

**QUALITY CONTROL FOR  
ASPHALT RUBBER BINDERS AND MIXES**

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## **ABSTRACT**

As the use of asphalt rubber binders in hot mix asphalt (HMA) and chip seals gains wider acceptance, it becomes imperative that the quality control testing programs become formalized and uniform throughout the industry. Even one failure attributed to the asphalt rubber binder can set the industry back substantially.

Asphalt rubber (AR) binder is designed to meet a given agency specification and the results of the design are generally furnished to the agency. AR is presently controlled in the field using viscosity tests, unlike other binders which are certified by the supplier.

This report summarizes the current practices used for quality control (QC) and quality assurance (QA) of asphalt rubber binders and mixes. Suggestions for improvements to the existing process have been identified. The report is intended to provide guidelines for new and/or existing producers of asphalt rubber binders to produce more uniform binders and to identify those factors which need to be closely monitored.

## **KEY WORDS**

asphalt cement, crumb rubber modifier, asphalt rubber, binder properties, quality control, quality assurance

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## **DISCLAIMER**

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# TABLE OF CONTENTS

	<u>Page</u>
1.0 Introduction .....	1
1.1 Background.....	1
1.2 Objectives .....	2
1.3 Study Approach .....	2
2.0 Quality Control Procedures for AR Binder Ingredients .....	3
2.1 Virgin Asphalt.....	3
2.1.1 Sampling and Testing of the Asphalt.....	3
2.1.2 Sources of Asphalt Used.....	3
2.1.3 Agency Testing.....	7
2.2 Crumb Rubber Modifier (CRM).....	7
2.2.1 Sampling and Testing the CRM.....	7
2.2.2 Agency Testing.....	11
2.3 Discussion.....	11
3.0 Binder Design .....	12
3.1 General Design Considerations.....	12
3.1.1. Pumping Consistency for Placement .....	12
3.1.2. High In-Use Temperature Stiffness .....	12
3.1.3 Moderate Temperature Consistency .....	13
3.1.4 Elastic Characteristics.....	13
3.1.5 Elongation Properties.....	13
3.1.6 Low Temperature Stiffness or Fracture Characteristics .....	14
3.2 Factors Which Influence AR Properties .....	14
3.2.1 Asphalt Cement.....	14
3.2.2 Crumb Rubber Modifier .....	15
3.2.3 Contaminants .....	16
3.2.4 Mixing Conditions .....	16
3.2.5 Time and Temperature.....	16
3.2.6 Extender Oil Additives .....	17

3.3	Binder Design Process Currently in Use .....	17
3.4	Discussion.....	23
4.0	QC Procedures for AR Binders and Mixes.....	24
4.1	Current Procedures Used for AR Binders.....	24
4.2	Ranking of Important Binder Factors .....	26
4.3	Important Factors for Mixes .....	29
4.4	QC Tests for AR Mixtures.....	29
4.5	Discussion.....	29
5.0	Recommendations for Industry Standards for QC/QA.....	32
5.1	Quality Control .....	32
5.2	Quality Assurance.....	34
6.0	Implementation Plan.....	35
6.1	Quality Control Procedures for AR Producers .....	35
6.2	Quality Control/Quality Assurance Specifications for Public Agencies .....	35
7.0	References .....	36

## Appendices

- A Interview Survey Forms for RPA User and Producer Members
- B List of Interviewees
- C Results of Interviews – User Members
- D Results of Survey – Producer Members

## LIST OF TABLES

<u>Table</u>	<u>Page</u>
2.1 QC/QA Procedures for Virgin Asphalt.....	4
2.2 QC/QA Procedures for Crumb Rubber Modifier.....	8
3.1 Procedures Used to Design AR Binders and Relate AR Binder Properties to Performance .....	18
3.2 Typical Design Profile of Type I Asphalt-Rubber Binder.....	20
3.3 Typical Design Profile of f Type II Asphalt-Rubber Binder .....	21
4.1 QC/QA Procedures Used in Production of AR Binders .....	25
4.2 Ranking of Important Factors – AR Binders .....	28
4.3 Important AR Mix Performance Factors .....	30
5.1 Recommended QC Guidelines for Ingredients.....	33
5.2 Recommended QC Guidelines for AR Binder.....	33
5.3 Recommended QC Guidelines for AR Mixtures.....	33

## LIST OF FIGURES

<u>Figure</u>	<u>Page</u>
2.1 Typical Certificate of Compliance – Paramount .....	5
2.2 Typical Certificate of Compliance – Navajo Western .....	6
2.3 Typical Certificate of Compliance – PolyTek Southwest.....	9
2.4 Typical Certificate of Compliance – BAS .....	10
4.1 Statistical Summary of AR Binder Properties .....	27

# 1.0 INTRODUCTION

## 1.1 Background

As the use of asphalt rubber binders in hot mix asphalt (HMA) and chip seals (CS) gains wider acceptance, it becomes imperative that the quality control testing programs become formalized and uniform throughout the industry. Even one failure attributed to the asphalt rubber binder can impact the industry greatly.

There is no guarantee that current procedures will result in consistent binders as time and temperature of reaction can easily affect the properties of the binder produced. Furthermore, the base asphalt and the crumb rubber modifier (CRM), and their uniformity can also produce binders with varying properties. To monitor the quality of the asphalt rubber binders, the asphalt rubber industry uses several tests to evaluate the asphalt rubber binders including (Chehovits, 1993):

- 1) Viscosity,
- 2) Cone penetration,
- 3) Resilience, and
- 4) Softening point

Descriptions of these tests can be found in ASTM D-3407. These tests have been used since the 1970s to evaluate the properties of asphalt rubber binders (Chehovits, 1993; Epps, 1994).

Questions which need to be addressed in this study include the following:

- 1) Do these tests ensure that the properties of the asphalt rubber binder on the pavement will be consistent and result in good performance?
- 2) Does time and temperature after measuring these properties vary such that there can be vast differences in binder properties?
- 3) Asphalt source can impact the reaction between the base asphalt and crumb rubber modifier. What steps are needed to ensure a more uniform source (or stream) of asphalt?
- 4) CRM source and uniformity can also affect the properties of the AR binder. What steps are needed to ensure a more uniform stream of CRM?
- 5) What is the optimum frequency of testing needed to ensure a uniform product?

## **1.2 Objectives**

The objectives of this study are two-fold, as follows:

- 1) Document the current procedures used by industry to control the quality of the asphalt rubber binder
- 2) Develop an industry standard (or guideline) to ensure that the asphalt rubber properties are consistent from batch to batch and from contractor to contractor.

## **1.3 Study Approach**

Several steps should be taken to develop better and more uniform quality control procedures for asphalt rubber binders. As a minimum, the following should be undertaken:

- 1) Collect existing QC procedures for asphalt rubber binders through interviews with selected producers (Appendix A contains the survey instruments used to collect the necessary information for the study; Appendix B includes a list of those surveyed),
- 2) Summarize the information collected during the survey (see Appendices C and D),
- 3) Identify shortcomings of the QC procedures currently in use, and
- 4) Identify new or improved QC procedures which are needed to ensure uniform and quality binders, including the identification of the AR properties which most influence pavement performance.

The end result of this study would be an industry-wide plan to ensure that AR binders are of high quality and uniform.

## **2.0 QUALITY CONTROL PROCEDURES FOR AR BINDER INGREDIENTS**

Both asphalt and/or CRM source can effect the properties of the resulting asphalt rubber (AR) binder. This section of the report summarizes the current procedures used to monitor the uniformity of the ingredients used in producing AR binders.

### **2.1 Virgin Asphalt**

A number of questions were asked of the AR binder producers regarding the QC/QA procedures they use for the virgin asphalt. The responses are provided in Table 2.1. Following is a brief discussion of the responses.

#### **2.1.1 Sampling and Testing of the Asphalt**

Most asphalt rubber producers or blenders sample from the asphalt supplier's transport when unloaded at the hot mix asphalt contractor's production facility. Some asphalt rubber producers sample the base asphalt from the hot mix asphalt contractor's storage tank. If the base asphalt is sampled and then subjected to additional heating, the properties could easily be altered due to the added heat.

Most of the asphalt rubber producers take a 1 gallon sample of base asphalt daily for themselves and the agency. The temperature and the time of sampling varies even within a state, but the temperatures are higher in California than in other states (see Table 2.1).

All of the AR binder producers rely on the supplier certification sheet to define the properties of the base asphalt. Typical certification sheets for Arizona and California are given in Figures 2.1 and 2.2.

#### **2.1.2 Sources of Asphalt Used**

Most asphalt rubber producers generally use a base asphalt binder from one to three asphalt suppliers per year. Some use only one supplier of base asphalt. Most asphalt binders can be used to successfully produce AR. Some base asphalts will require higher contents of CRM to meet the AR binder specifications. Only a few asphalt binder sources have been found to not react with the CRM. These sources seem to be widely known among the producers of AR binders.

Table 2.1. QC/QA Procedures for Virgin Asphalt

Question	Arizona			California					Others	
	FNF	ISS	Meadow Valley	FNF	Granite	Silvia	MAI	WSS	All States	Cox Paving
a) Where do you sample the asphalt?	From transport truck	From transport truck	From transport truck	From transport truck	From transport truck	From transport truck	From transport truck	From producer's heated tank	From producer's heated tank	From transport truck and/or producer's tank
b) How often do you <ul style="list-style-type: none"> <li>sample the asphalt?</li> <li>test the asphalt?</li> </ul>	Daily As needed	Daily —	Daily —	Daily As needed	Daily —	Each load	Daily	Weekly	Weekly	Weekly
c) What is the asphalt temperature (°F) at time of sampling? <ul style="list-style-type: none"> <li>average</li> <li>min</li> <li>max</li> </ul>	350 335 400	— 290 320	315 300 330	385 375 410	400 375 415	380 350 425	400 385 425	410 390 425	300 275 325	385 360 410
d) What tests are used for QC?	None, rely on certification	None, rely on certification	None, rely on certification	None, rely on certification	None, rely on certification	None, rely on certification	None, rely on certification	None, rely on certification	None, rely on certification	None, rely on certification
e) How many sources of asphalt do you use/season?	1-3	1-3	> 3	1-3	> 3	1-3	1	1	1-3	1-3
f) Are you able to use all sources?	No	No	Yes	Yes	Yes	Yes	Yes	No	Yes	No
g) Do you use asphalt supplier test results in lieu of your own for QC?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
h) Do you use public agency test results in lieu of your own for QA?	Yes	Yes, only if there are problems	Yes, only if there are problems	Yes	Yes	Yes	Yes	No	No	No

PRODUCT: RUBBER-ASPHALT BASE STOCK	Purchaser _____
CODE N°: 625	Destination _____
DATE: June 21, 1999	Transporter _____
TANK: Tk 20002	Truck or Railcar N° _____
	Bill of Lading N° _____
	Contract N° _____
	Purchase Order N° _____

Meets Specifications: ASTM D3381, Table 3; AASHTO M226, Table 3; PBA-1; PBA-1a; Caltrans 92-102; Section 203-1.2 of 1997 "Greenbook"

CERTIFICATE OF COMPLIANCE

TESTS	ASTM N°	ASHTO N°	SPEC	RESULTS
<b>Tests on Residue from Rolling</b>				
Thin-Film Oven Test:	D2872	T240		
Viscosity, 60°C (140°F), Poise	D2171	T202	3000-5000	4140
Viscosity, 135°C (275°F), cSt	D2170	T201	275 min	416
Penetration, 25°C, 100g, 5s	D5	T49	25 min	39
% of Original Penetration	D5	T49	45 min	66
Ductility, 25°C, 5cm/min, cm	D113	T51	75 min	100+
Loss on Heating, wt %	D2872	T240	- -	.20
Penetration, 4°C, 200g, 60s	D5	T49	- -	12
Absolute Viscosity Ratio, 60°C RTFO Vis./Original Vis.	D2171	T202	4.0 max	2.4
<b>Tests on Original Asphalt:</b>				
Penetration, 25°C, 100g, 5s	D5	T49	- -	59
Flash Point, C.O.C., °F	D92	T48	450 min	30
Solubility in				
Trichloroethylene %	D2042	T44	99.0 min	99.9
Viscosity, 60°C (140°F), Poise	D2171	T202	- -	1730
Viscosity, 135°C (275°F), cSt	D2170	T201	- -	279
Specific Gravity, 77/77°F	D70	T228	- -	1.023
Specific Gravity, 60/60°F	D70	T228	- -	1.024
API Gravity, 60°F	D70	T228	- -	6.7

We hereby certify that the above sample was tested according to the applicable ASTM and AASHTO standards and that it complies with all specifications.

Data Compiled By: _____	Released by: _____
Shift Chemist	Shift Team Leader

Figure 2.1. Typical Certificate of Compliance – Paramount

**Navajo Western Asphalt Company**  
**P.O. Box 2209**  
**Peoria, Arizona 85380**  
**Certificate of Compliance &**  
**Laboratory Analysis Report**  
**Superpave Asphalt Binder**  
**PG 58-22**



Tank Number \_\_\_\_\_ BL Number \_\_\_\_\_  
 Date \_\_\_\_\_ Quantity \_\_\_\_\_

I certify that the material indicated above complies with the specific requirements of AASHTO MP 1.

\_\_\_\_\_  
Navajo Western Asphalt Co.

**Analysis Report:**

Test	Test Temp, °C	Test Result	Specification
<i>Tests on Original Binder</i>			
Flash Point, ° C	n/a	230+° C	230° C min
Viscosity, Pa·s	135°	0.275 Pa·s	3.0 Pa·s max
Dynamic Shear, G*/sin δ, kPa	58°	1.14 kPa	1.00 kPa min
Strain Sweep	58°	Linear	Linear
<i>Tests on RTFO Residue</i>			
Mass Loss	n/a	0.09 %	1.00 % max
Dynamic Shear, G*/sin δ, kPa	58°	2.93 kPa	2.20 kPa min
<i>Tests on PAV Residue</i>			
Pressure Aging Temperature, °C	110°		
Dynamic Shear, G*/sin δ, kPa	22°	3950 kPa	5000 kPa
Bending Beam Creep Stiffness, MPa	-12°	103 MPa	300 MPa max
Bending Beam Creep Rate, m	-12°	0.315	0.300 min

Figure 2.2. Typical Certificate of Compliance – Navajo Western

### 2.1.3 Agency Testing

The AR binder producers generally provide samples of the virgin asphalt to the public agency for specification QA testing. The agency test results are generally provided to the AR binder producers anywhere from a few days to several weeks after receipt of the sample. If the binder is out of specification, penalties can be imposed.

For the protection of the AR producer, it is always wise to document the time and location where the sample was taken. Some producers will retain samples of the virgin asphalt for up to one year.

## 2.2 Crumb Rubber Modifier (CRM)

Several questions were asked of the AR producers regarding the QC/QA process used for the CRM. The responses are provided in Table 2.2. A brief discussion of all responses is given below.

### 2.2.1 Sampling and Testing the CRM

Most of the producers do not sample the CRM unless there is a problem. They rely on the CRM supplier's certification. Typical testing frequencies used by CRM suppliers are as follows:

<u>Property</u>	<u>Frequency</u>
• Sieve analysis	from every 4000 lbs to twice a day
• Chemical composition (e.g. carbon black, natural rubber content, ash content, and % hydrocarbon	every 500,000 lbs

However, there have been problems reported in California with respect to gradation recently. It is not clear whether this is due to sampling techniques or production methods. Regardless, a good sampling technique for the public agency is still needed.

None of the AR binder producers routinely test the CRM. Only one AR producer reported having any tests performed when they change CRM suppliers. All of the AR producers rely on the certification of the CRM supplier. Samples of certification sheets from selected CRM suppliers are given in Figures 2.3 and 2.4.

Table 2.2. QC/QA Procedures for Crumb Rubber Modifier

Question	Arizona			California					Other	
	FNF	ISS	Meadow Valley	FNF	Granite	Silvia	MAI	WSS	All States	Cox Paving
a) Where do you sample the CRM?	Do not sample normally	From the bag or hopper	Do not sample	Do not sample normally	Do not sample	From the bag or hopper	Do not sample normally	From the hopper	From the bag	From the hopper
b) How often do you sample the CRM?	As needed	As needed or if a new supplier	Do not sample	As Needed	Only if there is a problem	Every truck load	Only if there is a problem	Weekly	When received	Daily
c) Do you perform any QC tests?	No	Yes (gradation, metal, fabric moisture)	No	No	No	No	No	No	Yes, gradation	No
d) Do you use CRM supplier tests in lieu of your own for QC?	Yes, rely on certification	Yes, rely on certification	Yes, rely on certification	Yes	Yes, rely on certification	Yes, rely on certification	Yes	Yes	Yes	Yes
e) Do you use public agency test results in lieu of your own for QA?	Yes	Yes, but varies greatly with agency	Yes	Yes	Yes	Yes, and it has resulted in penalties	Yes	No	No	No



# PolyTek Southwest

A Subsidiary of PolyTek Rubber & Recycling, Inc.

11400 E. Pecos Road  
Queen Creek, Az 85242  
(602) 987-3006  
(602) 987-0965 FAX

-----+  
| CERTIFICATE OF COMPLIANCE |  
-----+

**GRANITE CONSTRUCTION**  
38000 Monroe St.  
Indio, CA 92203

Agency: City of Palm Desert  
Project No: 225802  
P.O.#: N / A  
Contractor: Granite Construction  
Contractor Project Number:  
Attn: **ROSS KASHIWAGI** {760-775-7500}

Lot Number: 916-06  
PROD.DATE: 7-14-99  
TEST DATE: 7-15-99  
TESTED BY: GCG

Customer Code: Mat-16d

Date Shipped: 7-27-99

Released By: GCG

Total Bags Shipped: 1 skid  
**Mat-16 Material complies in all respects with the specific requirements of the cited specifications.**

-----+  
LABORATORY TEST RESULTS FOR ABOVE SPECIFIED LOT:  
-----+

Test	Specification		Test Results
	Min.	Max.	
ASH	-	8.00%	4.30%
MOISTURE	-	.75%	.10%

APPROXIMATE TONS = 22

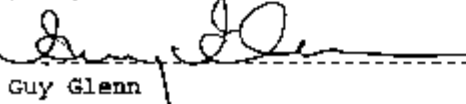
  
-----+  
Guy Glenn DIRECTOR OF Q.A.  
-----+





Figure 2.3. Typical Certificate of Compliance – PolyTek Southwest



1. DATE OF SIEVING 07/06/99
2. DATE OF PRODUCTION 07/06/99
3. TYPE OF RUBBER GR. TRA. 006
4. SIZE OF RUBBER 12 MESH
5. CONDITION OF BLADES    sharp    average    dull
6. WEIGHT OF SAMPLE 105 \_\_\_\_\_ grams
7. GRADATION OF RUBBER:

SIEVE	NO.	HOLDING (grams)	PASSING
	8	_____	_____
"	10	<u>0</u>	<u>100 %</u>
"	12	_____	_____
"	16	<u>49.3</u>	<u>51.3 %</u>
"	20	_____	_____
"	30	<u>87.6</u>	<u>13.4 %</u>
"	40	_____	_____
"	50	<u>97.4</u>	<u>3.8 %</u>
"	100	<u>100.5</u>	<u>0.7 %</u>
"	200	<u>101.2</u>	<u>0 %</u>
"	PAN	<u>104.9</u>	_____

1400 North H Street, San Bernardino, CA 92405 • (909) 383-7050 • Fax: (909) 383-7055

Figure 2.4. Typical Certificate of Compliance – BAS

### **2.2.2 Agency Testing**

All AR binder producers rely on the agency tests for QA. In California this has resulted in penalties due to gradation. However, it has been suggested that the out of specification material is due more to sampling methods used than to variation in the product. This still needs to be confirmed.

## **2.3 Discussion**

The asphalt rubber producers currently rely almost entirely on the QC tests performed by suppliers of virgin asphalt and CRM. They do little or no QA tests on the products used to produce AR binders. Consideration should be given to the development of a QA plan which would include, as a minimum, the factors given below:

- 1) types of tests,
- 2) sampling procedures,
- 3) frequency of testing,
- 4) control limits,
- 5) acceptance limits,
- 6) pay adjustments,
- 7) referee testing,
- 8) retained samples, and
- 9) coping with non-specification materials.

## 3.0 BINDER DESIGN

### 3.1 General Design Considerations

Binder design involves an evaluation of the components of AR (asphalt cement, CRM, and additive) to determine:

- 1) the properties of the blend reacted over a range of time and temperature,
- 2) the stability of the blend over time, and
- 3) the proper proportions of the components to achieve the desired properties.

It must be emphasized that the physical properties of AR binders are substantially different from virgin asphalt cements. For any application that an AR blend will be used, there are several general characteristics of the blend that should be considered for the application. Several types of tests have been used to evaluate these characteristics as discussed in the following sections.

#### 3.1.1 Pumping Consistency for Placement

Pumping consistency at typical placement temperatures (250-400°F) can be monitored using rotational type viscometers such as a Haake hand-held, portable viscometer<sup>1</sup> or a Brookfield viscometer (ASTM D2669). While these tests are being performed, it is important to ensure that the rotating probes are conditioned to the test temperature and that readings are taken at specific intervals because of a tendency with some AR blends for viscosity readings to reduce due to rubber particle migration away from the probe while it is rotating. The viscosity range at placement temperatures for AR blends is mainly affected by the rubber type, content, and degree of rubber swelling, and can vary from 100 to 20,000 centipoise for various applications.

#### 3.1.2 High In-Use Temperature Stiffness

Stiffness can be measured at typical high-range pavement surface temperatures of 120-170°F by several different testing procedures. The Ring and Ball Softening Point (ASTM D36) procedure provides an indication of relative stiffness of materials. A high softening point temperature indicates materials that are more resistant to softening at high temperatures. Ring and Ball Softening Points for AR binders will vary from approximately 110°F to 180°F. Results are mainly influenced by asphalt grade, rubber type and content, and degree of reaction.

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<sup>1</sup>No ASTM standard exists for the Haake Viscometer. It should be correlated to a Brookfield at 350°F ± 5°F over a range of values from 1.5 to 4.5 Pa-s.

Asphalt and CRM blends have also been tested using the Dynamic Shear Rheometer (DSR) to determine characteristics over a wide temperature range. The DSR procedure is used to specify asphalt stiffness at high pavement surface temperatures in the Strategic Highway Research Program's asphalt cement specification. This procedure has been adapted for use with AR, using the cup and plate test configuration, but its use is still under evaluation.

### **3.1.3 Moderate Temperature Consistency (77°F)**

Moderate temperature consistency (77°F) can be evaluated using the standard ASTM D5 penetration test or by using the cone penetration test as specified in ASTM D5329. The standard D5 test with the needle is most appropriate for finer rubber particles (minus 20 mesh) while the cone penetration test is more appropriate with larger rubber particles (10 mesh). Testing has shown that results for the two types of penetration tests (needle using 100 grams for 5 seconds, and cone using 150 grams for 5 seconds) typically agree within approximately 10 percent for tests at 77°F. The addition of CRM to asphalt cement decreases the penetration at 77°F. Typical penetration results range from approximately 30 for high CRM content materials with stiff asphalts to 150 for lower CRM content materials with soft asphalts.

### **3.1.4 Elastic Characteristics**

The elastic characteristics of asphalt and CRM blends can be evaluated using the ASTM D5329 resilience procedure. This procedure indicates the percentage of rebound of the material at 77°F under a 75 gram load after the material is compressed. Typical results for asphalt cement vary from approximately 0 to 5 percent for AC-20 or 30 grades to approximately 50 percent for AC-5. Addition of CRM to asphalt increases resilience up to approximately a value of 40 to 50 percent above the original asphalt result for high CRM contents.

### **3.1.5 Elongation Properties**

The elongation properties of AR have been evaluated using the standard ASTM D113 ductility procedure; however, many feel this test is not a reliable measure of ductile properties due to the particle interference of the CRM within the reduced area of the test specimen. Available results indicate the addition of CRM to asphalt tends to reduce ductility at 77°F, but may increase ductility at low temperatures (Huddleston, 2000). Results at 77°F for higher rubber content blends can vary between approximately 10 and 40 centimeters depending on the CRM type, asphalt physical and chemical characteristics, and degree of reaction. The ductility test can also be performed at lower temperatures to provide an indication of elongation properties at low temperatures.

### 3.1.6 Low Temperature Stiffness or Fracture Characteristics

Low temperature stiffness or fracture characteristics can be measured using several different types of procedures. Types of procedures that can be used include: 1) needle or cone penetration at low temperatures of 32 or 39.2°F (ASTM D5 or D5329), 2) ductility at 39.2°F (ASTM D113), 3) flexibility at a specific low temperature using the ASTM C711 flexibility procedure, or, with modifications, 4) the SHRP bending beam procedure, or 5) the Fraas brittle point procedure. CRM additions to asphalt cement can offer some improvements in low temperature properties. The major manner of improving low temperature properties, however, is to use softer grades of asphalt that offer improved low temperature properties, and then to add CRM to increase the high temperature stiffness to the desired level.

## 3.2 Factors Which Influence Asphalt Rubber Properties

The interaction that occurs between asphalt cement and CRM and the physical properties which result have been shown through many research studies to be dependent on a variety of factors including: 1) asphalt cement physical and chemical properties, 2) CRM physical and chemical properties, 3) reaction time and temperature, 4) mixing conditions, and 5) use of additives. When developing an AR blend for a specific use, the effect of each of these factors needs to be considered to assure that an appropriately functioning material is produced.

### 3.2.1 Asphalt Cement

The physical properties of the asphalt cement influence the properties of AR blends. The stiffness, temperature susceptibility and aging characteristics of the asphalt will affect the high temperature and low temperature performance of the blend. Typical grades of asphalt that are used with CRM for various applications and climate ranges are shown below:

<u>Climate</u>	<u>AC Grade</u>	<u>AR Grade</u>	<u>PG Grade</u>
Cold	AC-5	AR-2000	PG 52-28
Moderate	AC-10	AR-4000	PG 58-22
Hot	AC-20	AR-8000	PG 64-16

Use of stiffer asphalts will produce AR materials that have greater high temperature stiffness than obtained with softer asphalts. However, stiffer asphalts will produce AR materials that are harder at lower temperatures than those AR binders made with softer asphalts.

Chemical properties of the asphalt cement can also influence the characteristics of the AR by affecting reaction of the rubber. Asphalts that have lower levels of components which are absorbed by the rubber can tend to produce AR materials with lower viscosities and lesser degrees of modification of properties.

### 3.2.2 Crumb Rubber Modifier (CRM)

Many of the characteristics of the CRM can influence properties of AR. Previous research has reported on the effects of rubber quantity in the blend and particle size distribution. Additional effects include: 1) CRM surface area, 2) grinding process, 3) CRM chemical composition, and 4) contaminants such as water, fiber, mineral, or metal. Each is discussed below.

- 1) **CRM Quantities**. The amount of CRM added to the asphalt will influence blend properties with higher amounts providing greater changes in properties. Generally speaking, as the rubber content increases: 1) the viscosity of the material at 350°F increases, 2) the resilience increases, 3) the softening point increases, and 4) the cone penetration at 77°F decreases.
- 2) **CRM Particle Size Distribution (Gradation)**. The particle size distribution of the CRM has previously been shown to influence the physical properties of asphalt and CRM blends. Generally, small differences in the particle sizes do not affect blend properties significantly, but large differences in CRM size can produce larger differences. Finer sized CRM materials will generally experience quicker swelling due to their increased surface area and will produce higher viscosities than CRM with larger particle sizes. Additionally, very small particle size CRM will tend to more quickly experience viscosity reduction with storage due to its quicker and more thorough swelling and subsequent depolymerization.
- 3) **CRM Surface Area**. Surface area of the CRM can influence physical properties. In some ways, this is similar to gradation; however, surface area differences can exist even for CRM with similar gradations.
- 4) **CRM Grinding Process**. The CRM production process may influence the physical shape and surface area characteristics of the rubber particles. Additionally, ambient temperature size reduction results in rough shredded particles surfaces, while cryogenic size reduction results in smoother glassy surfaces.
- 5) **CRM Chemical Composition**. Tires are composed of several different types of rubber compounds. The major variations are in the synthetic rubber content, natural rubber content, total rubber hydrocarbon content, and acetone extractables. Ash and carbon black contents are typically similar for different tire rubber compounds. The major CRM compositional effect on AR physical properties is the total rubber hydrocarbon content of the rubber with additional effects from the natural rubber content. When using CRM, it is important to comprehend that tire rubber is typically composed only of about one-half of actual rubber polymer that will swell in the asphalt. The other major ingredients (carbon black, ash, oil) do not swell when added to hot asphalt cement binder. Therefore, the effective rubber hydrocarbon content (the AR rubber content times the rubber hydrocarbon content of the rubber) becomes a factor that should be considered during the AR design process. Additionally, it is important to note that adjustments of the chemical composition made to CRM by

blending with additional CRM with a different composition may not produce the same results in AR blends as an unblended CRM with the same composition.

### **3.2.3 Contaminants**

Various types of contaminants may be present in CRM. Typical contaminants are moisture, tire cord and belt fiber, particulate minerals, and fine metal particles. The effect of moisture in CRM is to cause foaming and swelling of the asphalt when moist CRM is added to the hot asphalt. Foaming causes a volume expansion of the blend just after the CRM is added to the asphalt that can cause production or storage vessels to overflow. Moisture contents of CRM can simply be determined by loss of heating procedures that dry the rubber particles at 230°F until a constant weight is achieved. The presence of even small amounts of moisture in the CRM can cause foaming to occur. Experience has shown that moisture amounts over 1 percent by weight can cause excessive foaming. The amount of foaming which can be tolerated is somewhat dependent on the production equipment, process, and rate of CRM addition. It is suggested that moisture contents be kept at less than 0.75 percent by weight of CRM to minimize foaming.

### **3.2.4 Mixing Conditions**

The intensity of mixing during the interaction time period can influence AR properties. Differences in mixing and shearing intensity can vary from low speed agitation that gently keeps the rubber particles in suspension to high speed shearing that can mechanically break down the rubber particles. With low speed agitation, the asphalt contents are simply absorbed as the rubber particles swell with little dispersion of the rubber polymer into the asphalt. During high intensity mixing, the rubber particles swell and soften due to asphalt absorption, and the high energy mixing tends to shear off the softened rubber outer surfaces and produces a dispersed rubber component in the asphalt phase of the material.

### **3.2.5 Time and Temperature**

The reaction process of rubber particles in asphalt cement is both time and temperature dependent. Higher temperatures result in quicker reaction and may result in greater amounts of swelling. These effects have been well documented in the literature. Typical temperatures that are used with AR materials range from 325 to 400°F. AR materials made with tire derived CRM generally maintain their physical properties for at least 24 hours at temperatures of up to 350°F. At higher temperatures (375 to 400°F), the CRM can begin to depolymerize within three to six hours to such an extent that physical properties are affected.

### 3.2.6 Extender Oil Additives

Various extender oil additives can be added to AR materials to modify the properties of the blend. Extender oil addition tends to soften the asphalt and decrease low temperature stiffness of the blend. Depending on the chemical characteristics of the asphalt, certain extender oil types may be preferentially absorbed by the CRM. Generally, aromatic or naphthenic oils are preferred.

### 3.3 Binder Design Process Currently in Use

The physical properties of an AR mixture depend on the physical and chemical properties of the materials used, the reaction between these materials, and the interaction conditions. Therefore, to obtain desired properties, appropriate materials and interaction conditions which will produce desired properties need to be identified. Specific items which should be addressed are: 1) asphalt cement source and grade, 2) CRM source and gradation, 3) CRM content, 4) interaction conditions of time, temperature, and mixing intensity, and 5) the need for additives, if required. Table 3.1 summarizes the general binder design procedures currently used by the AR producers. The binder design is generally established at a target viscosity for field testing. If the viscosity fluctuates greatly, an additional test for resilience might be warranted to insure the desirable properties are achieved. The concept of a “design profile” (Huddleston, 1999) is a useful tool to aid in determining the frequency of tests in the field. Examples of typical “design profiles” are given in Tables 3.2 and 3.3 for a type I and II AR binder.

Since the characteristics of AR vary depending on heating time and temperature, it is important that the characteristics of the blend be evaluated over a range of heating times and temperatures and mixing intensities that the material will be exposed to during the usage period. In general, it is recommended that the physical characteristics of AR be evaluated using the planned mixture temperature and mixing intensity, and at short, medium and long interaction time periods which would be appropriate for the specific application.

Mixing intensity for lab design operations should be correlated with the actual production unit and usage equipment characteristics. Several types of mixing conditions can be used to attempt to simulate actual conditions. One method consists of simply performing the reaction in a one-gallon, round, open-top can that is placed in a forced-draft oven to maintain the desired temperature. Agitation can consist of intermittent stirring with a spatula or glass rod at specified intervals (typically 30 minutes) during the interaction period. This procedure simulates low speed mixing with gentle agitation with minimal shearing of the rubber particles.

Another procedure consists of using an oil-jacketed, removable-can type melter specified in ASTM D-5167. This device can uniformly control the temperature of the mixture through indirectly heated oil while constantly stirring at 30 rpm. This procedure provides a higher degree and continuous agitation of the mixture during the interaction period and simulates typical crack and joint sealing and other typical field mixing operations.

Table 3.1a. Procedures Used to Design AR Binders and Relate AR Binder Properties to Performance (Arizona)

Question	Producers			Private Laboratories		
	FNF	ISS	Meadow Valley	Law Engineering	Western Technologies	Speedie & Associates
a) Do you perform a binder design?	Yes, use private laboratory	Yes, use private laboratory	Yes, use private laboratory	Yes	Yes	Yes
b) What procedures are used?	Experience and lab protocol	Experience and lab protocol	Experience and lab protocol	Experience and lab protocol	Experience	Experience plus lab protocol
c) What tests are used in the binder design? <ul style="list-style-type: none"> <li>• Viscosity</li> <li>• Resilience</li> <li>• Softening point</li> <li>• Cone (or needle) penetration</li> <li>• Other</li> </ul>	X X X X Ductility	X X X X —	X X X X —	X X X X	X X X X	X X X X Ductility, retained penetration and resilience
d) How often is a binder design performed?	Generally every project	Every project	Every time there is a change in oil or CRM	Every project normally; the exception would be when one binder is used on small jobs within short time frame	Every project or whenever the asphalt or CRM source is changed for small projects	Every project or whenever asphalt type or CRM source is changed
e) Is the binder design performed by <ul style="list-style-type: none"> <li>• an accredited lab?</li> <li>• a certified tech?</li> </ul>	Yes Yes	Yes Yes	Yes Yes	Yes (ARML) Yes (NICET)	Yes (ARML) Yes (NICET)	Yes Yes
f) Does the binder design require the use of an extender oil?	No	No	No	No (AZ) Yes (CA)	Yes (AZ)	Depends on project spec
g) Does the binder design result in good performance?	Yes	Yes	Yes	—	Yes	Yes, 90% of time
h) How are binder properties correlated with field performance?	Occasional field survey	Database on field projects	No problems to date	—	Only respond to problems	Occasional field surveys
i) Is a new binder design procedure needed?	No	No	No	Yes, always room for improvement	No	Yes, standardization of material specific test method

18

Table 3.1b. Procedures Used to Design AR Binders and Relate AR Binder Properties to Performance (Other Agencies)

Question	California Producers				Texas	New England
	Granite	Silvia	MAI	WSS	Cox Paving	All States
a) Do you perform a binder design?	Yes, use private lab when required; otherwise do the design in-house	Yes, use private lab	Yes, use private lab	Yes, use private lab	Yes, use private lab	Yes, do the design in-house
b) What procedures are used?	Laboratory testing protocol	Experience plus lab protocol	Experience	Laboratory testing protocol	Experience plus lab protocol	Laboratory testing protocol
c) What tests are used in the binder design?						
• Viscosity	X	X	X	X	X	X
• Resilience	X	X	X	X	X	X
• Softening point	X	X	X	X	X	X
• Cone (or needle) penetration	X	X	X	X	X	X
• Other	—	—	—	—	—	—
d) How often is a binder design performed?	Before every project	Whenever asphalt source is changed	Whenever asphalt source is changed	Every project	Every project	Whenever asphalt source is changed
e) Is the binder design performed by	Depends on whether done by private lab; Granite lab is not accredited	Yes Yes	Yes Yes	Yes —	Yes Yes	Done in-house, no certification
• an accredited lab?						
• a certified tech?						
f) Does the binder design require the use of an extender oil?	Yes (CA) No (AZ)	Yes	Yes	Yes	No	No
g) Does the binder design result in good performance?	Yes	Yes	Yes	Yes	Yes (90%)	Yes (90%)
h) How are binder properties correlated with field performance?	Occasional field survey and/or response to problems	Occasional field survey; problems only on a few projects	Annual field surveys of all jobs	Occasional field surveys	Annual field survey + respond to problems	Occasional field survey
i) Is a new binder design procedure needed?	No	No	No	No	No	No

Table 3.2. Typical Design Profile of Type I Asphalt-Rubber Binder [21.2% Polytek Southwest WRF-14 Crumb Rubber (Queen Creek, Arizona), by Weight of Asphalt Cement (Navajo Western Asphalt PG 64-16)], Law Engineering and Environmental Services, Phoenix, AZ

a) Properties of AR Binder

Test Performed	Minutes of Reaction					Specified Limits
	60	90	240	360	1440	
Viscosity, Haake at 177°C, Pa-s	2.8	2.8	2.6	2.3	2.1	1.5-4.0
Resilience at 25°C, % Rebound (ASTM D5329)	31		31		30	30 Minimum
Ring & Ball Softening Point, °F (ASTM D36)	146.5	146.0	146.5	144.0	140.0	135 Minimum
Needle Penetration at 4°C, 200 g, 60 sec., 1/10 mm (ASTM D5)	21		22		26	10 Minimum

Note: The asphalt-rubber mixture was held overnight at 135°C and heated back to 177°C for the final 24-hour reaction period.

b) Rubber Gradation, Percent Passing (ARIZ 714)

Sieve Size	Result	Specified Limits
No. 8	100	
No. 10	100	100
No. 16	86	65-100
No. 30	29	20-100
No. 50	10	0-45
No. 200	0.0	0-5

Table 3.3. Typical Design Profile of Type II Asphalt-Rubber Binder [21.9% CRM, Type B ADOT Crumb Rubber (Rancho Dominguez, California), by Weight of Asphalt Cement (Chevron Asphalt PG 58-22)], Law Engineering and Environmental Services, Phoenix, AZ

a) Properties of AR Binder

Test Performed	Minutes of Reaction					Specified Limits
	60	90	240	360	1440	
Viscosity, Haake at 350°F, cP	3600	3200	3400	3400	2900	1500-4000
Resilience at 77°F, % Rebound (ASTM D5329)	43		41		38	25 Minimum
Ring & Ball Softening Point, °F (ASTM D36)	157.5	154.5	155.0	154.5	150.0	130 Minimum
Needle Penetration at 39.2°F, 200 g, 60 sec., 1/10 mm (ASTM D5)	24		24		27	15 Minimum

Note: The asphalt-rubber mixture was held overnight at 275°F and heated back to 350°F for the final 24-hour reaction period.

b) Rubber Gradation, Percent Passing (ARIZ 714)

Sieve Size	Result	Specified Limits
No. 8	100	
No. 10	100	100
No. 16	99	65-100
No. 30	68	20-100
No. 50	18	0-45
No. 200	0.7	0-5

The last procedure consists of using a research device that is termed a “Torque Fork.” This device consists of an adjustable speed electric motor that stirs the asphalt and CRM blend at a constant speed. The device can monitor the electrical current level required to maintain the desired stirring speed as the viscosity of the mixture increases. This type of device has been used with stirrer speeds of 500 to 750 rpm. The mixing vessel size has been approximately 3000 milliliter (0.8 gallons) with sample weights of 1000 grams. The Torque Fork, when operated at speeds of 500 to 750 rpm, imparts a high degree of mixing intensity to the mixture.

Tests which are performed during the design process should be selected to provide an indication of required characteristics of the AR blend. When specifications for the specific application are available, testing required by the specification should be performed as a minimum. For any AR material the testing program for the specific use should be designed to provide the suppliers and users with the following information:

- 1) Placement temperature viscosity
- 2) High in-use temperature stiffness or consistency
- 3) Moderate in-use temperature consistency
- 4) Elastic characteristics
- 5) Elongation properties
- 6) Low in-use temperature consistency
- 7) Variation of properties over typical heating times encountered during use

Once a design blend of asphalt, CRM and additives is verified for the application, along with defined mixing and production times, temperatures and mixing process, the design process may be complete. For some applications such as chip seals and hot mixes, additional performance testing may be required to verify the appropriateness of the designed binder for the application or to determine if additives for improved adhesion are necessary.

The completed design for an AR binder should consist of the following documentation as a minimum:

- 1) Asphalt source, grade, and specification test results
- 2) Rubber source, type and specification test results
- 3) Additive identification, if required
- 4) Percentage blend (by weight) for each ingredient
- 5) Mixing temperature and times considered during the design

- 6) Mixing system used during the design
- 7) Test results for the designed blend at the various mixing times considered in accordance with the desired blend specification requirements
- 8) Additional tests and results used to verify performance in the final application, if required

It is important to realize that since asphalt cement and rubber specifications do not currently address all the factors related to the reaction process and blend characteristics (such as chemical composition, surface area, etc.), that whenever the source of any of the design ingredients change, or there is a change in the composition or properties of the specified asphalt or rubber, that the design should be reverified. This concept is similar to that of hot-mixed, asphalt concrete mix designs in which new designs are required when using different sources of asphalt or aggregate which meet the same specifications due to variations which can occur for materials within the specification limits.

### **3.4 Discussion**

A wide variety of physical properties can be achieved by adding CRM to asphalt cement. Different applications of AR materials require different physical properties, and therefore differing formulations. Factors which must be considered when specifying and designing an AR material for a specific use include:

- Climate conditions and temperature ranges the material will be subjected to
- Ranges of viscosity at placement temperature which are appropriate for the production equipment
- Constraints on CRM particle size for the intended use
- The desired performance level of the AR material in the specific application

Even though a wide variety of performance levels can be achieved by using CRM, there are limits. Performance characteristics of increased high temperature stiffness and reduced low temperature stiffness are achieved by using asphalt cement bases which have appropriate low temperature properties for the intended use, and then adding CRM of the appropriate type and quantity to yield required high temperature and elastic characteristics. The maximum amount of CRM which can be added (and thus the degree of modification of high temperature properties) is dependent on the maximum application temperature viscosity that can be used.

## 4.0 QC PROCEDURES FOR AR BINDERS AND MIXES

Producers were surveyed with regard to the quality control procedures they employ for AR binders as well as mixes. This chapter discusses the procedures used as well as a ranking of the factors to be controlled which are considered most important. It also discusses the need for QA by the agencies.

### 4.1 Current Procedures Used for AR Binders

Table 4.1 summarizes the questions dealing with QC of the AR binders. Each of the responses are discussed in more detail below:

- 1) **Sampling Location**. Most producers sample from the blending/holding tanks or from the feedline from the holding tank to the mixing unit.
- 2) **Sampling and Use Time**. As discussed earlier, time of reaction can greatly affect the binder properties. Since there is variation in the sampling time (due in part to differences in specifications), one would expect the AR properties could vary from producer to producer. However, as long as the AR is within the specification, the resulting product should produce a quality pavement.

On the other hand, there is also some variation in the reaction time before the product is used, varying from as little as 45 to 360 minutes. This large range in time could easily have a major impact on binder properties. AR producers need to assure user agencies that the variation in time of reaction before use will not adversely affect the properties of the binder.

- 3) **Reaction and Storage Temperature**. As discussed under binder design, these factors can also greatly affect binder properties. With a temperature range from a low of 325° to 400°F, it is possible the binder will meet specifications at the time of the test in the field, but could fall out of specification if held for longer periods. The binder design must be conducted over the range of temperatures expected in the field and over a range of time periods. Reaction time generally begins when all the rubber is completely introduced in the mixing unit.
- 4) **Frequency of Sampling**. Most producers sample every batch while some still sample daily. For work with public agencies, sampling every batch is recommended.
- 5) **QC Tests Performed**. Most producers use the Haake viscometer to check the consistency of the AR binder. However, there is no consistency in the temperature used to test the product or the allowable temperature range for performing the test. Since the properties of asphalt cement and AR are highly temperature susceptible, tighter controls on the temperatures used to run the viscosity tests are needed.

Table 4.1. QC/QA Procedures Used in Production of AR Binders

Question	Arizona Producers			California Producers					Other Producers	
	FNF	ISS	Meadow Valley	FNF	Granite	Silvia	MAI	WSS	Cox Paving	All States
a) Where is the AR binder sampled?	Blending tank	Blending tank	Blending tank	Blending tank	Hold tank	Feed line from holding tank	Blending tank	Hold tank	Blending tank, hold tank, and/or feedline	Hold tank
b) When is the AR binder sampled and used (min)?										
• Sampled (min-avg-max)	50-60-70	40-60-80	60-75-90	30-45-60	45-??	45-??-120	45-??-50	45-??-60	30-??-90	30-60-90
• Used (min-avg-max)	60-90-120	60-90-120	60-90-180	45-??-120	45-??-180	60-??-240	50-??-180	—	90-??-360	
c) What is the reaction and storage temperature (°F)? (min-avg-max)	325-350-370	325-350-375	325-350-375	370-380-400	375-385-400	375-385-400	375-400-425	375-390-400	350-360-380	350-375-400
d) What is the frequency of QC sampling?	Every batch	Every batch	Every batch	Every batch	Every batch	Every batch	Every batch	Daily	Every batch	Daily
e) What QC tests are performed? <sup>1</sup>	Haake viscosity @ 350 ± 5°F	Haake viscosity @ 350 ± 20°F	Haake viscosity @ 350 ± 10°F	Haake viscosity @ 375 ± 5°F	Haake viscosity @ 375 ± 1°F	Haake viscosity @ 375 ± 5°F	Haake viscosity @ 400 ± 20°F	Haake viscosity @ 390 ± 10°F	Haake viscosity @ 350 ± ??°F	Haake viscosity @ 375 ± 10°F
f) What QA tests are performed?	Spec tests performed by ADOT	Spec tests, only if needed	Spec tests, only if needed		Viscosity (local agency) and DSR (Caltrans)	Viscosity (local agency) and DSR (Caltrans)	Viscosity (local agency) and DSR (Caltrans)	Viscosity	Viscosity	None
g) What is the frequency of QA sampling?	Per batch	2 per day	As needed	Per batch	Daily	Varies with agency	Per batch	Daily	Daily	Not applicable
h) Where are the QA samples taken?	Same as for QC	Same as for QC	Same as for QC	Same as for QC	Same as for QC	Same as for QC	Same as for QC	Same as for QC	Same as for QC	Not applicable
i) Are statistical summaries showing variations in AR properties available?	No	Yes	No	No	Yes	No	No	No	No	No

<sup>1</sup>Varies because of agency's specification (AZ = 350 °F, CA = 375°F, TX = 350°F, MS = 375°F)

- 6) **QA Tests Performed.** Even though samples are taken for the agency (or owner), QA tests are not always run. The extent of testing varies with the agency.
- 7) **Frequency of QA Sampling.** Samples are taken by the producer for the owner agency as often as every batch and in some cases not at all. It would be useful for the industry to establish quality procedures for the agency to ensure disputes over binder quality do not develop.
- 8) **Statistical Summaries of AR Properties.** Only a few of the producers have a data base showing variations of properties over time (Fig. 4.1). It is essential this sort of information be collected and maintained in a database.

## 4.2 Ranking of Important Binder Factors

Each producer was surveyed as to the importance of factors such as

- 1) asphalt source and grade,
- 2) CRM source and gradation,
- 3) CRM content,
- 4) blending and agitation method,
- 5) time/temperature of reaction,
- 6) binder design, and
- 7) additives

on the properties of the binder. The results are given in Table 4.2. As expected, different producers ranked the importance of the factors differently. However, when all scores are combined, the following ranking emerges:

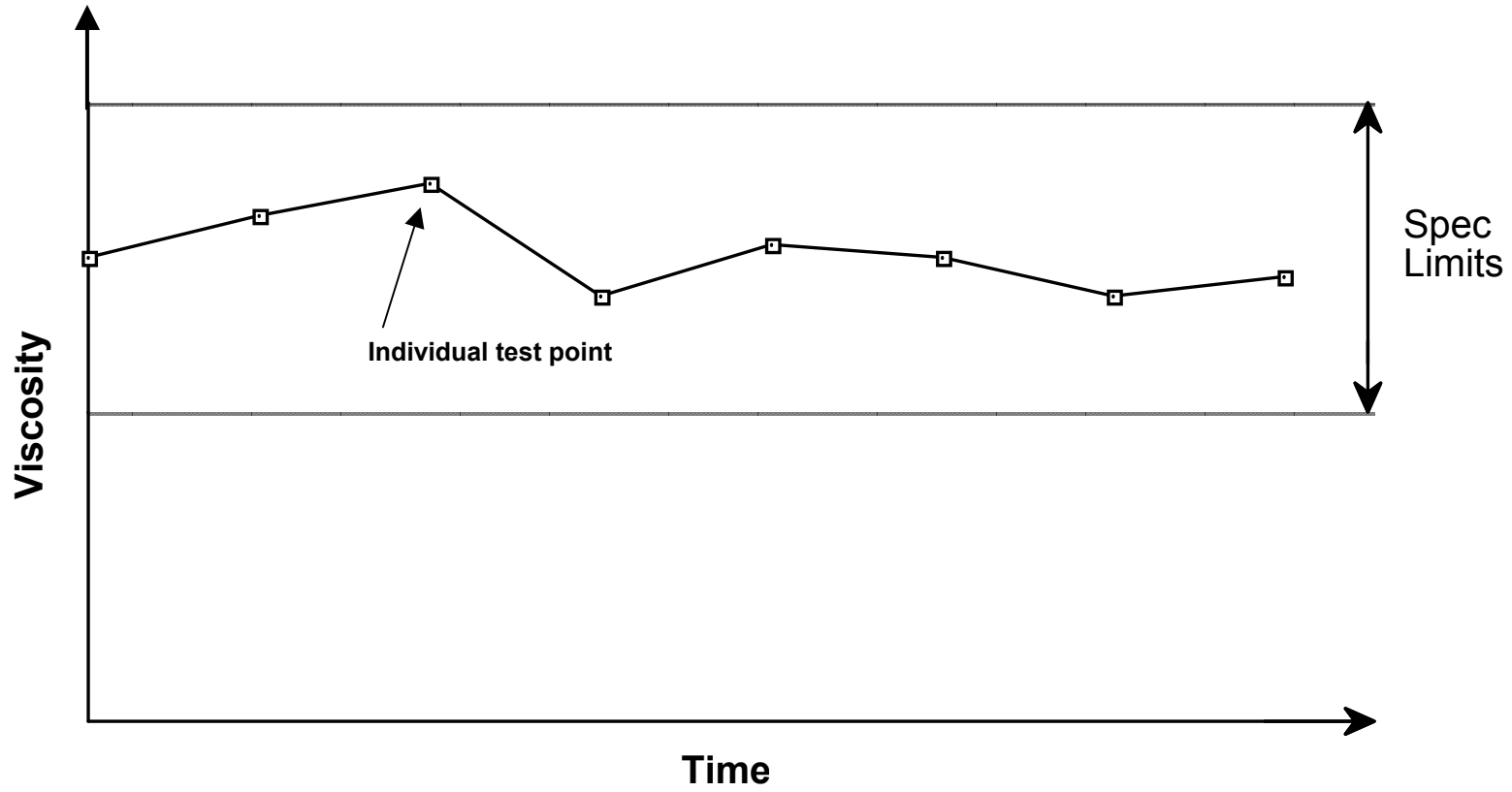


Figure 4.1. Statistical Summary of AR Binder Properties

Table 4.2. Ranking of Important Factors – AR Binders

Question	Arizona Producers			California Producers					Other Producers		Total
	FNF	ISS	Meadow Valley	FNF	Granite	Silvia	MAI	WSS	Cox Paving	All States	
Important binder properties*											
• Asphalt source and grade	1	3	3	1	2	1	1	1	1	3	17
• CRM source and gradation	3	2	3	3	2	2	1	1	2	2	21
• CRM content	2	3	3	2	2	1	1	2	2	1	19
• Blending and agitation method/equipment	4	1	1	4	1	2	1	2	1	2	18
• Time/temperature of reaction	1	1	2	1	1	1	1	1	2	3	14
• Binder design	4	1	1	4	2	1	1	1	2	1	18
• Additives (extender oils)	5	5	Not used	5	2	2	1	3	5	5	33

\*1 = most important  
5 = least important

Factor	Total Score	Order of Importance
Asphalt Source and Grade	17	2
CRM Source and Grade	21	6
CRM Content	19	5
Blending and Agitation Method	18	3
Time/Temperature of Reaction	14	1
Binder Design	18	3
Additives	33	7

### 4.3 Important Factors for Mixes

AR binders are just one of many factors that can affect the performance of the mix or the pavement. Table 4.3 summarizes the individual rankings of the producers surveyed with regard to the importance of other factors (aggregates, mix design, construction procedures, QC/QA, and structural design). As can be seen, most factors are considered important and should be considered.

### 4.4 QC Tests for AR Mixtures

Based on the survey, most contractors control the following items when producing AR mixes:

- 1) aggregate gradation,
- 2) binder content,
- 3) volumetrics (field mix – lab compacted), and
- 4) in-place air voids.

Control of these factors are important to ensuring a quality job.

### 4.5 Discussion

Quality control in binder production is very important. As indicated, there are significant differences in the QC processes used by the various producers. The next chapter provides recommendations for industry standards to ensure a consistent product between producers within a given state.

Table 4.3. Important AR Mix Performance Factors

Question	Arizona Producers			California Producers					Other Producers	
	FNF	ISS	Meadow Valley	FNF	Granite	Silvia	MAI	WSS	Cox Paving	All States
Important AR mixture performance factors*										
• AR binder	2	1	3	2	2	1	1	Not applicable, only do chip seal work	1	1
• Aggregates	2	1	1	2	2	1	1		2	1
• Mix design	3	1	2	3	2	1	1		1	1
• Construction procedures including weather during construction	1	1	4	1	1	1	1		1	1
• QC/QA	3	1	4	3	2	1	1		3	2
• Structural design including existing surface condition	4	1	4	4	1	1	1		4	2

\*1 = most important  
5 = least important

Also, the binder is but only one of the factors which must be controlled if the AR mix is to perform in the field. Placement of a quality binder does not guarantee the pavement containing the binder will perform. Guidelines for use of AR mixes need to be established. This will also be discussed in the next chapter.

## 5.0 RECOMMENDATIONS FOR INDUSTRY STANDARDS FOR QC/QA

As indicated in the prior chapters, there are considerable variations in the QC/QA procedures used. Some of this is due to the variations in the specifications used by the different agencies; others are simply because there is no industry standard for QC. This chapter presents a first attempt at an industry standard. Most of the recommendations are simply based on achieving the best practice currently available. Incremental improvements in processes need to continue as new and/or better techniques become available.

### 5.1 Quality Control

Based on the survey of producers and the authors experience with specifications, the following QC guidelines are recommended.

- 1) **AR Binder Ingredients.** Table 5.1 summarizes the QC recommendations for the virgin asphalt and the CRM. As indicated, samples are taken frequently but not always tested unless there is a dispute with the supplier. AR binder producers need to assure themselves that all the ingredients are the ones ordered. Certifications for all ingredients are required (e.g., PP-26 or equivalent).

It should be noted that the existing tests used to characterize AR are not the same as those used by the rest of the asphalt industry (e.g., performance tests evolving in the Superpave effort). The AR industry needs also to evaluate these tests for QC as the next generation of binder specifications will likely require the Superpave type of binder tests.

- 2) **AR Binder.** Considerable variation currently exists in sampling/testing frequency as well as test temperature. Binders should be tested at the specification temperature and the variation in test temperature should conform as closely as possible with ASTM requirements ( $\pm 0.2^\circ\text{F}$ ). Initial recommendations are provided in Table 5.2.

Pre-job testing (binder design) can be utilized to establish the standard to which field testing can be compared. It is recommended that the binder design yield a viscosity in the mid-range of the specification and that rubber content is adjusted in the field to maintain this number. The design profile concept presented in Tables 3.2 and 3.3 is a good tool to use to suggest an appropriate test frequency for monitoring the project. The AR producers may want to initiate a small field study to evaluate cost effective ways of controlling field temperatures (e.g., quart vs. gallon, oil bath, small high temperatures over) and to establish a reasonable field temperature control range (e.g.,  $\pm 1^\circ\text{F}$ ,  $\pm 5^\circ\text{F}$ ).

- 3) **AR Mixture.** Table 5.3 provides the recommended tests which should be performed on the AR mix. At present not all of these properties are being monitored.

Table 5.1. Recommended QC Guidelines for Ingredients

Ingredient	Sampling Frequency	Tests to Perform	Recommended Testing Frequency	Comments
Asphalt cement	Every truck load	<ul style="list-style-type: none"> <li>• Viscosity</li> </ul>	Every truck load	Certification must be provided
CRM	Every shipment	<ul style="list-style-type: none"> <li>• Gradation</li> <li>• Chemical composition</li> </ul>	4000 lbs 250 tons	Certification must be provided

Table 5.2. Recommended QC Guidelines for AR Binder

Property	Sampling Frequency	Testing Frequency	Test Temperature	Comments
Haake viscosity	Every batch	Every batch	Spec $\pm$ 5°F	Must use calibrated device
Resilience	Every batch	As needed	ASTM spec	Test performed in certified lab
Cone penetrometer	Every batch	As needed	ASTM spec	Test performed in certified lab
Softening point	Every batch	As needed	ASTM spec	Test performed in certified lab

Table 5.3. Recommended QC Guidelines for AR Mixtures

Property	Sampling Frequency	Testing Frequency	Comments
Aggregate			
<ul style="list-style-type: none"> <li>• absorption, crushed faces, abrasion</li> </ul>	As part of mix design process	As needed	Sample taken for mix design
<ul style="list-style-type: none"> <li>• gradation, sand equivalent, PI</li> </ul>	500 to 4000 tons	500 to 4000 tons	Sample taken from cold feed
AR binder content	500 to 4000 tons	500 to 4000 tons	Using ignition oven or nuclear gauge
CRM content in binder	500 to 4000 tons	500 to 4000 tons	Monitoring rubber input
Volumetric properties (voids, HMA)	500 to 4000 tons	500 to 4000 tons	Using Marshall or gyratory compactor

For all QC processes, summaries showing variations in the property being monitored should be developed. This information will provide assurance to the contractor and owner agency that the product is within specifications and will result in a quality product.

## **5.2 Quality Assurance**

The level of quality assurance testing will vary from owner to owner and whether the work is for a public agency or private owner. All owners should be encouraged to develop a QA program for their own protection. The types of tests would include those used for QC, only the frequency of testing need be altered.

## **6.0 IMPLEMENTATION PLAN**

This section of the report provides recommendations for implementing the findings of this study. Suggestions for both RPA user members and for public agencies are provided.

### **6.1 Quality Control Procedures for AR Producers**

The recommendations and processes presented in Chapter 5.0 need to be evaluated by each producer during the 2000 construction season. Constructive feedback on the processes is critical to ensuring incremental improvement in providing quality products.

An important consideration is for the AR producers to begin to establish control charts documenting variations in AR properties (e.g., viscosity and resilience) over time (see Fig. 4.1). Variations in properties of the AR binder can easily affect the performance of the AR mix.

All producers need to receive training on binder design and the importance of quality control programs. One way to accomplish this is for RPA to establish a training facility where producers' crews can be trained periodically (e.g., every year). The training program could be monitored by the Technical Advisory Board of RPA to ensure all critical aspects are covered. It is also imperative that all testing be performed by certified technicians in an accredited laboratory.

### **6.2 Quality Control/Quality Assurance Specifications for Public Agencies**

All producers must work with the owner agencies to establish acceptable specifications for AR binders and mixtures containing these binders. Training of the owner agencies on the importance of binder design and QC/QA is also needed.

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Oliver, J.W.H., "Modification of Paving Asphalts by Digestion with Scrap Rubber," *Transportation Research Record 821*, Transportation Research Board, 1981.

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**APPENDIX A**  
**Interview Survey Forms for**  
**RPA User and Producer Members**

## INTERVIEW FORM

### Quality AR Products – User Members

Company Interviewed \_\_\_\_\_ Phone \_\_\_\_\_

Name \_\_\_\_\_ Fax \_\_\_\_\_

E-Mail \_\_\_\_\_ Date \_\_\_\_\_

#### Purpose

The purpose of this interview is to:

- 1) document the current procedures used by industry to control the quality of the asphalt rubber binder, and
- 2) develop an industry standard to insure that the asphalt rubber binder properties are consistent from batch to batch and from contractor to contractor.

#### Questions

- 1) Asphalt Source

Asphalt source can impact the reaction between the asphalt and the crumb rubber. This question deals with the sampling of the neat asphalt to insure its properties are uniform and consistent.

- a) Where do you sample the neat asphalt?

- From asphalt supplier transport
- From producer's heated tank prior to blending with CRM
- \_\_\_\_\_

- b) How often do you sample and test the asphalt?

- Daily
- Weekly
- \_\_\_\_\_

c) What is the temperature of the asphalt used in AR production at the time of sampling?

\_\_\_\_\_ °F Max

\_\_\_\_\_ °F Mean

\_\_\_\_\_ °F Min

d) What tests are used for quality control of the neat asphalt?

Viscosity @ \_\_\_\_\_ °F

Agency spec tests

\_\_\_\_\_

e) How many sources of asphalt do you use in any construction season?

1

1-3

> 3

f) Are you able to use all asphalt sources to produce a quality AR product?

Yes

No

If no, what sources do not work for AR? \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

g) Do you use asphalt supplier test results in lieu of your own for QC?

Yes

No

If yes,

- What is the location of sampling? \_\_\_\_\_
- What is the frequency of sampling? \_\_\_\_\_
- What tests are performed? \_\_\_\_\_
- What is the timing and availability of test results? \_\_\_\_\_

h) Do you use public agency test results in lieu of your own for QA?

Yes

No

If yes,

- What is the location of sampling? \_\_\_\_\_
- What is the frequency of sampling? \_\_\_\_\_
- What tests are performed? \_\_\_\_\_
- What is the timing and availability of test results? \_\_\_\_\_

2) Crumb Rubber Modifier (CRM)

What is done by your organization to insure the CRM is uniform and consistent?

a) Where do you sample the CRM?

From the bag

From the hopper just prior to entering the blending unit

\_\_\_\_\_

b) How often do you sample the CRM?

- Daily
- Weekly
- \_\_\_\_\_

c) Do you perform any QC tasks on the CRM?

- Yes
- No

If yes, what tests are performed?

- Gradation
- Chemical analysis
- Metal or fabric content
- \_\_\_\_\_

d) Do you use CRM supplier test results in lieu of your own for QC?

- Yes
- No

If yes,

- What is the location of sampling? \_\_\_\_\_
- What is the frequency of sampling? \_\_\_\_\_
- What tests are performed? \_\_\_\_\_
- What is the timing and availability of test results? \_\_\_\_\_

e) Do you use public agency test results in lieu of your own for QA?

Yes

No

If yes,

- What is the location of sampling? \_\_\_\_\_
- What is the frequency of sampling? \_\_\_\_\_
- What tests are performed? \_\_\_\_\_
- What is the timing and availability of test results? \_\_\_\_\_

3) AR Binder Design

Asphalt rubber properties are primarily a function of the asphalt, the CRM, and the time and temperature of reaction. These questions are designed to determine the procedures used to insure the neat asphalt and CRM will produce an acceptable product.

a) Do you perform a binder design?

Yes

No

If yes, who performs the design?

Contractor

Private laboratory

Public agency

\_\_\_\_\_

b) What procedures are employed to design the AR binder?

- Experience
- Laboratory testing protocol
- \_\_\_\_\_

c) What tests are used in the binder design?

- Viscosity
- Resilience
- Softening point
- Cone (or needle) penetration
- DSR
- \_\_\_\_\_

d) How often do you perform a binder design?

- Every project
- Whenever the asphalt source is changed
- \_\_\_\_\_

e) Is the binder design performed by

- accredited laboratory (type of certification = \_\_\_\_\_)
- certified technician (type of certification = \_\_\_\_\_)
- \_\_\_\_\_

f) Does the binder design require the addition of an additive (e.g., extender oil)?

Yes

No

If yes, what are the typical percentages of each ingredient in the AR binder?

\_\_\_\_\_ Asphalt cement

\_\_\_\_\_ CRM

\_\_\_\_\_ Additive (e.g., \_\_\_\_\_)

g) Does the binder design procedure used result in good field performance?

100% of the time

> 90% of the time

> 80% of the time

\_\_\_\_\_

h) How do you correlate the binder lab properties with the binder performance you see in the field?

Annual field surveys

Occasional field survey

Response to problems only

\_\_\_\_\_

i) Is a new binder design test or procedure needed?

Yes

No

If yes, what do you recommend? \_\_\_\_\_  
\_\_\_\_\_

4) AR Binder Information

The time and temperature of reaction plus other factors determine the properties of the asphalt rubber. These questions are designed to determine the procedures used to control the AR production.

a) Where do you sample the AR blend?

Blending tank

Hold tank (reaction vessel)

Feed line from holding tank and hot mix plant mixing chamber

\_\_\_\_\_

b) When do you sample after rubber addition and when do you mix the AR binder with the aggregate?

Sample:

Mix:

Average \_\_\_\_\_ min.

Average \_\_\_\_\_ min.

Range \_\_\_\_\_ min.

Range \_\_\_\_\_ min.

c) What is the normal temperature of reaction and storage?

Average \_\_\_\_\_ °F

Range \_\_\_\_\_ °F

d) What is the normal frequency of QC sampling and testing used by your organization for quality control?

- Per batch
- Daily
- Per job
- \_\_\_\_\_

e) What QC tests are performed on the AR binder?

- viscosity @ \_\_\_\_\_ °F ± \_\_\_\_\_ °F
- \_\_\_\_\_
- \_\_\_\_\_

f) What QA tests are performed by the owner on the AR binder?

- Viscosity
- DSR
- \_\_\_\_\_

g) What is the frequency of the QA tests?

- Daily
- Per job
- \_\_\_\_\_

h) Where are the QA samples taken?

- Hold tank
- \_\_\_\_\_

i) Do you have statistical summaries showing variations in AR properties for recent jobs?

- Yes
- No

If yes, please provide copies of this data.

5) Summary

a) In your opinion, what factors are the most important to insure a quality AR binder?  
(1 = most important, 5 = least important)

	1	2	3	4	5
Asphalt source and grade	_____	_____	_____	_____	_____
CRM source and gradation	_____	_____	_____	_____	_____
CRM content	_____	_____	_____	_____	_____
Blending and agitation method/equipment	_____	_____	_____	_____	_____
Time/temperature of reaction	_____	_____	_____	_____	_____
Binder design	_____	_____	_____	_____	_____
Additives	_____	_____	_____	_____	_____

b) As an experienced contractor, what other factors must be controlled to insure a quality hot mix product? (1 = most important, 5 = least important)

	1	2	3	4	5
AR binder	_____	_____	_____	_____	_____
Aggregates	_____	_____	_____	_____	_____
Mix design	_____	_____	_____	_____	_____
Construction procedures	_____	_____	_____	_____	_____
Weather conditions during construction	_____	_____	_____	_____	_____
QC/QA	_____	_____	_____	_____	_____
Structural design (existing surface condition)	_____	_____	_____	_____	_____

c) What tests are routinely used to evaluate the properties of resulting AR mixtures?

- Aggregate gradation
- Binder content
- Volumetrics (field mix-lab compacted)
- Strength test
- In-place air voids (field mix-field compacted)

d) Please provide (or send) a current specification for AR binders and AR mixes used in your operating area to

R.G. Hicks  
 Professor Emeritus  
 Department of Civil, Construction, and Environmental Engineering  
 202 Apperson Hall  
 Oregon State University 97331-2302

Phone: 541-737-5318  
 Fax: 541-737-3052  
 Internet: R.G. Hicks@orst.edu

**SURVEY FORM ON  
QUALITY CONTROL PROCEDURES  
FOR RPA PRODUCER MEMBERS**

1) What tests do you perform to control the quality of the crumb rubber?

- Gradation
- Moisture Content
- Fiber Content
- Metal Content
- Chemical Composition
- \_\_\_\_\_
- \_\_\_\_\_

2) How frequently (e.g. per ton) do you perform each of the tests?

Test	Frequency
Gradation	
Moisture Content	
Fiber Content	
Metal Content	
Chemical Composition	

3) Who performs the tests?

Property	Tester	
	In-House	Other
Gradation		
Moisture Content		
Fiber Content		
Metals Content		
Chemical Composition		

4) What tests are run to establish chemical composition?

- \_\_\_\_\_
- \_\_\_\_\_
- \_\_\_\_\_
- \_\_\_\_\_

5) What reports are provided to AR producers and what is the frequency of the report?

Test	Frequency
Gradation	
Moisture Content	

6) Do you think the current QC procedures assure a uniform and consistent product?

- Yes                                       No

If no, what other QC steps do you think are needed?

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Please return by **Feb 18, 2000** to:

R.G. Hicks  
 Department of Civil, Construction, and Environmental Engineering  
 Oregon State University  
 202 Apperson Hall  
 Corvallis, OR 97331-2302  
 Fax: 541-737-3052  
 Phone: 541-737-5318  
 E-mail: R.G.Hicks@orst.edu

**APPENDIX B**  
**List of Interviewees**

## RPA USER MEMBERS

### **All States Asphalt**

Paul Montenegro  
260 Doyle Ave.  
Providence, RI 02906  
Phone: 401-351-9556  
Fax: 508-7890-2545  
Web: [www.allstatesasphalt.com](http://www.allstatesasphalt.com)

### **FNF Construction, Inc.**

Mark Belshe, A-R Manager  
115 S 48th St  
Tempe, AZ 85281  
Phone: 480-784-2910  
Fax: 480-921-8720  
E-Mail: [mark@fnfinc.com](mailto:mark@fnfinc.com)  
Web: [www.fnfinc.com](http://www.fnfinc.com)

### **International Surfacing Systems**

Andy Zappettini, VP  
6751 W Galveston  
Chandler, AZ 85226  
Phone: 480-268-0874  
Fax: 480-961-0766  
Web: [www.slurry.com](http://www.slurry.com)

### **Meadow Valley Corporation**

Sam Grasmick  
P O Box 6072  
Phoenix, AZ 85082-0726  
Phone: 602-437-5400  
Fax: 602-437-1681  
E-Mail: [akr@meadowvalley.com](mailto:akr@meadowvalley.com)  
Web: [www.meadowvalley.com](http://www.meadowvalley.com)

### **Western States Surfacing, Inc.**

Gregory Reed, President  
P O Box 4770  
Modesto, CA 95352  
Phone: 209-525-9065  
Fax: 209-525-9062  
E-Mail: [greedwss@aol.com](mailto:greedwss@aol.com)  
Web: [www.chipseal.com](http://www.chipseal.com)

### **Cox Paving Co., Inc.**

Sidney Cox  
Box 519  
Blanco, TX 78606  
Phone: 830-833-4547  
Fax: 830-833-4136  
MP: 512-658-9102

### **Granite Construction, Inc.**

Mark Chalfa  
38000 Monroe St  
Indio, CA 92203  
Phone: 760-775-7500  
Fax: 760-775-8229  
E-Mail: [mchalfa@granite-socal.com](mailto:mchalfa@granite-socal.com)  
Web: [www.graniteconstruction.com](http://www.graniteconstruction.com)

### **Manhole Adjusting, Inc.**

Cliff Ashcroft, Marketing Manager  
2300 Greenwood Ave  
Monterey Park, CA 91754  
Phone: 323-725-1387  
Fax: 323-725-7620  
E-Mail: [cashcroft@earthlink.net](mailto:cashcroft@earthlink.net)

### **Silvia Construction, Inc.**

Wayne Silvia, President  
9007 Center Ave  
Rancho Cucamonga, CA 91729  
Phone: 909-949-1127  
Fax: 909-481-8122

## RPA PRODUCER MEMBERS

### **Atlas Rubber, Inc.**

1522 Fishburn Ave  
Los Angeles, CA 90063  
Phone: 323-266-4570  
Fax: 323-267-4312  
E-mail: ari2000@mindspring.com

### **Bay Area Tire Recycling**

2200 Sacramento St, Suite 1106  
San Francisco, CA 94115-2309  
Phone: 415-931-3381  
Fax: 415-929-8123  
E-Mail: wheels@aol.com

### **CRM Co., LLC**

15800 S Avalon Blvd  
Rancho Dominguez, CA 90220  
Phone: 760-396-9936  
Fax: 310-538-2227  
E-mail: hbtak@aol.com

### **Gibson Recycling, Inc.**

P O Box 1208  
Atlanta, TX 75551  
Phone: 903-796-8640  
Fax: 903-796-0115

### **Recovery Technologies, Inc.**

KTI, Inc.  
7000 Blvd East  
Guttenberg, NJ 07093  
Phone: 201-854-7777  
Fax: 201-854-1771  
Web: [www.recoverytechnologies.com](http://www.recoverytechnologies.com)

### **BAS Recycling, Inc.**

1400 North H St  
San Bernardino, CA 92405  
Phone: 909-383-7050  
Fax: 909-383-7055  
E-mail: cmqbas@aol.com

### **CR3 of Indiana**

2501 Mt Pleasant Blvd  
Muncie, IN 47302  
Phone: 888-783-7859  
Fax: 765-286-5404  
E-mail: Wgrindle@aol.com

### **First Nation Recovery, Inc.**

P O Box 297  
Mecca, CA 92254  
Phone: 760-396-9936  
Fax: 760-396-0215  
E-mail: fnri@aol.com

### **PolyTek Rubber & Recycling, Inc.**

6245 N 24th Parkway, #202  
Phoenix, AZ 85016  
Phone: 602-840-2266  
Fax: 602-840-8717  
E-mail: ceo@polytekrubber.com  
Web: [www.polytekrubber.com](http://www.polytekrubber.com)

## RPA ASSOCIATE MEMBERS

### **LAW Engineering & Environmental Svcs**

Sam Huddleston  
4634 S 36th Place  
Phoenix, AZ 85040  
Phone: 602-437-0250  
Fax: 602-437-3675  
E-Mail: shuddles@kennesaw.lawco.com

### **Speedie & Associates**

Donald Cornelison, P.E.  
11029 N 24th St #805  
Phoenix, AZ 85029  
Phone: 602-997-6391  
Fax: 602-943-5508  
E-Mail: dcornelisen@speedie.net

### **Western Technologies, Inc.**

Phillip Feliz, Principal  
3737 E Broadway Rd  
Phoenix, AZ 85040  
Phone: 602-437-3737  
Fax: 602-470-1341  
E-Mail: wt-phx@primenet.com

**APPENDIX C**  
**Results of Interviews – User Members**

## **PREFACE**

The survey form in Appendix A was sent to all AR producers. Responses were received from all. The authors wish to acknowledge the cooperation received from the producers. Each producer is encouraged to review the information produced for accuracy.

Table C.1. QC/QA Procedures for Virgin Asphalt

Question	Arizona			California					Others	
	FNF	ISS	Meadow Valley	FNF	Granite	Silvia	MAI	WSS	All States	Cox Paving
a) Where do you sample the asphalt?	From transport truck	From transport truck	From transport truck	From transport truck	From transport truck	From transport truck	From transport truck	From producer's heated tank	From producer's heated tank	From transport truck and/or producer's tank
b) How often do you • sample the asphalt? • test the asphalt?	Daily As needed	Daily —	Daily —	Daily As needed	Daily —	Each load	Daily	Weekly	Weekly	Weekly
c) What is the asphalt temperature (°F) at time of sampling? • average • min • max	350 335 400	— 290 320	315 300 330	385 375 410	400 375 415	380 350 425	400 385 425	410 390 425	300 275 325	385 360 410
d) What tests are used for QC?	None, rely on certification	None, rely on certification	None, rely on certification	None, rely on certification	None, rely on certification	None, rely on certification	None, rely on certification	None, rely on certification	None, rely on certification	None, rely on certification
e) How many sources of asphalt do you use/season?	1-3	1-3	> 3	1-3	> 3	1-3	1	1	1-3	1-3
f) Are you able to use all sources?	No	No	Yes	Yes	Yes	Yes	Yes	No	Yes	No
g) Do you use asphalt supplier test results in lieu of your own for QC?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
h) Do you use public agency test results in lieu of your own for QA?	Yes	Yes, only if there are problems	Yes, only if there are problems	Yes	Yes	Yes	Yes	No	No	No

Table C.2. QC/QA Procedures for Crumb Rubber Modifier

Question	Arizona			California					Other	
	FNF	ISS	Meadow Valley	FNF	Granite	Silvia	MAI	WSS	All States	Cox Paving
a) Where do you sample the CRM?	Do not sample normally	From the bag or hopper	Do not sample	Do not sample normally	Do not sample	From the bag or hopper	Do not sample normally	From the hopper	From the bag	From the hopper
b) How often do you sample the CRM?	As needed	As needed or if a new supplier	Do not sample	As Needed	Only if there is a problem	Every truck load	Only if there is a problem	Weekly	When received	Daily
c) Do you perform any QC tests?	No	Yes (gradation, metal, fabric moisture)	No	No	No	No	No	No	Yes, gradation	No
d) Do you use CRM supplier tests in lieu of your own for QC?	Yes, rely on certification	Yes, rely on certification	Yes, rely on certification	Yes	Yes, rely on certification	Yes, rely on certification	Yes	Yes	Yes	Yes
e) Do you use public agency test results in lieu of your own for QA?	Yes	Yes, but varies greatly with agency	Yes	Yes	Yes	Yes, and it has resulted in penalties	Yes	No	No	No

Table C.3a. Procedures Used to Design AR Binders and Relate AR Binder Properties to Performance (Arizona)

Question	Producers			Private Laboratories		
	FNF	ISS	Meadow Valley	Law Engineering	Western Technologies	Speedie & Associates
a) Do you perform a binder design?	Yes, use private laboratory	Yes, use private laboratory	Yes, use private laboratory	Yes	Yes	Yes
b) What procedures are used?	Experience and lab protocol	Experience and lab protocol	Experience and lab protocol	Experience and lab protocol	Experience	Experience plus lab protocol
c) What tests are used in the binder design?						
• Viscosity	X	X	X	X	X	X
• Resilience	X	X	X	X	X	X
• Softening point	X	X	X	X	X	X
• Cone (or needle) penetration	X	X	X	X	X	X
• Other	Ductility	—	—			Ductility, retained penetration and resilience
d) How often is a binder design performed?	Generally every project	Every project	Every time there is a change in oil or CRM	Every project normally; the exception would be when one binder is used on small jobs within short time frame	Every project or whenever the asphalt or CRM source is ci	

C-4

































































































































Table C.3b. Procedures Used to Design AR Binders and Relate AR Binder Properties to Performance (Other Agencies)



























































































































































































































































































Table C.4. QC/QA Procedures Used in Production of AR Binders













































































































































































































































































































































































Table C.5. Ranking of Important Factors – AR Binders and Mixes



























































































































































































































































































































































































































































































































































































**APPENDIX D**  
**Results of Survey – Producer Members**

## **PREFACE**

The survey form in Appendix D was sent to all CRM producers. Responses received are included in this appendix. It is unfortunate that not all producers contributed information to this report. Each producer who provided information is encouraged to check it for accuracy.

1) What tests do you perform to control the quality of the crumb rubber?































































2) How frequently are the tests performed?





























































3) Who performs the tests?































































4) What tests are run to establish chemical composition?





























































5) What reports are provided to AR users and what are the frequency of the reports?





























































6) Do you believe the current QC procedures assure a uniform and consistent product?

Atlos Yes

BAS Yes

PolyTek Yes