.0	54.5	53.5	29.5
s	5.3	7.1	47.8	16.8	41.6	31.0
CV	35.4	78.8	113.9	30.9	77.8	105.1

Table B-16 One-Way ANOVA Summary, 0% Diluent, $\eta_{0.05}$, 10^6 Pa-s, G-tube

Source	df	SS	MS	F	F.05	F.01
Mixture	5	3741.4	748.3	1.32	4.39	8.75
Error	6	3405.5	567.6			
Total	11	7146.9				

Table B-17 Field-Lab Comparison, Supplier No. 1, 4% Diluent, $\eta_{0.05}$, 10^6 Pa-s, G-tube

MIXTURE	3A	L-0	L-1	L-4	L-24	L-168
DATA	1.5	15.0	16.0	4.9	8.7	4.90
	3.0	14.0	2.8	11.0	15.0	22.0
$\bar{X}$	2.3	14.5	9.4	8.0	11.9	35.5
s	1.3	.9	11.7	5.4	5.6	23.9
CV	59.1	6.1	124.4	68.0	47.1	67.4

Table B-18 One-Way ANOVA Summary, 4% Diluent, $\eta_{0.05}$, 10^6 Pa-s, G-tube

Source	df	SS	MS	F	F.05	F.01
Mixture	5	1323.73	264.75	3.23	4.39	8.75
Error	6	491.70	81.95			
Total	11	1815.42				

Table B-19 Field-Lab Comparison, Supplier No. 2, $\eta_{0.05}$, 10^6 Pa-s, G-tube

MIXTURE	LAB	4A	2A	403	101
DATA	34	21	19	7	270
	21	110	7.2	22	420
$\bar{X}$	27.5	65.5	13.1	14.5	345
s	11.5	78.9	10.5	12.9	132.9
CV	41.9	120.4	79.8	88.0	38.5

Table B-20 One-Way ANOVA Summary, $\eta_{0.05}$, 10^6 Pa-s, G-tube

Source	df	SS	MS	F	F.05	F.01
Mixture	4	162193	40548	13.10	5.19	11.4
Error	5	15477	3095			
Total	9	177670				

Table B-21 Field-Lab Comparison, Supplier No. 1, 0% Diluent, $\eta_{0.05}$, 10^6 Pa-s, F-tube

MIXTURE	8NC	L-0	L-1	L-4	L-24	L-168
DATA	16	3.7	240	540	430	43
	170	130	140	300	120	210
$\bar{X}$	93	66.9	190	420	275	126
s	136.4	111.9	88.6	212.6	274.7	148.0
cv	146.7	167.4	46.6	50.6	99.9	117.0

Table B-22 One-Way ANOVA Summary, 0% Diluent, $\eta_{0.05}$, 10^6 Pa-s, F-tube

Source	df	SS	MS	F	F.05	F.01
Mixture	5	177137	35427	1.84	4.39	8.75
Error	6	115628	19271			
Total	11	292765				

Table B-23 Field-Lab Comparison, Supplier No. 1, 4% Diluent, $\eta_{0.05}$, 10^6 Pa-s, F-tube

MIXTURE	3A	L-0	L-1	L-4	L-24	L-168
DATA	2.0	21	14	14	16	200
	1.7	21	29	24	18	68
$\bar{X}$	1.9	21.0	21.5	19.0	17.0	134
s	.3	.0	13.3	8.9	1.8	116.9
CV	14.4	0.0	61.8	46.6	10.4	87.3

Table B-24 Log $\eta_{0.05}$, F-tube

MIXTURE	3A	L-0	L-1	L-4	L-24	L-168
DATA	.3010	1.3222	1.1461	1.1461	1.2041	2.3010
	.2304	1.3222	1.4624	1.3802	1.2553	1.8325
$\bar{X}$	.2657	1.3222	1.3043	1.2632	1.2297	2.0668
s	.0626	0.0	.2802	.2074	.0454	.4151
CV	23.5	0.0	21.5	16.4	3.7	20.1

Table B-25 One-Way ANOVA Summary, 4% Diluent, $\eta_{0.05}$, 10^6 Pa-s, F-tube

Source	df	SS	MS	F	F.05	F.01
Mixture	5	3.289	.658	20.66	4.39	8.75
Error	6	0.191	.032			
Total	11	3.480				

Table B-26 Field-Lab Comparison, Supplier No. 2, $\eta_{0.05}$, 10^6 Pa-s, F-tube

MIXTURE	LAB	4A	2A	403	101
DATA	370	190	800	150	4600
	2700	260	120	170	540
$\bar{X}$	1535	225	460	160	2570
s	2064	62.0	602.5	17.7	3597.2
CV	134.5	27.6	131.0	11.1	140.0

Table B-27 One-Way ANOVA Summary, $\eta_{0.05}$, 10^6 Pa-s, F-tube

Source	df	SS	MS	F	F.05	F.01
Mixture	4	8.70-E06	2.17-E06	.97	5.19	11.4
Error	5	1.12-E07	2.24-E06			
Total	9	1.99-E07				

Table B-28 Field-Lab Comparison, Supplier No. 1, 0% Diluent, Engineering Stress at Failure, psi

	MIXTURE 8NC	L-0	L-1	L-4	L-24	L-168
DATA	65.0	125.5	133.1	129.3	120.9	138.1
	67.6	170.9	102.7	126.2	119.4	155.9
$\bar{X}$	66.3	148.2	117.9	127.8	120.2	147.0
s	2.3	40.2	26.9	2.7	1.3	15.7
CV	3.5	27.1	22.8	2.2	1.1	10.7

Table B-29 One-Way ANOVA Summary, 0% Diluent, Engineering Stress at Failure, psi

Source	df	SS	MS	F	F.05	F.01
Mixture	5	8927.1	1785.4	6.45	4.39	8.75
Error	6	1660.4	276.7			
Total	11	10587.5				

Table B-30 Field-Lab Comparison, Supplier No. 1, 4% Diluent, Engineering Stress at Failure, psi

	MIXTURE 3A	L-0	L-1	L-4	L-24	L-168
DATA	5.1	36.0	42.3	39.9	29.9	81.2
	10.4	24.6	29.2	38.7	44.5	99.8
$\bar{X}$	7.8	30.3	35.8	34.3	37.2	90.5
s	4.7	10.1	11.6	1.1	12.9	16.5
CV	60.6	33.3	32.5	2.7	34.8	18.2

Table B-31 One-Way ANOVA Summary, 4% Diluent, Engineering Stress at Failure, psi

Source	df	SS	MS	F	F.05	F.01
Mixture	5	7421.4	1484.3	20.01	4.39	8.75
Error	6	445.1	74.2			
Total	11	7866.5				

Table B-32 Field-Lab Comparison, Supplier No. 2, Engineering Stress at Failure, psi

MIXTURE	LAB	4A	2A	403	101
DATA	116.8	47.8	32.6	41.9	13.5
	120.0	89.9	19.8	41.6	11.4
$\bar{X}$	118.4	68.9	26.2	41.8	12.5
s	2.8	37.3	11.3	.3	1.9
CV	2.4	54.2	43.3	.6	14.9

Table B-33 One-Way ANOVA Summary, Engineering Stress at Failure, psi

Source	df	SS	MS	F	F.05	F.01
Mixture	4	14032	3508	17.98	5.19	11.4
Error	5	975	195			
Total	9	15007				

Table B-34 Field-Lab Comparison, Supplier No. 1, 0% Diluent, Engineering Strain at Failure, mm/mm

	MIXTURE: 8NC	L-0	L-1	L-4	L-24	L-168
DATA	4.83	2.96	3.91	3.85	3.64	3.54
	4.63	3.31	2.56	3.35	3.91	3.26
$\bar{X}$	4.73	3.14	3.23	3.60	3.78	3.40
s	.18	.31	1.2	.44	.24	.25
CV	3.8	9.9	36.9	12.3	6.3	7.3

Table B-35 One-Way ANOVA Summary, 0% Diluent, Engineering Strain at Failure, mm/mm

Source	df	SS	MS	F	F.05	F.01
Mixture	5	3.369	.674	3.39	4.39	8.75
Error	6	1.193	.199			
Total	11	4.562				

Table B-36 Field-Lab Comparison, Supplier No. 1, 4% Diluent, Engineering Strain at Failure, mm/mm

MIXTURE	3A	L-0	L-1	L-4	L-24	L-168
DATA	6.75	3.27	3.23	3.06	4.08	3.70
	5.75	3.25	3.21	3.68	3.32	3.49
$\bar{X}$	6.3	3.3	3.2	3.4	3.7	3.6
s	.9	.02	.02	.6	.7	.2
CV	14.2	.5	.6	16.3	18.2	5.2

Table B-37 One-Way ANOVA Summary, 4% Diluent, Engineering Strain at Failure, mm/mm

Source	df	SS	MS	F	F.05	F.01
Mixture	5	13.62	2.72	16.28	4.39	8.75
Error	6	1.0	0.17			
Total	11	14.62				

Table B-38 Field-Lab Comparison, Supplier No. 2, Engineering Strain at Failure, mm/mm

MIXTURE	LAB	4A	2A	403	101
DATA	7.49	9.66	12.14	10.31	12.56
	7.69	8.75	14.50	10.96	14.04
$\bar{X}$	7.59	9.21	13.32	10.64	13.30
s	.18	.81	2.09	.58	1.31
CV	2.3	8.8	15.7	5.4	9.9

Table B-39 One-Way ANOVA Summary, Engineering Strain at Failure, mm/mm

Source	df	SS	MS	F	$F_{.05}$	$F_{.01}$
Mixture	4	50.95	12.74	14.07	5.19	11.4
Error	5	4.53	.91			
Total	9	55.48				

Table B-40 Field-Lab Comparison, Supplier No. 1, 0% Diluent, True Stress at Failure, psi

MIXTURE	8NC	L-0	L-1	L-4	L-24	L-168
DATA	351.4	499.6	652.8	628.1	564.2	626.9
	404.0	736.1	373.5	549.5	582.6	664.4
$\bar{X}$	377.7	617.9	513.1	588.8	573.4	645.7
s	46.6	209.5	247.4	69.7	16.2	33.2
CV	12.3	33.9	48.2	11.8	2.8	5.2

Table B-41 One-Way ANOVA Summary, 0% Diluent, True Stress at Failure, psi

Source	df	SS	MS	F	F.05	F.01
Mixture	5	93610.2	18722.0	1.55	4.39	8.75
Error	6	72315.1	12052.5			
Total	11	165925.3				

Table B-42 Field-Lab Comparison, Supplier No. 1, 4 % Diluent, True Stress at Failure, psi

MIXTURE	3A	L-0	L-1	L-4	L-24	L-168
DATA	35.1	149.3	178.8	162.3	151.4	382.3
	77.2	104.7	123.7	182.1	192.6	451.0
$\bar{X}$	56.2	126.9	151.3	172.2	172.0	416.7
s	37.3	39.7	48.8	17.5	36.5	60.9
CV	66.4	31.3	32.3	10.2	21.2	14.6

Table B-43 One-Way ANOVA Summary, 4% Diluent, True Stress at Failure, psi

Source	df	SS	MS	F	F.05	F.01
Mixture	5	150127.37	30025.47	26.48	4.39	8.75
Error	6	6803.38	1133.90			
Total	11	156930.75				

Table B-44 Field-Lab Comparison, Supplier No. 2, True Stress at Failure, psi

	MIXTURE: LAB	4A	2A	403	101
DATA	991.6	500.9	410.0	448.7	182.8
	1041.0	882.4	297.1	476.0	165.4
$\bar{X}$	1016.3	691.7	354.0	462.4	174.1
s	43.8	338.0	101.0	24.2	15.4
CV	4.3	48.9	28.5	5.2	8.9

Table B-45 One-Way ANOVA Summary, True Stress at Failure, psi

Source	df	SS	MS	F	F.05	F.01
Mixture	4	8.49-E05	2.12-E05	13.12	5.19	11.4
Error	5	8.09-E04	1.62-E04			
Total	9	9.30-E05				

Table B-46 Field-Lab Comparison, Supplier No. 1, 0% Diluent, True Strain at Failure, mm/mm

	MIXTURE 8NC	L-0	L-1	L-4	L-24	L-168
DATA	1.75	1.37	1.59	1.58	1.54	1.51
	1.73	1.46	1.26	1.47	1.57	1.45
$\bar{X}$	1.74	1.42	1.43	1.52	1.55	1.48
s	.02	.08	.29	.09	.03	.06
CV	1.0	5.4	20.3	6.2	1.7	3.8

Table B-47 One-Way ANOVA Summary, 0% Diluent, True Strain at Failure, mm/mm

Source	df	SS	MS	F	F.05	F.01
Mixture	5	.142	.028	2.55	4.39	8.75
Error	6	.067	.011			
Total	11	.209				

Table B-48 Field-Lab Comparison, Supplier No. 1, 4% Diluent, True Strain at Failure, mm/mm

	MIXTURE 3A	L-0	L-1	L-4	L-24	L-168
DATA	2.05	1.41	1.44	1.40	1.62	1.55
	1.91	1.45	1.93	1.54	1.47	1.50
$\bar{X}$	1.98	1.43	1.44	1.47	1.55	1.53
s	.10	.03	.01	.10	.11	.04
CV	6.3	6.3	.6	8.4	8.6	2.9

Table B-49 One-Way ANOVA Summary, 4% Diluent, True Strain at Failure, mm/mm

Source	df	SS	MS	F	F.05	F.01
Mixture	5	.44	.088	15.91	4.39	8.75
Error	6	.03	.006			
Total	11	.47				

Table B-50 Field-Lab Comparison, Supplier No. 2, True Strain at Failure, mm/mm

	MIXTURE: LAB	4A	2A	403	101
DATA	2.140	2.36	2.59	2.43	2.60
	2.157	2.27	2.74	2.48	2.71
$\bar{X}$	2.149	2.32	2.67	2.46	2.66
s	.015	.08	.13	.04	.10
CV	.7	3.4	5.0	1.8	3.7

Table B-51 One-Way ANOVA Summary, True Strain at Failure, mm/mm

Source	df	SS	MS	F	$F_{.05}$	$F_{.01}$
Mixture	4	.395	.099	21.70	5.19	11.4
Error	5	.023	.005			
Total	9	.417				

Table B-52 Field-Lab Comparison, Supplier No. 1
0% Diluent, Engineering Creep
Compliance at Failure, psi^{-1}

MIXTURE	8NC	L-0	L-1	L-4	L-24	L-168
DATA	.0743	.0235	.0295	.0299	.0301	.0256
	.0686	.0194	.0252	.0266	.0333	.0209
$\bar{X}$	.0715	.0215	.0274	.0283	.0317	.0233
s	.0051	.0036	.0038	.0029	.0028	.0042
CV	7.1	16.9	13.9	10.4	8.9	17.9

Table B-53 One-Way ANOVA Summary,
0% Diluent, Engineering Creep
Compliance at Failure, psi^{-1}

Source	df	SS	MS	F	F.05	F.01
Mixture	5	.00352	.00070	76.02	4.39	8.75
Error	6	.000156	.000014			
Total	11	.00357				

Table B-54 Field-Lab Comparison, Supplier No. 1, 4% Diluent, Engineering Creep Compliance at Failure, psi^{-1}

MIXTURE		3A	L-0	L-1	L-4	L-24	L-168
DATA		1.3806	.0976	.0780	.0768	.1372	.0457
		.5952	.1320	.1109	.0952	.0749	.0353
	$\bar{X}$	.9879	.1148	.0945	.0860	.1061	.0405
	s	.6959	.0305	.0291	.0163	.0552	.0092
	cv	70.4	26.5	30.8	18.9	52.0	22.7

Table B-55 Log Engineering Creep Compliance at Failure

MIXTURE		3A	L-0	L-1	L-4	L-24	L-168
DATA		1.1750	.3125	.2793	.2771	.3704	.2138
		.7715	.3633	.3330	.3085	.2737	.1879
	$\bar{X}$	.9733	.3379	.3062	.2928	.3221	.2009
	s	.3575	.0451	.0476	.0278	.0857	.0229
	cv	36.7	13.3	15.5	9.5	26.6	11.4

Table B-56 One-Way ANOVA Summary, 4% Diluent, Engineering Creep Compliance at Failure, psi^{-1}

Source	df	SS	MS	F	$F_{.05}$	$F_{.01}$
Mixture	5	.797	.159	10.66	4.39	8.75
Error	6	.090	.015			
Total	11	.886				

Table B-57 Field-Lab Comparison, Supplier No. 2, Engineering Creep Compliance at Failure, psi^{-1}

	MIXTURE				
	LAB	4A	2A	403	101
DATA	.0643	.2057	.3974	.2496	1.1122
	.0692	.0977	.7459	.2661	1.2473
$\bar{X}$	.0643	.1517	.5717	.2579	1.1798
s	.0001	.0957	.3088	.0146	.1197
CV	.1	63.1	54.0	5.7	10.1

Table B-58 One-Way ANOVA Summary, Engineering Creep Compliance at Failure, psi^{-1}

Source	df	SS	MS	F	F.05	F.01
Mixture	4	1.644	.411	27.10	5.19	11.4
Error	5	.076	.015			
Total	9	1.720				

Table B-59 Field-Lab Comparison, Supplier No. 1, 0% Diluent, True Creep Compliance at Failure, psi^{-1}

MIXTURE	8NC	L-0	L-1	L-4	L-24	L-168
DATA	.0053	.0028	.0025	.0025	.0027	.0024
	.0043	.0020	.0036	.0027	.0027	.0024
$\bar{X}$	.0048	.0024	.0030	.0026	.0027	.0024
s	.0009	.0007	.0010	.0001	0	0
CV	18.5	30.4	34.2	5.0	0	0

Table B-60 One-Way ANOVA Summary, 0% Diluent, True Creep Compliance at Failure, psi^{-1}

Source	df	SS	MS	F	F.05	F.01
Mixture	5	.0000084	.0000017	7.00	4.39	8.75
Error	6	.0000014	.00000024			
Total	11	.0000099				

Table B-61 Field-Lab Comparison, Supplier No. 1, 4% Diluent, True Creep Compliance at Failure, psi^{-1}

	MIXTURE 3A	L-0	L-1	L-4	L-24	L-168
DATA	.0611	.0096	.0082	.0087	.0107	.0040
	.0254	.0139	.0119	.0086	.0076	.0034
$\bar{X}$	.0433	.0118	.0101	.0087	.0092	.0037
s	.0316	.0038	.0033	.0001	.0027	.0005
CV	73.1334	22.4238	32.6189	1.0243	30.0175	14.2676

Table B-62 One-Way ANOVA Summary, 4% Diluent, True Creep Compliance at Failure, psi^{-1}

Source	df	SS	MS	F	F.05	F.01
Mixture	5	.0021	.0004	3.77	4.39	8.75
Error	6	.0007	.0001			
Total	11	.0027				

Table B-63 Field-Lab Comparison, Supplier No. 2, True Creep Compliance at Failure, psi^{-1}

	MIXTURE LAB	4A	2A	403	101
DATA	.00215	.0047	.0072	.0055	.0150
	.00208	.0028	.0094	.0052	.0167
$\bar{X}$	.0021	.0038	.0083	.0054	.0159
s	.0001	.0017	.0019	.0003	.0015
CV	2.9	44.9	23.5	5.0	9.5

Table B-64 One-Way ANOVA Summary, True Creep Compliance at Failure, psi^{-1}

Source	df	SS	MS	F	$F_{.05}$	$F_{.01}$
Mixture	4	.00023	.000059	51.22	5.19	11.4
Error	5	.00006	.000001			
Total	9	.00024				

Table B-65 Field-Lab Comparison, Supplier No. 1, 0% Diluent, Ring and Ball Softening Point, ^{o}C

MIXTURE	8NC	L-0	L-1	L-4	L-24	L-168
DATA	74.4	91.0	69.0	71.5	71.0	76.5
	71.1	79.8	71.3	70.0	73.8	78.8
$\bar{X}$	72.8	85.4	70.1	70.8	72.4	77.6
s	2.9	10.0	2.0	1.3	2.4	2.0
CV	4.0	11.7	2.8	1.9	3.4	2.6

Table B-66 One-Way ANOVA Summary, 0% Diluent, Ring and Ball Softening Point, ^{o}C

Source	df	SS	MS	F	$F_{.05}$	$F_{.01}$
Mixture	5	336.91	67.38	5.15	4.39	8.75
Error	6	78.50	13.08			
Total	11	415.41				

Table B-67 Field-Lab Comparison, Supplier No. 1, 4% Diluent, Ring and Ball Softening Point, °C

MIXTURE	3A	L-0	L-1	L-4	L-24	L-168
DATA	49.0	68.0	57.5	69.0	64.8	70.3
	53.5	61.0	58.3	68.8	67.3	68.5
$\bar{X}$	51.3	64.5	57.9	68.9	66.1	69.4
s	4.0	6.2	.7	.2	2.2	1.6
CV	7.8	9.6	1.2	.3	3.4	2.3

Table B-68 One-Way ANOVA Summary, 4% Diluent, Ring and Ball Softening Point, °C

Source	df	SS	MS	F	F.05	F.01
Mixture	5	502.8	100.6	15.19	4.39	8.75
Error	6	39.7	6.6			
Total	11	542.5				