RUBBERIZED ASPHALT CONCRETE DISTRICT 1 PROJECT

VOLUME 3 - CONSTRUCTION REPORT

State of California Department of Transportation
Materials Engineering and Testing Services
Office of Flexible Pavement Materials
5900 Folsom Blvd
Sacramento, California 95819

November 29, 2005

TABLE OF CONTENTS

1.0 INTRODUCTION 1
- **1.1 BACKGROUND 1**
- **1.2 OBJECTIVES 1**

2.0 PROJECT DESIGN 4
- **2.1 PROJECT INFORMATION 4**
  - *2.1.1 Climatic Data 4*
  - *2.1.2 Traffic Data 4*
  - *2.1.3 Overlay Designs 4*
  - *2.1.4 PES Information 5*
- **2.2 MIX DESIGNS 6**

3.0 CONSTRUCTION 8
- **3.1 GENERAL 8**
- **3.2 ASPHALT PLANT AND CONSTRUCTION EQUIPMENT 8**
  - *3.2.1 Asphalt Plant 8*
  - *3.2.2 Construction Equipment 8*
- **3.3 TEST SECTION CONSTRUCTION 9**
  - *3.3.1 Dense-Graded Asphalt Concrete (DGAC) 9*
  - *3.3.2 Modified Binder Dense-Graded Asphalt Concrete (MB-D) 11*
  - *3.3.3 Rubberized Asphalt Concrete (RAC-G) 12*
  - *3.3.4 Rubberized Asphalt Concrete (RUMAC) 12*
- **3.4 FIELD SAMPLING 13**
- **3.5 QC/QA DATA 14**
  - *3.5.1 Asphalt Cement 14*
  - *3.5.2 Crumb Rubber Modifier 14*
  - *3.5.3 Relative Compaction 14*
  - *3.5.4 Binder Content, Stability, Voids, and VMA Data 16*
  - *3.5.5 Aggregate Gradation 16*
- **3.6 EMISSION DATA 17**
- **3.7 OBSERVATIONS AND COMMENTS 17**

4.0 SUMMARY AND RECOMMENDATIONS 19
- **4.1 SUMMARY 19**
- **4.2 RECOMMENDATIONS 19**

5.0 REFERENCES 20

APPENDIX A - Construction Photos

APPENDIX B - Material Testing Data

LIST OF FIGURES

Figure 1.1 Project Location 2
Figure 1.2 Layout of Test Sections 3
Figure 1.3 Layout of Performance Evaluation Section (PES) 3
Figure 3.1 Comparison of Mix Temperatures 18

LIST OF TABLES

Table 2.1 Temperature and Precipitation Data 4
Table 2.2 Average Daily Truck Traffic Data (AADT) for 2004 4
Table 2.3 Overlay Recommendations 5
Table 2.4 Test Sections Material Type, Thickness, and Location 5
Table 2.5 Approximate PES Locations and Deflection Data 6
Table 2.6 Job Mix Formula Based on the District 1 Materials Laboratory Test Results 7
Table 3.1 Paving Schedule 8
Table 3.2 List of Paving Equipment 9
Table 3.3 Construction of DGAC Mix Bottom Lift 9
Table 3.4 Paving Temperature at Various Locations – Bottom Lift of DGAC Mix 10
Table 3.5 Construction of DGAC Mix Top Lift 10
Table 3.6 Paving Temperature at Various Locations – Top Lift of DGAC Mix 11
Table 3.7 Construction of MB-D Mix 11
Table 3.8 Paving Temperature at Various Locations – MB-D Mix 11
Table 3.9 Construction of RAC-G Mix 12
Table 3.10 Paving Temperature at Various Locations – RAC-G Mix 12
Table 3.11 Construction of RUMAC Mix 13
Table 3.12 Paving Temperature at Various Locations – RUMAC Mix 13
Table 3.13 Summary of Materials Sampling 14
Table 3.14 Laboratory Test Results on Asphalt Cement 15
Table 3.15 CRM Gradation Results 16
Table 3.16 CRM Chemical Analysis Results 16
Table 3.17 Summary of Relative Compaction (%) 16
Table 3.18 Summary of Binder Content, Stability, Voids, and VMA Data 17

ACKNOWLEDGEMENTS

Caltrans District 1 designed the project. Granite Construction Company (GCC) constructed the project. Many thanks go to Michael Stapleton (District Materials Engineer) and Sergio Mendoza (Resident Engineer) for their support before and during the construction and to Pete Pradere (Consultant to APTech) who participated in the construction, collected materials testing data, obtained and delivered field samples, and prepared field construction notes.

1.0 INTRODUCTION

1.1 BACKGROUND

The District 1 rubberized asphalt concrete experimental project (Contract 01-316104) is located on State Route 20 in Mendocino County near Potter Valley from Cold Creek Bridge (BR No.10-0040) to 1.8 km (1.1 miles) west of the Lake County line (Figure 1.1). The project is approximately 8.1 km (5.1 miles) long, beginning at KP R60.9 (PM R37.9) and ending at KP 69.2 (PM 43.0).

A portion of this overlay project, approximately 4 km (2.5 miles) long, was used to construct four test sections with four different asphalt concrete mixes [Caltrans, 2004a and 2004b]. The four test sections included a control section consisting of a dense-graded asphalt concrete (DGAC), a rubberized asphalt concrete (RAC) Type-G (wet process), a Rubber Modified Asphalt Concrete (RUMAC, dry process), and a Type-D Modified Binder asphalt concrete (MB-D, terminal blend process).

Shown in Figure 1.2 is the layout of the test sections. Within each test section a 152 m (500 ft) performance evaluation section (PES) as shown in Figure 1.3 was established for performance monitoring for at least five years.

During the production of four types of asphalt concrete mixes, emission tests were performed to determine pollutant emission rates for each mix in accordance with the request from the North Coast Mendocino and Lake County Air Quality Management Districts. The tests were conducted by the Avogadro Group identified by the contractor, Granite Construction Company.

The construction of the project took place between August 9 and August 25, 2005.

1.2 OBJECTIVES

For Caltrans METS, the primary objectives of this study are as follows:

- assess relative performance (field and laboratory) of the DGAC, RAC-G, MB-D, and RUMAC mixes;
- evaluate constructability of asphalt rubber using the wet, dry, and terminal blend processes; and
- compare field and lab performance with findings from the Firebaugh project and the HVS study for similar mixes.

For the Air Quality Management Districts, the objective is to determine the amount of emissions produced at the asphalt hot plant during the production of the four different types of asphalt concrete mixes [Caltrans, 2004c]. Caltrans District 1 had used asphalt rubber products in the past, but because of concerns related to potential pollution of air quality, the use of asphalt rubber products has been halted. This project is an opportunity to address these concerns and to revitalize the use of asphalt rubber products in District 1.

This report is Volume 3 of a series reports on the District 1 RAC project. The report focuses primarily on the construction aspects of the project, including a brief description of project design. Volume 1 is work plan [Caltrans, 2005a] that discusses specific activities associated with pre-construction, construction, laboratory testing, post-construction and performance monitoring. Volume 2 is pre-construction report [Caltrans, 2005b] that presents key activities took place prior to the construction, including establishment of performance monitoring sections and deflection testing, coring, and pavement condition survey.

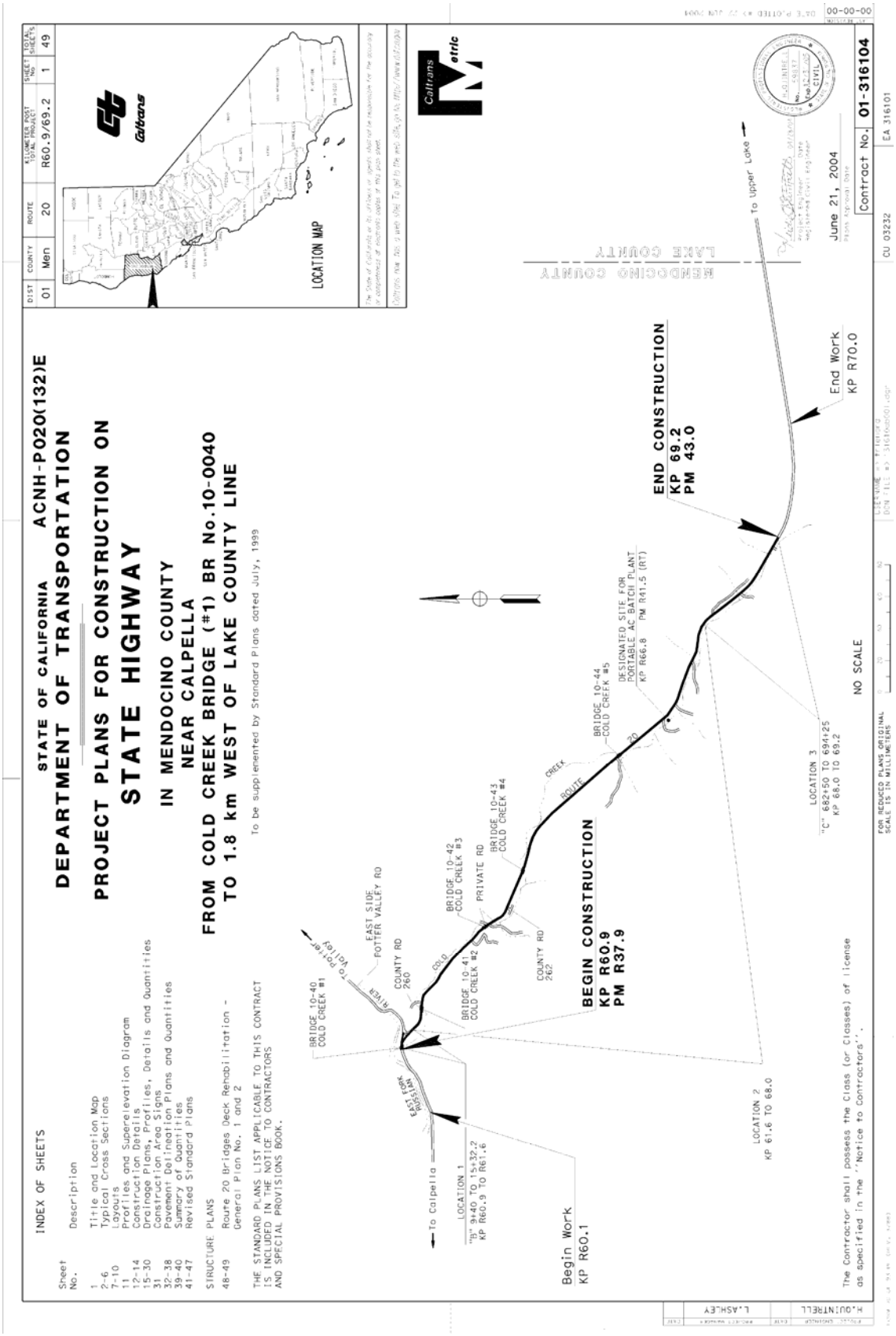


Figure 1.1 Project Location

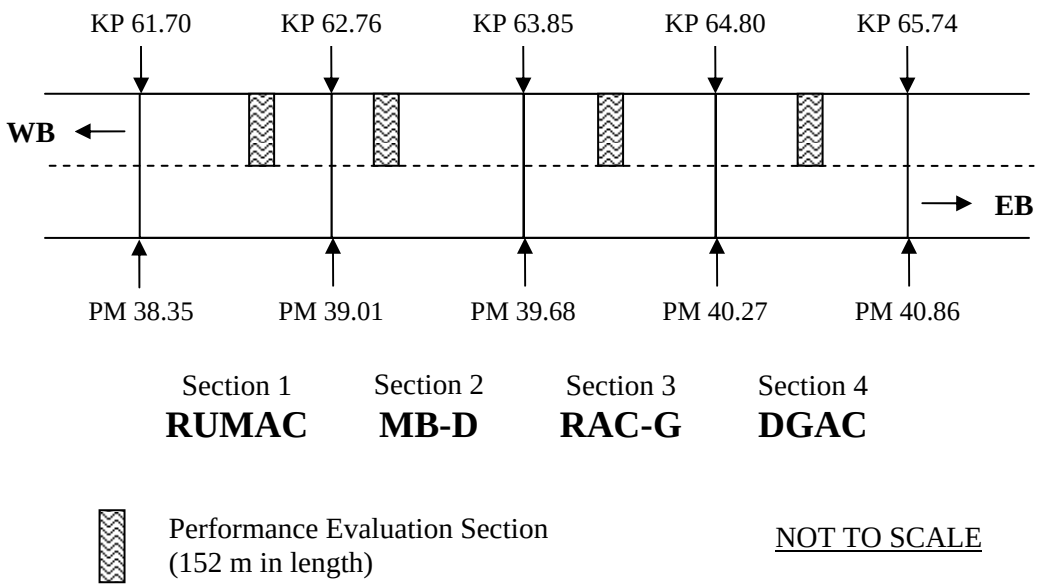


Figure 1.2 Layout of Test Sections

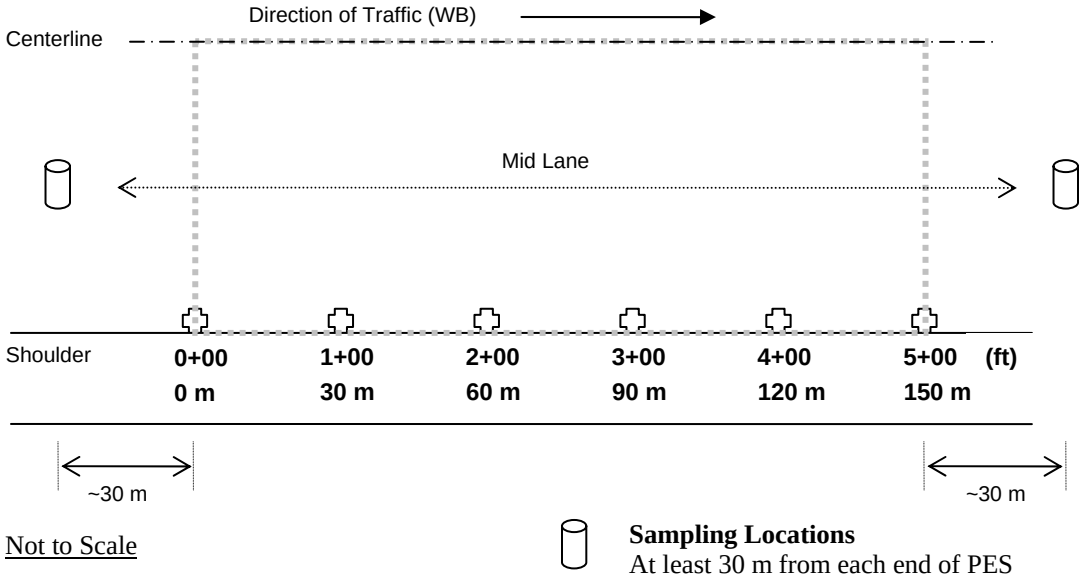


Figure 1.3 Layout of Performance Evaluation Section (PES)

2.0 PROJECT DESIGN

2.1 PROJECT INFORMATION

2.1.1 Climatic Data

The project is located within the Caltrans "Northwest Coast" climatic area. The temperature and precipitation data near the project site are shown in Table 2.1.

Table 2.1 Temperature and Precipitation Data

Element	Annual
Average Max Temp (°F)	73.9
Average Min Temp (°F)	43.7
Average Total Precipitation (in)	37.1
Average Total Snow Fall (in)	0.2
Average Snow Depth (in)	0.0

Source: Western Regional Climate Center. Ukiah CA (049122) [WRCC, 2005]
Period of Record: 3/9/1906 – 3/31/2005.

2.1.2 Traffic Data

Traffic data [Caltrans, 2004d] in the vicinity of the project is characterized in Table 2.2.

Table 2.2 Average Daily Truck Traffic Data (AADT) for 2004

PM	KP	LEG[1]	Description	Vehicle AADT Total	Truck AADT Total	Truck % Total Vehicle	EAL 1-Way (1000)	Year[2] Ver/Est
R33.16	53.35	B	NORTH JCT, RTE. 101	5100	551	10.8	89	03E

[1] A leg is given for each count location and is denoted by A, B, or O. For traffic volumes purposes, a highway intersection or interchange has two legs. According to ascending post miles (route direction) and a post mile reference at the center of the intersection or interchange, B=back leg, A=ahead leg, and O=traffic volume is equal for the back and ahead legs.
[2] Ver=year data was verified; Est=year data was estimated.

2.1.3 Overlay Designs

Overlay thickness recommendations were developed by Caltrans in June 2003 [Caltrans, 2003]. The evaluated 80th percentile deflections, based on nine analysis sections of Dynaflect deflections, ranged from 0.158 mm to 0.222 mm with an overall average of 0.200 mm. The tolerable deflection level was 0.305 mm, based on an average existing asphalt concrete thickness of 145 mm over cement treated base and 10-year traffic index of 10.5.

A pavement condition survey, conducted at the time of deflection study and field evaluation in 2002, indicated areas of transverse and longitudinal cracking, alligator cracking, and a significant amount of pumping. Analysis of the deflections showed no need of an overlay for structural adequacy; however, the existing pavement condition indicated rehabilitation was warranted for reflective crack retardation [Caltrans, 2003].

Initially, four alternates (summarized in Table 2.3) were developed by Caltrans in 2003 [Caltrans, 2003]. Alternate 1 was used in non-test section areas of the project. For the test sections, the overlay thicknesses are shown in Table 2.4.

Table 2.3 Overlay Recommendations

Alternate	Description
1	Conduct a field review locating areas of severe failure identified by rutting greater than 15 mm and/or loose spalling pavement. Digout and repair localized failed areas and seal all cracks wider then 5 mm by rout and seal method. Place 60 mm rubberized asphalt concrete (RAC) followed by 25 mm of RAC open-graded (RAC-O).
2	Repair localized failed areas and seal cracks as defined above, then place either a rubber stress absorbing membrane interlayer (SAMI-R), or pavement reinforcing fabric (SAMI-F) followed by 45 mm RAC-G and 25 mm RAC-O.
3	Repair localized failed areas and seal cracks as defined in alternate 1, then place 105 mm DGAC Type A, followed by 25 mm open-graded asphalt concrete.
4	Repair localized failed areas and seal cracks as defined in alternate 1, then place a pavement reinforcing fabric (SAMI-F), followed by 80 mm DGAC Type A and 25 mm open-graded asphalt concrete.

Table 2.4 Test Sections Material Type, Thickness, and Location

Section	Mix	Process	Thick (mm)	From KP (PM)	To KP (PM)	Length m (ft)
1	RUMAC	Dry	60	61.70 (38.35)	62.76 (39.01)	1060 (3478)
2	Type-D MB	Terminal Blend	60	62.76 (39.01)	63.82 (39.66)	1060 (3478)
3	RAC-G	Wet	60	63.85 (39.68)	64.80 (40.27)	950 (3117)
4	DGAC (Type A)	Control	105	64.80 (40.27)	65.74 (40.86)	940 (3084)

2.1.4 PES Information

In the spring of 2005, pre-construction activities including deflection testing, field coring, and pavement condition survey were performed [Caltrans, 2005b]. A PES of 152 m (500 ft) in length within each test section was selected based on deflection, pavement condition, and roadway geometry in the westbound travel lane. In most cases, the PES was established based on available non-digout areas within the test section. Table 2.5 provides a summary of the established PES location within each test section and average deflection normalized 40 kN (9,000 lbs) for each PES. In most cases, the average outer wheel path deflection exceeded the mid-lane deflection.

Field cores revealed that the existing pavement generally consisted of 125 to 165 mm (5 to 6.5 inches) of asphalt concrete (AC) over approximately 150 mm (6 inches) of cement treated base (CTB). The construction plans shows the existing pavement has 60-90 mm AC, 200 mm CTB, and 300-480 mm aggregate subbase [Caltrans, 2004a]. The existing pavement data shown in the construction plans are not compatible with the core data.

Table 2.5 Approximate PES Locations and Deflection Data

PES	Mix	PES KP (PM)		OWP Deflection (mm)			Mid-Lane Deflection (mm)		
		Begin	End	Average	Std. Dev	CV[1], %	Average	Std. Dev	CV[1], %
1	RUMAC	62.7206 (38.9811)	62.5682 (38.8864)	0.121	0.038	31.9	0.103	0.028	27.0
2	Type-D MB	62.9763 (39.1400)	62.8239 (39.0453)	0.140	0.026	18.4	0.092	0.014	15.1
3	RAC-G	64.3690 (40.0056)	64.2166 (39.9109)	0.250	0.062	24.8	0.173	0.059	34.2
4	DGAC (Type A)	65.0591 (40.4345)	64.9067 (40.3398)	0.145	0.025	17.2	0.164	0.031	18.9

[1] CV = Coefficient of Variation. CV is the ratio of standard deviation divided by the mean (average) for a given sample used to measure spread.

Pavement condition survey of the PESs indicated that the severities of distresses vary; the primary wheel path distresses were longitudinal cracking and/or fatigue cracking. Low to moderate severity of block cracking and transverse cracking were also observed. Maximum rut depths in both outer and inner wheel paths were measured using a 6-ft straight edge starting at the beginning of the PES and at 15 m (50 ft) intervals thereafter. The maximum rut depths varied by PES. In most locations, the rut depths were generally less than 7 mm. Detailed deflection profiles and pavement condition evaluations for each PES are presented in the pre-construction report [Caltrans, 2005b].

2.2 MIX DESIGNS

Mix designs were developed by the District 1 Materials Laboratory in accordance with Section 39-2.02 of the Standard Specifications and the Special Provisions [Caltrans, 2004b] for the project. The RUMAC is 19 mm maximum medium gap-graded mix, the MB-D is a 19 mm maximum medium dense-graded mix, the RAC-G is a maximum medium gap-graded mix, and the DGAC is a 19 mm maximum medium Type A dense-graded mix. The job mix formula for each mix is shown in Table 2.6. The aggregate used in the mix design was from GCC's Highway 175 rock pit west of Lakeport in Lake County.

The Valero-Benicia asphalt plant supplied the asphalt binders. These included AR-4000 binder used in RUMAC and RAC-G; the PBA-1 binder used in DGAC; and the RAC-15 binder used in the MB-D.

Crumb rubber modifier (CRM), derived from whole scrap tires generated within the State of California, was supplied by Crumb Rubber Manufacturers, Rancho Dominguez, California. The high natural rubber, produced from industrial scrap, was also supplied by Crumb Rubber Manufacturers.

Table 2.6 Job Mix Formula Based on the District 1 Materials Laboratory Test Results

Sieve Size, mm	RUMAC	MB-D	RAC-G	DGAC
25 (1”)	100	100	100	100
19 (3/4”)	99	98	99	98
12.5 (1/2”)	85	80	86	84
9.5 (3/8”)	68	71	73	73
4.75 (4)	41	54	39	55
2.36 (8)	20	38	20	42
0.6 (30)	8	16	9	17
0.075 (200)	3	4	4	4
Asphalt Binder Grade	AR-4000	RAC-15	AR-4000	PBA-1
Optimum Binder Content (OBC), %	7.8	5.2-5.5	7.7-8.0	5.2-5.5
Maximum Density @ OBC	2.34	2.44	2.35	2.40
Asphalt Absorption @ OBC, %	1.7	1.6	2.1	1.7
Stability @ OBC	28	42	26	39
Air Voids, %	5.2	4-4.7	4.4-5.4	7-7.7
Crushed Coarse (min 90%)	98	98	100	96
LA Rattler: @ 100 rev (max 10%) @ 500 rev (max 45%)	3 13	4 14	4 14	3 13
Crushed Fine (min 70)	98	94	100	97
Sand Equivalent (min 50%)	79	61	50	79

3.0 CONSTRUCTION

3.1 GENERAL

Paving started on August 9, 2005 and was completed on August 25, 2005. Construction (including traffic control) was performed by Granite Construction Company (GCC). Specific paving dates for each test section are shown in Table 3.1. All construction was performed at night. Weather was clear and there was no rain during the entire paving. Ambient temperatures were generally greater than 12°C and pavement surface temperatures were greater than or equal to 20°C.

Table 3.1 Paving Schedule

Paving Date	Test Section	Mix Type	Process	Lift Thickness
August 9	4	DGAC	Control	Bottom (55 mm)
August 10, 11				Top (50 mm)
August 17	2	MB-D	Terminal Blend	Single (60 mm)
August 18	3	RAC-G	Wet	Single (60 mm)
August 23, 24	1	RUMAC	Dry	Single (60 mm)

Digouts and replacement limited to 50 mm deep were performed prior to the overlay. The pavement surface was tacked with CRS-2 for all lifts at a rate of 0.362 liter/m^2 (0.08 gal/sq. yd.) sprayed at 40°C. The tack distributor truck placed the tack coat on the area to be paved 15 minutes to 1 hour prior to placing the hot mix overlay.

The construction methods and sequences for all four test sections and mixes were same: bottom dump trucks (either single or double trailer) unloaded mix on the pavement surface, windrow elevators picked up the material and placed it in the hopper of paver, paving machines distributed mix to desired thickness, and rollers compacted mat to required density.

3.2 ASPHALT PLANT AND CONSTRUCTION EQUIPMENT

3.2.1 Asphalt Plant

The asphalt concrete mixes were produced by GCC's Gencor counter flow hot plant located approximately 25 miles away from the project site. The average haul time was approximately 50 minutes. The plant produced 200 to 280 tonnes of mix per hour for all test sections. For the construction of the RUMAC test section, ECOPATH equipment was used to monitor and feed the correct amount of dry CRM to the drum in close coordination with the operator of the hot plant. For the construction of the RAC-G test section, GCC's equipment was used to blend CRM with asphalt cement.

3.2.2 Construction Equipment

The equipment utilized on the project is given in Table 3.2. Two different pavers were utilized to build the different test sections. A CAT AP1055C paver was used to construct the westbound travel lane and shoulder, the eastbound travel lane in test section 1; part of the westbound travel lane and shoulder in test section 2; and the eastbound travel lane and shoulder in test section 3. A CAT AP655C paver was utilized to construct all of test section 4; the westbound travel lane and shoulder of test section 3; part of WB travel lane and shoulder, and the eastbound shoulder and travel lane in test section 2.

The CAT AP655C paver was equipped with an electronic ski on the left side of the paver. There were 4 ultrasonic sensors on the ski with the first three reading the existing pavement and the fourth reading the

freshly placed mat behind the screed. The CAT AP1055C paver was equipped with a single ultrasonic sensor on the left side placed adjacent to the auger. Photos taken during the construction are presented in Figure A.1 of Appendix A.

Table 3.2 List of Paving Equipment

Make	Type	Model
Caterpillar	Paver - 10-20 Extend-A-Mat Screed Pickup Machine	AP1055C
Caterpillar	Paver - 10-20 Extend-A-Mat Screed Lincoln Pickup Machine	AP655C
Caterpillar	Double Drum Vibratory Roller	CAT534C
Caterpillar	Double Drum Vibratory Roller	CAT434C
Troxler	Thin Lift Density Gage	4640
Unknown	Nuclear Asphalt Content Gage	Unknown
Various	Bottom Dump Haul Trucks	Various

3.3 TEST SECTION CONSTRUCTION

The following descriptions are presented in the order of paving dates shown in Table 3.1.

3.3.1 Dense-Graded Asphalt Concrete (DGAC)

The DGAC test section was constructed in two lifts. The bottom lift was constructed on August 9, 2005 and the top lift was constructed on August 10 and August 11, 2005. Photos taken during the construction are presented in Figure A.2 of Appendix A.

Construction of Bottom Lift

Paving of the bottom lift was in the order of westbound (WB) shoulder, travel lane, eastbound (EB) travel lane, and shoulder, respectively. Table 3.3 shows the construction sequences, mix placement, and compaction process relevant to the paving of the DGAC PES. Temperature data collected at various stages and PES locations are summarized in Table 3.4.

Table 3.3 Construction of DGAC Mix Bottom Lift

Time	Description (August 9)	Remarks
6:00 pm	Set up traffic control	There was a minor plant breakdown which created a delay of about one hour at the end of the shoulder paving. There was a problem with the aggregate feeder on the plant. One stoppage about 15 minutes waiting for material.
6:15 pm	Swept westbound (WB) shoulder and travel lane	
6:30 pm	Tacked part of the WB shoulder	
7:20 pm	Started paving of WB shoulder	
9:45 pm	Completed paving of WB shoulder	
10:50 pm	Started placing tack coat and the mix on WB travel lane	
11:35 pm	Started paving of PES section	
11:45 pm	Completed paving of PES section	
6:30 am	Completed the entire bottom lift	
Mix placement	Two pavers were used: AP655C and AP1055C. Mix was placed 2.9 m wide by 70 mm loose thickness.	
Breakdown compaction	Roller CAT534C made two passes in each direction using double drum vibratory in a high amplitude mode. Roller CAT434C also made two to three passes in each direction using double drum vibratory mode.	
Final compaction	Roller CAT434C made two passes in each direction in static mode.	

Table 3.4 Paving Temperature at Various Locations – Bottom Lift of DGAC Mix

Description	Temperature (°C) at Location			
	0-25 m Before PES	Begin PES	80 m within PES	End PES
Ambient	18	18	18	18
Surface	23	23	23	23
Windrow	142	132	143	142
Behind Paver	132	124	132	130
Breakdown	132	124	132	130
After Breakdown	---	112	---	117
After Compaction	---	85	76	---

All temperatures were measured using an infrared temperature gage.

Construction of Top Lift

Paving of the top lift was in the order of WB shoulder, travel lane, EB travel lane, and shoulder, respectively. Table 3.5 shows the construction sequences, mix placement, and compaction process relevant to the paving of the DGAC PES. Temperature data collected at various stages and PES locations are summarized in Table 3.6.

Table 3.5 Construction of DGAC Mix Top Lift

Time	Description	Remarks
August 10		
6:00 pm	Set up traffic control	A major breakdown occurred at the hot plant. Paving was suspended.
6:15 pm	Swept westbound (WB) shoulder and travel lane	
6:50 pm	Began placing tack coat on the shoulder. Only WB shoulder was constructed.	
August 11		
6:00 pm	Set up traffic control	This test section was constructed quickly without any stops.
7:00 pm	Started placing tack coat and the mix on WB travel lane	
7:15 pm	Started paving of test section	
7:55 pm	Started paving of PES section	
8:05 pm	Completed paving of PES section	
Mix placement	Paver AP655C was used. Mix was placed 3.6 m wide by 65 mm loose thickness.	
Breakdown compaction	Roller CAT534C made two passes in each direction using double drum vibratory in a high amplitude mode. Roller CAT434C also made two to three passes in each direction using double drum vibratory mode.	
Final compaction	Roller CAT434C made two passes in each direction in static mode.	

Table 3.6 Paving Temperature at Various Locations – Top Lift of DGAC Mix

Description	Temperature (°C) at Location	
	0-30 m Before PES	150 m Within PES
Ambient	18	18
Surface	43	---
Windrow	145	144
Behind Paver	135	132
Breakdown	132	129
After Breakdown	---	118
After Compaction	---	90

All temperatures were measured using an infrared temperature gage.

3.3.2 Modified Binder Dense-Graded Asphalt Concrete (MB-D)

Paving of the MB-D mix was in the order of WB shoulder, travel lane, EB travel lane, and shoulder, respectively. Table 3.7 shows the construction sequences, mix placement, and compaction process relevant to the paving of the MB-D PES. Photos taken during the construction are presented in Figure A.3 of Appendix A. Temperature data collected at various stages and PES locations are summarized in Table 3.8.

Table 3.7 Construction of MB-D Mix

Time	Description (August 17)	Remarks
6:00 pm	Set up traffic control	There were several delays of 5-10 min waiting for trucks. In general, the operation went smoothly.
6:45 pm	Swept and tacked westbound (WB) shoulder and travel lane	
7:15 pm	Started paving of WB shoulder and travel lane	
10:00 pm	Completed paving of WB shoulder and travel lane	
11:15 pm	Started placing tack coat in EB shoulder and travel lane	
12:05 am	Started paving of EB shoulder and travel lane	
1:00 am	Completed paving	
Mix placement	Two pavers were used: AP655C and AP1055C depended on paving width. For wider width, the screed was extended on both sides approximately 1.8 m. Mix was generally placed 6 m wide by 70 mm loose thickness.	
Breakdown compaction	Roller CAT534C made two passes in both directions over the entire width using double drum vibratory in a high amplitude mode. Roller CAT434C also made two passes in both directions using double drum vibratory mode.	
Final compaction	Roller CAT534C was used in static mode.	

Table 3.8 Paving Temperature at Various Locations – MB-D Mix

Description	Temperature (°C) at Location		
	10 m Within PES	90 m Within PES	150 m Within PES
Ambient	17	14	---
Surface	22	20	20
Windrow	165	163	164
Behind Paver	149	147	147
Breakdown	147	143	143
After Breakdown	---	122	---
After Compaction	87	---	---

All temperatures were measured using an infrared temperature gage.

3.3.3 Rubberized Asphalt Concrete (RAC-G)

Paving of the RAC-G mix was in the order of WB shoulder, travel lane, EB travel lane, and shoulder, respectively. Table 3.9 shows the construction sequences, mix placement, and compaction process relevant to the paving of the RAC-G PES. Photos taken during the construction are presented in Figure A.4 of Appendix A. Temperature data collected at various stages and PES locations are summarized in Table 3.10.

Table 3.9 Construction of RAC-G Mix

Time	Description (August 18)	Remarks
6:00 pm	Set up traffic control	The operation went smoothly without any delays.
6:30 pm	Swept and tacked westbound (WB) shoulder and travel lane	
7:15 pm	Started paving of WB shoulder	
9:00 pm	Started paving of WB travel lane	
10:06 pm	Started paving of PES	
10:24 pm	Completed paving of PES	
Mix placement	Two pavers were used: AP655C and AP1055C. Mix was placed 3.6 m wide by 70 mm loose thickness using paver AP655C.	
Breakdown compaction	Roller CAT534C made two passes in both directions using double drum vibratory in a high amplitude mode. Roller CAT434C also made two passes in both directions using double drum vibratory mode.	
Final compaction	Roller CAT534C was used in static mode.	

Table 3.10 Paving Temperature at Various Locations – RAC-G Mix

Description	Temperature (°C) at Location		
	Begin PES	90 m Within PES	150 m Within PES
Ambient	16	---	14
Surface	24	23	22
Windrow	155	148	148
Behind Paver	137	140	140
Breakdown	137	138	138
After Breakdown	---	125	---
After Compaction	84	---	85

All temperatures were measured using an infrared temperature gage.

3.3.4 Rubberized Asphalt Concrete (RUMAC)

Paving of the RUMAC mix was in the order of WB shoulder, travel lane, EB travel lane, and shoulder, respectively. Table 3.11 shows the construction sequences, mix placement, and compaction process relevant to the paving of the RUMAC PES. Photos taken during the construction are presented in Figure A.5 of Appendix A. Temperature data collected at various stages and PES locations are summarized in Table 3.12.

Table 3.11 Construction of RUMAC Mix

Time	Description	Remarks
August 23		
6:00 pm	Set up traffic control	Ran out of AR-4000 binder and stopped paving.
6:30 pm	Swept and tacked eastbound (EB) shoulder and travel lane	
6:50 pm	Started paving of EB shoulder	
7:45 pm	Completed paving of EB shoulder	
August 24		
6:00 pm	Set up traffic control	Paving was delayed for 1 hour plus due to a broken hydraulic line in the paver. A long windrow of mix was formed in front of the paper.
7:20 pm	Swept and tacked EB travel lane	
7:30 pm	Started paving of EB travel lane	
10:30 pm	Completed paving of EB travel lane	
11:30 pm	Placed tack on WB shoulder and travel lane	
12:05 am	Started paving of PES	
12:45 am	Completed paving of PES	
Mix placement	Two pavers were used: AP655C and AP1055C. Mix was placed 6 m wide by 70 mm loose thickness.	
Breakdown compaction	Roller CAT534C made two passes in both directions using double drum vibratory in a high amplitude mode. Roller CAT434C also made two passes in both directions using double drum vibratory mode.	
Final compaction	Roller CAT534C was used in static mode.	

Table 3.12 Paving Temperature at Various Locations – RUMAC Mix

Description	Temperature (°C) at Location		
	Begin PES	90 m Within PES	150 m Within PES
Ambient	14	14	14
Surface	23	23	22
Windrow	138	145	---
Behind Paver	132	130	112
Breakdown	132	130	112
After Breakdown	---	120	---
After Compaction	84	---	---

All temperatures were measured using an infrared temperature gage.

3.4 FIELD SAMPLING

Materials sampled during the construction included aggregate, asphalt binders, crumb rubber modifiers, extender oil, and loose mixes. Aggregates were obtained from the GCC's Highway 175 rock pit; asphalt binders, crumb rubber modifiers, extender oil were taken at the hot plant; and loose mixes were sampled from windrow. Quantities of each material are summarized in Table 3.13. All materials were delivered to Translab in August 2005.

Table 3.13 Summary of Materials Sampling

Material Type	Quantity	Sampling Date	Delivery Date
Aggregate	26 Sacks	8/9/05	8/12/05
Asphalt Binder			
AR-4000 Binder	5 Gallons	8/9/05	8/12/05
Modified Binder	5 Gallons	8/17/05	8/19/05
AR-4000 Binder	5 Gallons	8/23/05	8/25/05
Modifier			
Extender Oil	2 Gallons	8/9/05	8/12/05
High-Natural Rubber	5 Gallons	8/18/05	8/19/05
RAC-G Rubber	5 Gallons	8/23/05	8/25/05
RUMAC Rubber	5 Gallons	8/23/05	8/25/05
Loose Mix			
DGAC Mix (Top Lift) (Control)	39 Boxes (19 boxes from 0-30 m before the PES; 20 boxes from 30 m after the end of the PES)	8/11/05	8/12/05
MB-D Mix (Terminal Blend)	40 Boxes(20 boxes from 0-30 m before the PES; 20 boxes from 30 m after the end of the PES)	8/17/05	8/19/05
RAC-G Mix (Wet Process)	40 Boxes (20 boxes from 0-30 m before the PES; 20 boxes from 30 m after the end of the PES)	8/18/05	8/19/05
RUMAC Mix (Dry Process)	40 Boxes (20 boxes from 15 m after the PES; 20 boxes from 30 m after the end of the PES)	8/24/05	8/25/05

3.5 QC/QA DATA

Prior to the construction, the asphalt hot plant was inspected in accordance with CT-109 and approved by Caltrans.

3.5.1 Asphalt Cement

Laboratory test results on asphalt cements, provided by Valero-Benicia Asphalt Plant, are summarized in Table 3.14. A review of the test results indicates that all asphalt cements met Caltrans specifications.

3.5.2 Crumb Rubber Modifier

CRM data are summarized from Certificates of Compliance provided by the supplier for the project. CRM gradations are shown in Table 3.15. CRM gradations for both RAC-G and RUMAC met the Caltrans special provision requirements for the project. CRM chemical analysis results are shown in Table 3.16 and they also met Caltrans special provision requirements.

3.5.3 Relative Compaction

Relative compactions measured within the test sections are summarized in Table 3.17. All measured compactions passed Caltrans compaction requirement of minimum 96 percent. Detailed measurements are presented in Table B.1 of Appendix B.

Table 3.14 Laboratory Test Results on Asphalt Cement

		AR-4000						PBA-1		RAC-15
Test Parameter	AASHTO	Aug-03	Aug-09	Aug-10	Aug-17	Aug-25	Sep-01	Aug-01	Aug-09	Aug-16
Test on Original Asphalt										
Flash Point, C.O.C., °C	T48	316	292	286	294	294	316	302	292	288
Solubility in TCE., %	T44	99.99	99.99	99.99	99.97	99.97	99.97	99.99	99.99	
Absolute Viscosity @ 60°C, poise	T202							1688	1621	
Penetration @ 25°C, 100 g/5 sec	T49	70	69	69	65	67	68			
Specific Gravity (15/15C)	T228	1.027	1.027	1.031	1.027	1.027	1.027			
Brookfield Rotational Viscosity @ 135°C, cP	T316									1875
Tests on Residue from RTFO	T240									
Absolute Viscosity @ 60°C, poise	T202	3724	3647	3959	4104	3664	3826	4019	3647	
Kinematic Viscosity @ 135°C, cSt	T201	377	380	425	408	389	391	398	380	
Penetration @ 25°C, 100 g/5 sec	T49	43	35	43	40	41	40	44	35	
Percent of Original Penetration	Calc.	61.4	50.7	62.3	61.5	61.2	58.8			
Absolute Viscosity Ratio @ 60°C, Max	Calc.							2.38	2.25	
Ductility @ 25°C, 5 cm/min, cm	T51	80+	80+	80+	80+	80+	80+	80+	80+	
Mass Loss	T240							0.4	0.458	
Tests on PAV Residue @ 90°C	R28									
BBR, Creep Stiffness, Mpa, -6°C	T313							103	159	
BBR, m-value, -6°C	T313							0.438	0.423	

Table 3.15 CRM Gradation Results

Sieve Size, mm	For RAC-G Mix, % Passing		For RUMAC Mix, % Passing	
	Test	Specs	Test	Specs
2.36 (#8)	100	100	---	---
2.00 (#10)	100	98-100	100	100
1.18 (#16)	52	45-75	92	85-100
0.60 (#30)	4	2-20	58	30-60
0.30 (#50)	3	0-6	19	10-30
0.15 (#100)	1	0-2	---	---
0.075 (#200)	0	0	4	0-5

Table 3.16 CRM Chemical Analysis Results

Test Parameter	Scrap Tire CRM, %			High Natural CRM, %		
	Test	Specs		Test	Specs	
		Min	Max		Min	Max
Acetone Extract	7.2	6.0	16.0	7.0	4.0	16.0
Ash Content	5.3	---	8.0	---	---	---
Carbon Black Content	29.1	28.0	38.0	---	---	---
Rubber Hydrocarbon	51.1	42.0	65.0	52.1	50.0	---
Natural Rubber Content	30.6	22.0	39.0	40.8	40.0	48.0

Table 3.17 Summary of Relative Compaction (%)

Test Section	Mix	Average	Std. Dev.	CV	Max	Min
1	RUMAC	97.5	0.9	0.9	98.0	96.4
2	MB-D	97.5	0.9	0.9	98.4	96.7
3	RAC-G	97.1	0.7	0.8	97.9	96.3
4	DGAC	97.3	1.0	1.0	98.8	96.3

3.5.4 Binder Content, Stability, Voids, and VMA Data

Binder content, stability, voids, and VMA data relative to the test sections are summarized in Table 3.18. A review of the test results indicates that the average stability values for all mix types met the requirements of the project specification. VMA values for RAC-G and RUMAC also met specification requirements. Detailed data are presented in Table B.2 of Appendix B.

3.5.5 Aggregate Gradation

These data have not yet been received. Communication with the Resident Engineer indicates that all aggregate gradation met the requirements of the project specification.

Table 3.18 Summary of Binder Content, Stability, Voids, and VMA Data

Mix Type	Item	Target	Max	Min	n	Average	Std. Dev.	CV, %
DGAC	Binder Content, %	5.4	5.9	5.1	6	5.6	0.3	4.9
	Stability	37 min	46	42	6	44.8	1.6	3.6
	Voids, %		4.7	2.8	6	3.9	0.8	21.7
RAC-G	Binder Content, %	7.9	8.8	7.9	3	8.5	0.5	6.1
	Stability	23 min	38	21	3	26.7	9.8	36.8
	VMA, %	18 min	20.8	18.7	3	19.9	1.1	5.5
MB-D	Binder Content, %	5.4	5.8	5.5	2	5.7	0.2	3.8
	Stability	23 min	49	44	2	46.5	3.5	7.6
	Voids, %		4.3	3.9	2	4.1	0.3	6.9
RUMAC	Binder Content, %	7.8	8.3	7.6	4	7.9	0.3	4.2
	Stability	28 min	35	27	4	32.3	3.8	11.7
	VMA, %	18 min	19.3	18.4	4	18.8	0.4	2.2

3.6 EMISSION DATA

There was no noticeable odor or irritation from any of the products placed.

The Avogadro Group, LLC (contracted by Granite Construction Company) conducted a series of emission tests at the hot plant located in Lakeport, California. The following species were measured:

- Polycyclic aromatic hydrocarbons (PAH)
- Benzene, toluene, ethyl benzene, total (m, p, o) xylene (BTEX)
- Total non-methane volatile organic compounds (VOC)
- Particulate matter (PM), recorded as PM less than 10 microns (PM_{10})
- Carbon monoxide (CO) and nitrogen oxide (NO_X)
- Oxygen (O_2) and carbon dioxide (CO_2)
- Stack gas volumetric flow rates and moisture content

A draft source test report was prepared by the Avogadro Group, LLC, in October 2005 [The Avogadro Group, 2005]. The draft report did not conclude whether all emission test results were within permits; however, a review of the results indicates that measured species from DGAC (conventional process), RAC-G (wet process), MB-D (terminal process), and RUMAC (dry process) are similar to each other. It is anticipated that an independent third party will review and analyze the test results and develop conclusions.

3.7 OBSERVATIONS AND COMMENTS

The construction method and sequences for all mixes were same. Prior to placing traffic, the contractor placed a fine-grained sand on the new mat and lightly swept it.

As indicated, both pavers (AP655C and AP1005C) were equipped with electronic depth control; however, it appeared that it was operated on manual control. The screed operator made all depth adjustments using the mechanical screed adjustment arm or would manually adjust the tow point using the electronic controller since the tow arm could not adjust without the operator's manual adjustment. This paving crew was experienced and there were only minor depth adjustments needed throughout all paving. All of the longitudinal construction joints were 'bumped' and excess material cast on to the new mat.

Bumps on shoulders were noticeable at night, but not during the day. The bumps were a result of crack seal that reflects through the mat. In general the bumps are not felt.

A comparison of mix temperatures at various stages of paving is shown in Figure 3.1. Compared to DGAC mix, the average windrow temperature for the MB-D mix is more than 20°C higher than that of DGAC; the average windrow temperature for the RAC-G mix is 9°C higher than that of DGAC. The average behind paver and breakdown temperatures for the MB-D and RAC-G mixes are also at least 8°C higher than that of DGAC. Temperatures for RUMAC are about the same as those of DGAC.

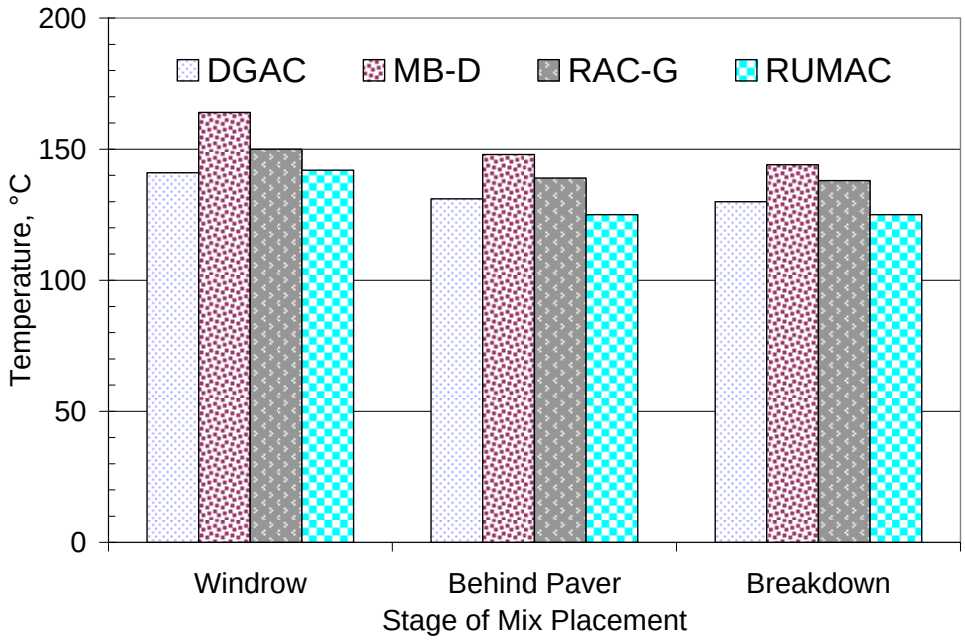


Figure 3.1 Comparison of Mix Temperatures

4.0 SUMMARY AND RECOMMENDATIONS

4.1 SUMMARY

This report documents the work conducted during the construction phase of this experimental project. Relevant project design information is also included. The construction of all four test sections went smoothly except for some delays either due to material supply or breakdown of the hot plant or the paver.

QC data indicated that the properties of asphalt cements and CRM and field relative compactions met Caltrans specifications. The average stability values for all mix types met the requirements of the project specification. VMA values for RAC-G and RUMAC also met spec requirements.

4.2 RECOMMENDATIONS

Post-construction field sampling (cores and slabs) should commence late this year. Pavement condition survey and deflection testing should also be conducted the same time in accordance with the project work plan [Caltrans, 2005a].

For future projects where field sampling is needed, it is recommended the materials sampling be included in the project special provisions as part of the contract to reduce extra effort needed to collect the materials.

5.0 REFERENCES

Caltrans, 2003. "Final Materials Report, North Region," Caltrans, June 4, 2003.

Caltrans, 2004a. "Project Plan for Construction on State Highway in Mendocino County Near Calpella, District 01, Route 20 (Contract No. 01-316104)," Sacramento, CA, July 2004.

Caltrans, 2004b. "Special Provisions for Construction on State Highway in Mendocino County Near Calpella , District 01, Route 20 (Contract No. 01-316104)," Sacramento, CA, July 2004.

Caltrans, 2004c. "California Air Resources Board Agreement Number 01A0748 Exhibit A," Caltrans, Sacramento, CA, July 29, 2004.

Caltrans, 2004d. "Traffic and Vehicle Data System, Caltrans Business, Transportation and Housing Agency – November 2004," Caltrans, Sacramento, CA, 2004.

Caltrans, 2005a. "Rubberized Asphalt Concrete District 1 Project Volume 1 – Work Plan, Office Flexible Pavement Materials," Caltrans, Sacramento, CA, July 2005.

Caltrans, 2005b. "Rubberized Asphalt Concrete District 1 Project Volume 2 – Pre-Construction Report," Office Flexible Pavement Materials, Caltrans, Sacramento, CA, July 2005.

The Avogadro Group, 2005. "Source Test Report 2005 Emission Source Tests Portable Hot Mix Asphalt Plant Granite Construction Company, Lakeport, California," Prepared by the Avogadro Group, LLC for Granite Construction Company, October 10, 2005.

WRCC, 2005. "Ukiah, California (049122)," Western Regional Climate Center, http://www.wrcc.dri.edu. 2005.

APPENDIX A
CONSTRUCTION PHOTOS

GCC Gencor Counter Flow Dryer Drum Hot Plant

Aggregate Feeder Belt

ECOPATHS Equipment

Silo and Control Room

CAT AP655C Paver

CAT Roller

Figure A.1 Hot Plant and Construction Equipment

Pre-Construction Pavement Condition

Placing Tack Coat

Paving

Compacting

Completed Surface

Close-up

Figure A.2 Construction of DGAC Test Section

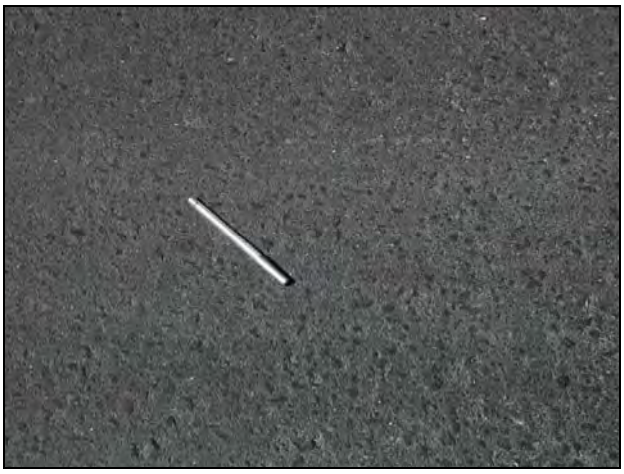
Pre-Construction Pavement Condition

Placing Tack Coat

Paving

Completed Surface

Completed Surface



Close-up

Figure A.3 Construction of MB-D Test Section

Pre-Construction Pavement Condition

Windrow and Pickup Machine

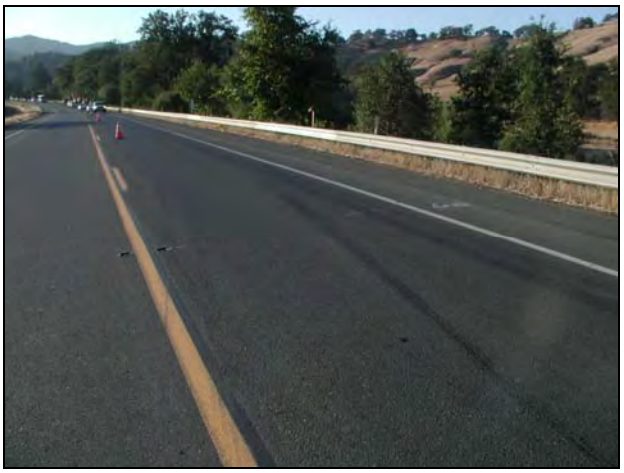
Material Sampling Behind Paver

Density Gage

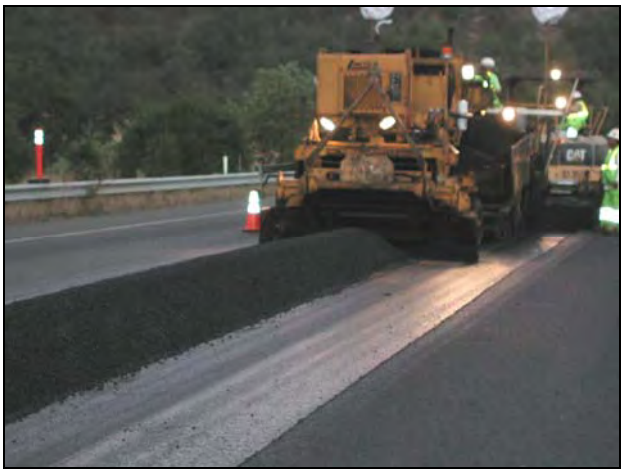
Completed Surface

Close-up

Figure A.4 Construction of RAC-G Test Section



Pre-Construction Pavement Condition



Windrow

Paving

Compaction

Completed Surface

Close-up

Figure A.5 Construction of RUMAC Test Section

APPENDIX B
MATERIAL TESTING DATA

Table B.1 Relative Compaction Results

DATE	AC TYPE	TEST NO.	RELATIVE COMP.	PASS/FAIL	LOCATION
08/09/05	A	1	97.5	PASS	TEST SECTION 4 - PM 40.27 TO BM #A (PM 40.85)
08/09/05	A	2	96.7	PASS	TEST SECTION 4 - PM 40.27 TO BM #A (PM 40.85)
08/09/05	A	3	96.3	PASS	TEST SECTION 4 - PM 40.27 TO BM #A (PM 40.85)
08/09/05	A	4	96.3	PASS	TEST SECTION 4 - PM 40.27 TO BM #A (PM 40.85)
08/10/05	A	5	98.4	PASS	TEST SECTION 4 - PM 40.27 TO BM #A (PM 40.85)
08/10/05	A	6	97.9	PASS	TEST SECTION 4 - PM 40.27 TO BM #A (PM 40.85)
08/11/05	A	7	98.8	PASS	TEST SECTION 4 - PM 40.27 TO BM #A (PM 40.85)
08/11/05	A	8	96.7	PASS	TEST SECTION 4 - PM 40.27 TO BM #A (PM 40.85)
08/12/05	G	9	97.9	PASS	LOCATION 3 - BM #B (40.85) TO PM 42.10
08/16/05	G	10	97.0	PASS	LOCATION 3 - BM #B (40.85) TO PM 42.10
08/16/05	G	11	97.5	PASS	LOCATION 3 - BM #B (40.85) TO PM 42.10
08/16/05	G	12	97.5	PASS	LOCATION 3 - BM #B (40.85) TO PM 42.10
08/17/05	DMB	13	98.4	PASS	TEST SECTION 2 - BM #C (PM 39.66) TO PM 39.04
08/17/05	DMB	14	96.7	PASS	TEST SECTION 2 - BM #C (PM 39.66) TO PM 39.04
08/17/05	DMB	15	98.4	PASS	TEST SECTION 2 - BM #C (PM 39.66) TO PM 39.04
08/18/05	G	16	96.3	PASS	TEST SECTION 3 - BM #D (PM 39.68) TO PM 40.30
08/18/05	G	17	96.7	PASS	TEST SECTION 3 - BM #D (PM 39.68) TO PM 40.30
08/18/05	G	18	97.9	PASS	TEST SECTION 3 - BM #D (PM 39.68) TO PM 40.30
08/18/05	G	19	97.5	PASS	TEST SECTION 3 - BM #D (PM 39.68) TO PM 40.30
08/19/05	G	20	97.0	PASS	LOCATION 3 - PM 41.5 TO 42.2
08/19/05	G	21	96.3	PASS	LOCATION 3 - PM 41.5 TO 42.2
08/19/05	G	22	100.0	PASS	LOCATION 3 - PM 41.5 TO 42.2
08/19/05	G	23	96.3	PASS	LOCATION 3 - PM 41.5 TO 42.2
08/22/05	G	24	97.5	PASS	LOCATION 3 - PM 42.2 TO 42.9
08/22/05	G	25	96.7	PASS	LOCATION 3 - PM 42.2 TO 42.9
08/22/05	G	26	96.3	PASS	LOCATION 3 - PM 42.2 TO 42.9
08/22/05	G	27	97.5	PASS	LOCATION 3 - PM 42.2 TO 42.9
08/23/05	RUMAC	28	98.0	PASS	TEST SECDTION 1 - BM #E (PM 37.72) TO PM 38.34
08/24/05	RUMAC	29	98.0	PASS	TEST SECDTION 1 - BM #E (PM 37.72) TO PM 38.34
08/24/05	RUMAC	30	96.4	PASS	TEST SECDTION 1 - BM #E (PM 37.72) TO PM 38.34
09/06/05	G	31	96.7	PASS	LOCATION 3 - PM 42.5 TO PM 43.0
09/06/05	G	32	95.8	FAIL	LOCATION 3 - PM 42.5 TO PM 43.0
09/06/05	G	33	96.7	PASS	LOCATION 3 - PM 42.5 TO PM 43.0
09/06/05	DMB	34	96.7	PASS	LOCATION 3 - PM 42.5 TO PM 43.0

Table B.2 Binder Content, Stability, Voids, and VMA Data from the Test Sections

Date Sampled	TL-101	Binder Content, %	Stability	Voids, %	VMA, %
DGAC	Target	5.4	37 min		
08/09/05	706401	5.9	44	2.8	
08/09/05	706402	5.6	46	4.3	
08/09/05	706403	5.7	46	4.3	
08/10/05	706404	5.5	45	2.8	
08/11/05	706405	5.7	42	4.7	
08/11/05	706406	5.1	46	4.3	
RAC-G	Target	7.9	23 min		18 min
08/18/05	706414	8.8	21		18.7
08/18/05	706415	7.9	38		20.8
08/18/05	706416	8.8	21		20.3
MB-D	Target	5.4	23 min		
08/17/05	706411	5.8	49	3.9	
08/17/05	706412	5.5	44	4.3	
RUMAC	Target	7.8	28 min		18 min
08/23/05	706423	7.6	32		18.4
08/24/05	706424	7.7	35		18.8
08/24/05	701026	8.1	27		18.5
08/24/05	706425	8.3	35		19.3