RUBBERIZED ASPHALT CONCRETE WARRANTY PILOT PROJECTS

VOLUME 1 - CONSTRUCTION REPORT

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Materials Engineering and Testing Services
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EXECUTIVE SUMMARY

Between 2002 and 2004 Caltrans built five pilot projects through its rehabilitation program that contain specifications for rubberized asphalt concrete (RAC) overlay and include a 5-year warranty on the RAC materials and workmanship. The overall objective of these RAC warranty pilot projects was to provide a "level playing field" for "wet process" (rubber-modified asphalt binders produced in the field or at a terminal) and "dry process" (CRM as an aggregate substitute) rubber-modified mixes that contain a minimum of 15% CRM (by total mass of binder).

This report is Volume 1 of a three volume series. Volume 2 is the interim performance report, which accompanies this report and includes performance monitoring results to date. Volume 3 will be a final report which will be prepared by Caltrans at the completion of the 5-year performance monitoring period.

This report presents a compendium of the available information related to site conditions, design, materials, and construction for the five individual RAC warranty projects. It is intended to provide information to supplement annual performance monitoring data and to help identify factors related to materials and/or construction that may affect the performance of the respective RAC pavements. Each of the 5 projects is presented in an individual chapter that addresses: traffic and environmental data; preconstruction activities including deflection testing, structural design, pavement condition survey; selection of performance evaluation sections (PESs) for warranty enforcement; surface preparation; construction activities (e.g., plant, materials, paving equipment, QC/QA data); post-construction testing and/or monitoring. Information and guidelines developed for the Resident Engineers (RE) overseeing RAC warranty projects are included in the Appendices which also contain detailed project-specific information, such as: pre-construction pavement condition survey data, photos, and deflection data; construction photos; and materials and testing data.

Performance of the respective projects and PESs is to be evaluated over time. Annual monitoring will provide the performance information required for warranty enforcement. However a full evaluation of RAC performance requires consideration of materials characteristics (including but not limited to gradation, binder content, mixture voids, stability), construction factors including compaction, structural adequacy of the pavement section including subgrade and base courses, and site conditions including drainage.

The warranty approach created some confusion regarding needs and responsibilities for sampling and testing. The warranty specifications did not include requirements for frequency of sampling and testing and thus available resources (which were typically limited), rather than the guidelines supplied to the REs, governed how much testing was performed. There were considerable differences in the amount of sampling and testing performed for the respective pilot RAC warranty projects by Caltrans, Contractors, and their respective agents. As a result, there are gaps in the available data. For some projects, the information needed for in-depth performance analysis is not available. If pavement distress does occur, additional sampling and testing may be required to identify the likely causes.

Recommendations include continuation of condition monitoring throughout the life of the subject RAC overlays. Limited District resources may require extending the interval between condition surveys of PESs to several years, but long term performance documentation would be useful even if limited. In addition, if Caltrans performs similar studies of any paving material in the future where sampling and testing are critical to the overall evaluation, it is recommended that the requirements for sampling and testing be included in the project special provisions to assure that they are followed.

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1.0 INTRODUCTION

1.1 BACKGROUND AND OBJECTIVES

Between 2002 and 2004 Caltrans built five pilot projects through its rehabilitation program that contain specifications for rubberized asphalt concrete (RAC) and include a 5-year warranty on the RAC materials and workmanship. Originally, it was envisioned that seven projects, CAPM or rehabilitation, would be constructed using the range of crumb rubber modifier (CRM) technologies. Candidate technologies included both the "wet process" (rubber-modified asphalt binders produced in the field or at a terminal) and "dry process" (CRM as an aggregate substitute). The overall objective of these RAC warranty pilot projects was to provide a "level playing field" for rubber-modified mixes that contain a minimum of 15% CRM (by total mass of binder).

Shifting some of the risk to the contractor is fundamental to the warranty concept. As such, two standard special provisions (SSPs) were developed which required the contractor to warrant the RAC materials and performance. In the way of review, performance is measured in terms of the following: rutting, raveling, flushing, delamination, cracking and potholes.

Ideally, a study of this scope and objective should have been based on a carefully crafted experimental design to include the full range of CRM technologies with "test" and "control" sections constructed in locations that reflect California's diverse climatic regimes. Given the political pressure to broaden and expand Caltrans use of scrap tires in paving applications, a side-by-side comparison of RAC and conventional asphalt concrete mixes might have generated additional supporting data as to performance and cost effectiveness of RAC. Unfortunately, attempts to identify projects during the planning and design stage were unsuccessful due to funding cycles and State budget problems. Furthermore, unfamiliarity with the CRM technology and/or uncertainty as to likely success may have compounded the difficulty in recruiting candidate projects. That said, the expected outcomes of the RAC warranty projects study include the following:

- Uniform application of the construction and performance criteria by the Resident Engineer (RE) in decisions regarding the enforcement of the warranty;
- Objective assessment of RAC performance and cost effectiveness; and
- Efficacy of the warranty specification and the resulting process.

As evident by the title, the emphasis of this report is on the construction-related activities of the RAC warranty projects. Still, to present a relatively complete compendium of the RAC Warranty project perspective and data, the information packet developed for the RE overseeing the design and construction of a RAC warranty project is included as Appendix A. This document provides background information as well as data collection guidelines and standard special provisions for the warranty (materials, workmanship and performance). These data collection guidelines encompass the following: pre-construction; mix design and laboratory testing; sampling and testing during construction; post-construction condition; and annual monitoring. As to annual monitoring, performance to date of the RAC warranty projects is addressed in a companion document [Caltrans, 2005]. Similarly, some project-specific design elements, e.g. traffic and environment, are included as they are critical factors in long-term field pavement performance and evaluation thereof.

As noted previously, only five of the original seven projects were constructed. Table 1.1 provides basic information on the RAC warranty projects, four of which employed the "wet process" technology. The Lassen project was constructed using a terminal blend process. Project locations are shown in Figure 1.1.

Table 1.1 RAC Warranty Projects

District	County	Route	Region	Project Limits		Project Length	
				Post Mile (PM)	Kilo Post (KP)	(mi)	(km)
02	Lassen	395	Mountainous	11.8-24.8	19.0 – 39.9	13.0	19.9
06	Fresno	33	Central Valley	62.4-69.4	100.4 – 111.7	7.0	11.3
07	Ventura	150	Coastal	15.2-24.0	24.4 – 38.6	8.8	14.2
10	Merced	140	Central Valley	27.0-30.2	43.4 – 48.6	3.2	5.2
11	San Diego	75	Coastal	11.0-17.4	17.7 – 28.0	6.4	10.3

Figure 1.1 Location of RAC Warranty Projects

1.2 ORGANIZATION OF THE REPORT

Each of the 5 projects is described in individual chapters, i.e., Chapters 2 through 6. Typically addressed for each project are the following: traffic and environmental data; preconstruction activities (e.g., deflection testing, pavement condition survey, design and surface preparation); construction activities (e.g., plant, materials, paving equipment, QC/QA data); post-construction testing and/or monitoring. Chapter 7 is an overall summary of observations, conclusions and recommendations. As previously noted, Appendix A is the information packet developed for the RE overseeing the RAC warranty project. Appendices B through F contain project-specific information: pre-construction pavement condition survey data; pre-construction photos and deflection data; construction photos; and materials and testing data.

2.0 VENTURA COUNTY, HIGHWAY 150

2.1 PROJECT LOCATION

The Ventura RAC Warranty project (EA No. 07-105484) is located along State Highway 150 in District 7, Ventura County, in and beyond Ojai, CA, which is primarily a two-lane roadway. The project extends 14.2 km (8.8 miles) from PM 15.0 (KP24.4 at Loma Drive) to PM 23.9 (KP 38.6 near the second Lion Canyon Creek Bridge). The project includes sections of roadway with curb and gutter and on-street parking within Ojai's central business district, local arterial and residential areas, and winding climbing and descending sections in rock-cut and embankment transition areas crossing over the foothill.

Figure 2.1 is a vicinity map illustrating the layout of the project. Construction of the RAC overlay for this project was completed in October 2002. Table 2.1 identifies the location and provides some basic information on the six PESs selected for this project.

Table 2.1 Location and Description of Six PESs for Ventura County, Highway 150

PES ID	Begin KP	Begin PM	Overlay or Mill/Fill
EB1	26.738	16.43	Overlay
EB2	31.446	19.35	Overlay
WB3	38.480	23.72	Overlay
WB4	31.850	19.60	Overlay
WB5	29.436	18.10	Mill/Fill
WB6	25.652	15.75	Overlay

2.2 DESIGN CONSIDERATIONS

The project is located within the Caltrans "South Coast" climatic area. Precipitation and temperature data [Caltrans, 2004a (Station #046399)] are shown in Table 2.2. Traffic [Caltrans, 2004b] in the vicinity of the project is characterized in Table 2.3.

Several design alternatives were considered by District 7 staff, as shown in Table 2.4, and a 60 mm gap-graded rubberized asphalt concrete (RAC-G) overlay was selected. However, the changing nature and existing structure of the roadway along the length of the project and constraints for matching existing adjacent structures resulted in four structural sections, with two different thicknesses of RAC. These structural sections are listed as shown on the project plans, along with a brief description of the RAC mix and placement.

1. 60 mm RAC overlay (single lift of 3/4" RAC Type G mix)
2. Cold plane existing AC pavement (45 mm max depth) and replace with 45 mm of RAC (single lift of 1/2" RAC Type G mix)
3. Cold plane existing AC pavement (60 mm max depth) and replace with 60 mm of RAC (single lift of 3/4" RAC Type G mix)
4. 45 mm RAC overlay (single lift of 1/2" RAC Type G mix)

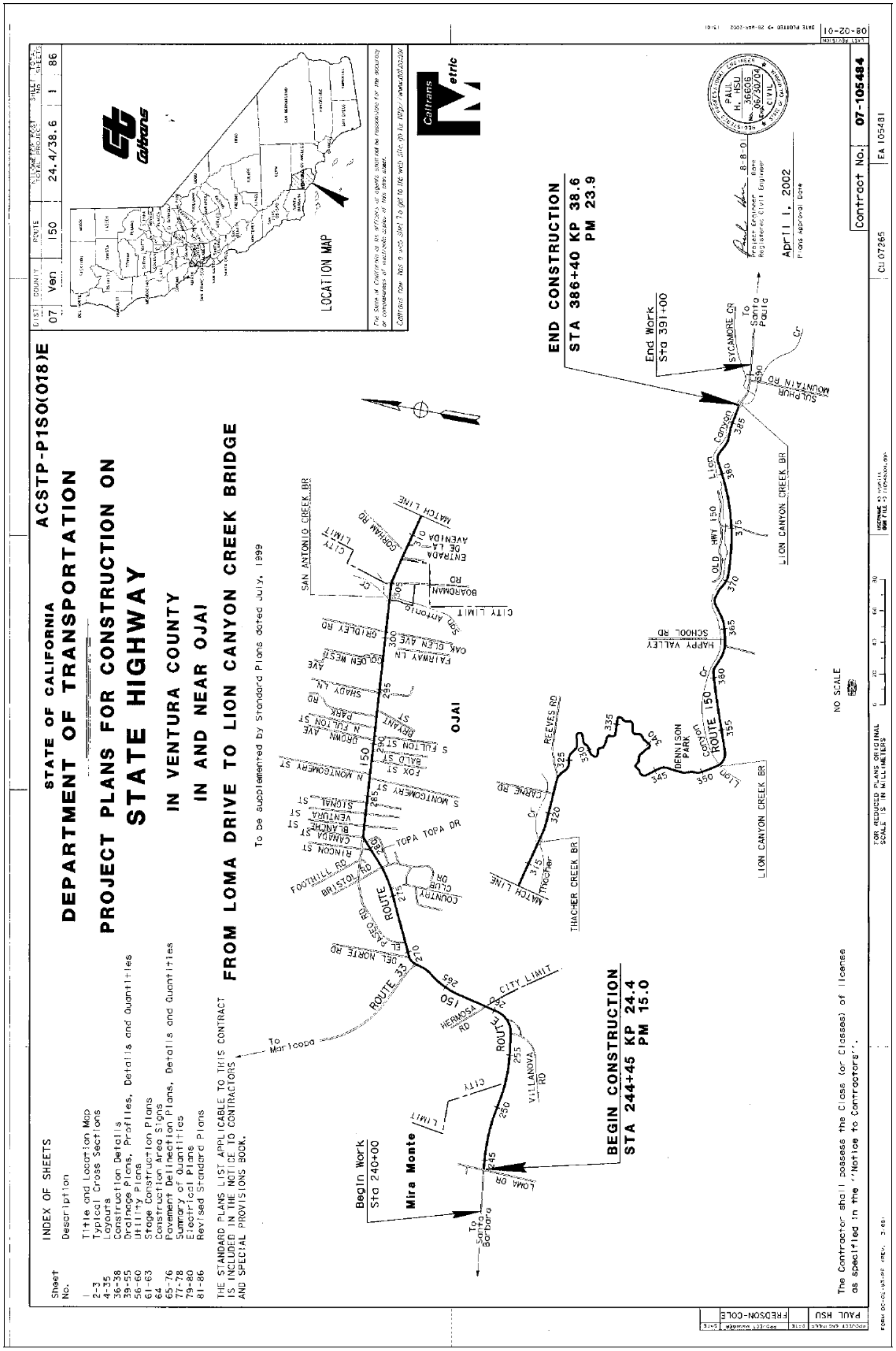

Figure 2.1 Ventura Project Location Plan

Table 2.2 Ventura Temperature and Precipitation Data

Element	Annual
Average Max Temp (°F)	77.7
Average Min Temp (°F)	45.3
Average Total Precipitation (in)	21.21
Average Total Snow Fall (in)	0.1
Average Snow Depth (in)	0.0

Table 2.3 Ventura 2003 Annual Average Daily Truck Traffic Data (AADT)

PM	KP	LEG*	Description	Vehicle AADT Total	Truck AADT Total	Truck % Total Vehicle	EAL 1-Way (1000)	Year Ver/Est
16.57	26.1	B	JCT. RTE. 33 NORTH	20000	438	2.19	76	03V
16.57	26.1	A	JCT. RTE. 33 NORTH	24400	776	3.18	70	03V
18.86	57.6	B	OJAI EAST CITY LIMITS	7800	112	1.44	13	03V
31.95	57.6	A	SANTA PAULA NORTH CITY LIMITS	3900	149	3.81	22	03V
34.39	55.3	B	JCT. RTE. 126, SANTA PAULA FREEWAY	15200	439	2.89	57	03V
* 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.								

Ver=Verified; Est=Estimated

Structural Section 1, the 60 mm RAC overlay was used on most of the project where surroundings are more rural (east and west ends). Sections 2 and 3 were used in the “urban” section of the project, where milling was required to match overlay surface elevation with the existing profile and grade of adjacent curb and gutter and other structures. Section 4 was located in one relatively short section in the eastern outskirts of Ojai, which transitioned to Structural Section 1. The plans included details for transitions in thickness between the structural sections.

2.3 PRE-CONSTRUCTION

The original 60 mm RAC overlay design thickness was based on a deflection study conducted in October 2000 by Caltrans Office of Materials Engineering & Testing Services (METS). A condition survey made at the time of this deflection study revealed the presence of longitudinal cracks, transverse cracks and isolated areas of alligator (fatigue) cracking.

Table 2.4 Ventura Caltrans Pavement Design Alternatives

<table>
<tr><td colspan="3">SOUTHBOUND TRAVELED WAY RECOMMENDATIONS FOR A 10-YEAR TI</td></tr>
<tr><td colspan="3">1. Test Traffic Numbers = 1-6 (0.014)
2. Area Limits (TI) = 9.0
3. Average Existing KP (PM) = 24.1/25.6 (15.0/15.9)
4. Average 80th percentile AC Pavement mm (ft) = 246mm (0.81)
5. Tolerable Percentile mm (in) = 0.402 (0.016)
6. Deflection mm (in) 0.356 (0.014)</td></tr>
<tr><td>Alternate 1 - DGAC Overlay - Conduct a field-review and locate specific areas of severe distress such as rutting greater than 15 mm and/or loose or spalling pavement. Dig out and repair the localized distressed areas and seal all cracks wider than 5 mm. Then:
1. Place dense graded asphalt concrete (DGAC) 105 mm (0.35 ft) thick
2. This will increase the profile grade 105 mm (0.35 ft)</td><td>Alternate 2 - RAC-G Overlay - Conduct a field-review and locate specific areas of severe distress such as rutting greater than 15 mm and/or loose or spalling pavement. Dig out and repair the localized distressed areas and seal all cracks wider than 5 mrn. Then:
1. Place rubberized asphalt concrete Type G (RAC-G) 60 mm (0.20 ft) thick This will increase the profile grade 60 mm (0.20 ft)</td><td>Alternate 3 - COLD PLANE OUSTING, REPLACE WITH DGAC - Conduct a field review and locate specific areas of severe distress such as rutting greater than 15 mm and/or loose or spalling pavement. Cold plane 90 mm (0.30 ft) and stockpile for future use. Dig out and repair the localized distressed areas and seal all cracks wider than 5 mm. Then:
1. Place DGAC 90 mm. (0.30 ft) thick
2. This will maintain the existing profile grade</td></tr>
<tr><td>Alternate 4 - SANH-R/DGAC - Conduct a field-review and locate specific areas of severe distress such as rutting greater than 15 mm and/or loose or spalling pavement. Dig out and repair the localized distressed areas and seal all cracks wider than 5 mm. Then:
1. Place a rubberized stress absorbing membrane interlayer (SANH-R)
2. Place 60 mm (0.20 ft) of DGAC, this will increase the profile grade 60 mm (0.20 ft)</td><td>Alternate 5 - SANE-F/DGAC - Conduct a field-review and locate specific areas of severe distress such as rutting greater than 15 mm and/or loose or spalling pavement. Dig out and repair the localized distressed areas and seal all cracks wider than 5 mm. Then:
1. Place a fabric stress absorbing membrane interlayer (SANH-F)
2. Place 75 = (0.25 ft) of DGAC
3. This will increase the profile grade 75 mm (0.25 ft)</td><td></td></tr>
</table>

2.3.1 Deflection Testing and PES Selection

Deflection testing (FWD) was undertaken by Caltrans in October 2000 prior to construction. Deflections were measured along the project at a typical spacing of 38m (125 ft), alternating from one roadway direction to the opposite at approximate 0.8 km (0.5 mi) intervals. Deflection data are shown graphically in Figures 2.2 and 2.3. Also, these figures show the HMA surface thickness. From these figures it is evident that there was considerable variability along the project though there were eight (8) areas of reasonable uniformity: two sections exhibited low sensor-1 deflections (less than 10 mils); three exhibited moderate deflections (10 to 15 mils); and three exhibited high deflections (greater than 15 mils). Deflection data are shown in Appendix B. In conjunction with the deflection data, pavement condition surveys conducted and FHWA/LTPP guidelines, six performance evaluation sections (PES) were selected for long-term monitoring as shown Table 2.5.

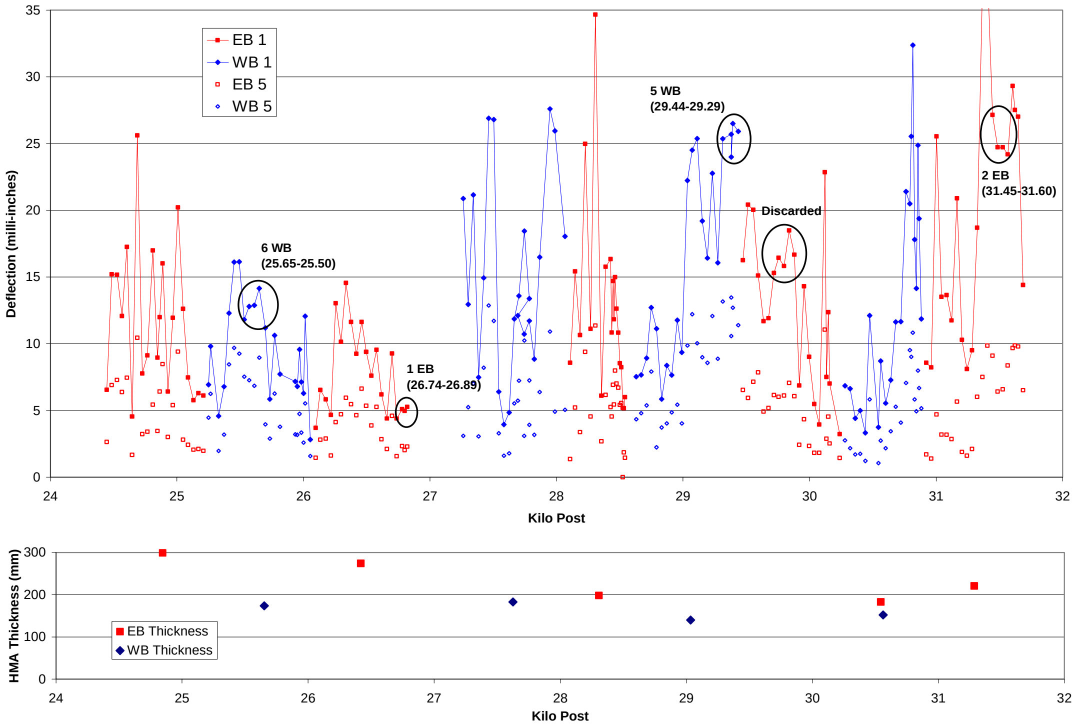

Figure 2.2 Ventura Profile Plot of FWD Deflections and HMA Surface Thickness KP 24.4 and 31.7

Figure 2.3 Ventura Profile Plot of FWD Deflections and HMA Surface Thickness KP 31.7 and 38.6

Table 2.5 Ventura Performance Evaluation Section Locations

PES ID	Begin Kilo Post	Begin Mile Post	Avg. Deflection (mils)	Overlay or Mill/Fill	Condition Description
EB1	26.738	16.425	5 (low)	Overlay	L-M severity longitudinal crack along construction joint; L-M-H severity fatigue cracking in left wheel path with water bleeding in first 100 ft; several M-H severity transverse cracks.
EB2	31.446	19.350	26 (high)	Overlay	Minimal distress: some L severity longitudinal cracking (with some water bleeding) and some L severity (onset of) transverse cracking.
WB3	38.480	22.721	14 (mod)	Overlay	Minimal distress: some L severity longitudinal and transverse cracking (onset)
WB4	31.850	19.601	6 (low)	Overlay	Probably milled and filled previously. Minimal distress – onset of transverse cracking.
WB5	29.436	18.101	26 (high)	M/F	Minimal distress: some L severity transverse cracking and some signs of flushing in WP.
WB6	25.652	15.750	13 (mod)	Overlay	Extensive distress: M-H severity transverse and block cracking.

Based on the FWD deflection data (low, moderate and high) each section was visually examined for type and distribution of distress. Overall, there was a relatively wide range of distress, as summarized in Table 2.5 and detailed in the condition survey data sheets in Appendix B. Photos are also included in Appendix B. Four of the PESs had minimal distress while other exhibited considerable distress, primarily in the form of transverse and block cracking of varying severity. As a result of the condition evaluation, one of the candidate sections (between KP 29.65 and 29.85 in the EB direction) was discarded because of variability in distress from one end to the other.

Most of State Highway 150 is on a relatively flat grade with little curvature. However, there is a foothill located between KP 32.5 and 34.5 which the road climbs over. This area exhibited relatively steep slopes, sharp curves and switchbacks, and some cut/fill areas. One candidate PES with relatively uniform deflections was located in this area between KP 33.78 and 33.94, but had to be discarded due to the slopes and curves.

The PESs were located in areas where overlay thickness was designated as 60 mm. Only one of the PES locations, WB5, required cold milling prior to overlay (i.e., mill and fill). For the remaining PES locations, only minor pre-overlay repairs were performed prior to the RAC overlay. For each of the RAC Warranty projects, the extent of pre-overlay repairs needed to make the project warrantable, aside from those required by the project special provisions, was up to the Contractor. With limited exceptions, such repairs had to be performed at no additional cost to the State and thus had to be included in the RAC bid price.

2.3.2 Pavement Condition Surveys and Surface Preparation

Results of the pre-construction manual distress surveys of the PESs, completed in September 2002, are summarized in Appendix B. Photos of the roadway and cores obtained during FWD testing are also presented in Appendix B. The existing in-place pavement generally exhibited relatively little distress (including some moderate to severe transverse cracks scattered throughout and spot locations where pumping, possible base movement, or flushing was observed) except for the west end of the project outside the Ojai city limits, which included PESs EB1 and WB6. The pavement in this area exhibited longitudinal cracks along construction joints and severe fatigue cracking in the wheel paths with evidence of base failure and water pumping to the surface. This area is at the base of a long tall hill on the south side of the roadway, which appears to drain directly into the roadbed and is the likely source of the water in the pavement structure. Deflections in PES EB1 were lower than would be expected based on the observed structural distress, but there is an old PCC pavement underneath some of the AC in this section that would affect FWD measurements. Sections of failed pavement in this area were removed and replaced with conventional DGAC prior to RAC overlay construction and the locations of the patches are summarized in Table 2.6.

Some pumping of water was observed in PES EB2, which is near Thacher Creek. There may have been some previous rehabilitation work in the vicinity of PES WB4 (KP 31.85) although this has not been verified.

Information provided to the bidders indicated that the minimum thickness of the existing asphalt concrete was 203 mm. However, cores taken near the high-severity fatigue cracking areas in the west end indicated an average asphalt concrete thickness of 138 mm, which may account for the observed structural distress, alligator cracking and base/subgrade failure. This discrepancy prompted a change order to add a 19 to 25 mm thick leveling course from Sta. 244+45 to Sta. 261+00, which corresponds to the area where most of the patching was done. Conventional DGAC was used for patching and for the leveling course. The Engineer noted that the leveling course would correct the surface cross slope and improve the ride quality of the roadway. It will also improve the pavement structural capacity, but does not provide a cross section equivalent to the 203 mm thickness that was the basis for the 60 mm overlay thickness design. Therefore, the long term performance of this section of the project and the two PESs within it may be affected by structural issues.

Table 2.6 Ventura Pre-Overlay Patching

Date	Lane	Station	Length (m)	Width (m)	Area (m^2)
10/21/2002	EB	247+89 to 248+29	40	1.22	48.8
10/21/2002	EB	248+60 to 248+75.7	15.1	1.68	25.37
10/21/2002	EB	249+15.12 to 249+90.92	75.8	1.22	92.48
10/21/2002	EB	250+01.58 to 250+27.66	26.08	1.22	31.82
10/21/2002	EB	250+66 to 250+94.44	28.44	1.52	43.23
10/21/2002	EB	251+62 to 254+04.32	242.32	1.52	368.33
10/22/2002	EB	254+45.77 to 255+18.92	73.15	1.22	89.24
10/22/2002	EB	255+39.65 to 256+04.27	64.62	1.22	78.84
10/21/2002	EB	259+41.07 to 259+59.05	17.98	1.37	24.63
10/21/2002	EB	260+10.26 to 260+40.74	30.48	1.22	37.19
10/22/2002	EB	261+14.5 to 261+33.7	19.2	0.91	17.47
10/22/2002	EB	261.67.87 to 262+15.69	47.85	1.22	58.38
10/22/2002	EB	262+33.06 to 262+47.39	14.33	1.22	17.48
10/22/2002	WB	259+13.63 to 259+66.67	53.04	1.52	80.62
10/22/2002	WB	259+95.63 to 260+42.87	47.24	1.52	71.8
	WB	256+16.27 to 256+74.77*	29.25	5.25	153.5
Area was divided in half due to grinding only being 4 inches rather than 8 inches 58.5 m long/2 = 29.25 m.				Totals	1239.23

2.4 CONSTRUCTION

2.4.1 General

Paving was done between 7 p.m. and 6 a.m. from 23 September 2002 through 29 October 2002. Traffic was controlled with the use of two flag personnel and a pilot car. The RAC-G was placed in windrows, picked up, and spread with a paving machine. Throughout most of the paving operation, the weather was relatively mild with temperatures ranging from 80ºF in the early evening to the low to mid 50sºF in the early morning, which is marginal for RAC paving. However there were nights in late October when air and pavement temperatures dropped below 50ºF which is colder than the minimum of 55ºF typically specified for RAC paving and may have affected compaction in some areas. The RAC paving lift thickness ranged from 45 mm to 60 mm, and paving width varied from 3.4 m and 5.4 m. Approximately 1.7 km of the project included steep grades and tight curves which presented some difficulties when attempting profilograph measurements. Paving was suspended by the contractor on 4 October due to issues with the California Profilograph. More detailed accounts of the PES paving, including windrow and mat temperatures, are shown in Tables 2.7 and 2.8.

2.4.2 Materials and Mix Design

The asphalt rubber binder consisted of 13.9% Pacific tire rubber and 4.1% Pacific high-natural rubber with 80.0% Greka AR-4000 Paving asphalt and 2.0% San Joaquin Extender Oil (all by weight of total binder). Crumb rubber gradation and physical properties of the asphalt rubber binder are summarized in Appendix B. The crushed aggregate (19 mm, 12.5 mm, 9.5 mm) and dust were provided by Vulcan Materials from its Palmdale source, California Mine ID 91-19-0020. The sand source was Best Rock from Grimes Canyon, California Mine ID 91-56-0010. Two mix designs were performed by Vulcan and verified by BTC Laboratories and the District 7 Materials Lab, a ½" mix for the 45 mm overlay, and a ¾" mix for the 60 mm overlay. Mix design target values for the two RAC-G mixes are shown in Table 2.9.

Table 2.7 Ventura PES EB1, EB2 and WB3 Associated Paving Details

PES EB1				PES EB2				PES WB3			
Paved Sunday October 20, 2002 First load down at 7:30am on the intersection of Hwy 33. At approximately 11:30-12:00, the hot plant sustained an electrical power surge, as such AC production ceased. At 11:19pm the breakdown roller was still near PES 0+00 the temperature was 194^{0}C At 11:48 the finishing roller was still on the test section and the temp was an average of 167^{0}C at PES STA 0+45 At 11:53, the finishing roller was off the 0+00 mark and the temperature was 161^{0}C				Paved Sunday October 28, 2002 Completed the westbound road to the west end of the project at approximately 11:45. Contractor paved the Villanova turnout (south side of road). Hermosa turnout was not milled correctly and the RAC was a little deeper than expected, but it may have turned out to be a good thing. A water line was hit somewhere in the upper section, and water flooded the section. It estimated to be 10 feet under ground and the water company hit the line at 6 feet and burst a 600 mm main water line. Repairs effected this evening. Contractor moved to pave the partial section in town on the westbound lane slightly west of Shady Lane and extending through Terrace Gardens and the vacant lot east of Terrace Gardens. The trucks sat for a little while and when the first load hit the grade, the temp was only 135^{0}C at 03:15am.				Monday, September 23, 2002 First load of RAC type ARHM-GG- B, onsite at 8:20pm, haul time is between 40 minutes and I hour, paving in the west bound lane first Began paving 8:40pm Completed 9:30pm. (40 min. pave time). Small area of diesel spill from the tack truck within the Performance Evaluation Section between section stations 1+13 and 1+15, in the outer wheel path. Tack is heavy between PES STA 1+10 and 1+12 Some dirt in the mix (windrow) PES STA 1+20 - 1+50 BTC Laboratories took cores within the PES Section limits STA 0+30 (top-lift only) and 0+120 (314 mm) in the mid-lane. Paved approx. 940 meters, 1029 Tonnes of RAC mix Stopped paving approx. 4:30am			
STA	Screed	Mat	Lift	STA	Windrow	Mat	Lift	STA	Windrow	Mat	Lift
0+00	113^{0}C	166^{0}C	75mm	0+00	150^{0}C	146^{0}C	70mm	0+30	151^{0}C	146^{0}C	70mm
0+15	113^{0}C	165^{0}C	74mm	0+45	155^{0}C	147^{0}C	70mm	0+75	151^{0}C	147^{0}C	70mm
0+30			74mm	0+75	150^{0}C		70mm	1+50	151^{0}C		65mm
0+75	116^{0}C		72mm	1+50	155^{0}C						
1+50		150^{0}C	72mm								
				Breakdown roller temp ranges from 111-126^{0}C Finishing roller temp ranges from 60-76^{0}C							

Table 2.8 Ventura PES WB4, WB5 and WB6 Associated Paving Details

<table>
<tr><th colspan="4">PES WB4</th><th colspan="4">PES WB5</th><th colspan="4">PES WB6</th></tr>
<tr><td colspan="4">Paved Tuesday October 01, 2002

First load of RAC onsite at 8:15pm

Began PES at 3:15am, completed paving PES at 4:10am

Ambient air temperature at 12:45am was 13^{0}C.

Paved approx. 732 meters in the west bound lane and 798 meters in the east bound lane tonight, finished paving at 5:15am.

Profile measurements using the James Cox & Son model CS8200 computerized Profilograph.

Performed vertical calibration procedure and checked tire pressure at 25 psi.

Profile measurements began in the outer wheel path of the east bound lane at 7:20pm on the original pavement surface station 322+61 to 317+22, began left wheel path profile at 7:50pm.</td><td colspan="4">Paved Wednesday October 02, 2002

Began paving at 7:30pm

Paving went smoothly with the exception of an occasional lag in RAC delivery.

Last load onsite at 5:00am</td><td colspan="4">Paved Thursday, October 03, 2002

Began paving at 7:30pm

Standing water is present in front of the Capri Hotel next to the curb and gutter, contractor paved over it.

It took two passes in the west bound lane to pave PES due to the street parking in this area.

Began paving the PES 01:15am, Completed paving PES 3:45am

Ambient air temperature during PES paving 21^{0}C

Variability in the thickness measurements within the PES due to the mill and fill against the curb and gutter.

Paving went smoothly with the exception of an occasional lag in RAC delivery.

Last load onsite at 5:30am</td></tr>
<tr><td>STA</td><td>Windrow</td><td>Mat</td><td>Lift</td><td>STA</td><td>Windrow</td><td>Mat</td><td>Lift</td><td>STA</td><td>Windrow</td><td>Mat</td><td>Lift</td></tr>
<tr><td>0+15</td><td>157^{0}C</td><td>148^{0}C</td><td>65mm</td><td>0+15</td><td>158^{0}C</td><td>124^{0}C</td><td>75mm</td><td>0+15</td><td>158^{0}C</td><td>149^{0}C</td><td>95mm</td></tr>
<tr><td>0+45</td><td>157^{0}C</td><td>149^{0}C</td><td>70mm</td><td>0+75</td><td>155^{0}C</td><td></td><td>75mm</td><td>0+75</td><td>155^{0}C</td><td></td><td>80mm</td></tr>
<tr><td>0+90</td><td>157^{0}C</td><td>148^{0}C</td><td>75mm</td><td>1+35</td><td>143^{0}C</td><td>144^{0}C</td><td>75mm</td><td>1+30</td><td>143^{0}C</td><td>153^{0}C</td><td>95mm</td></tr>
<tr><td>1+35</td><td>157^{0}C</td><td>148^{0}C</td><td>75mm</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Table 2.9 Ventura Mix Design Data

Sieve Size (mm)	½ inch RAC-G	¾ inch RAC-G
	Percent Passing	
25	100	100
19	100	98
12.5	96	79
9.5	84	70
4.75	36	32
2.36	16	16
0.6	9	9
0.075	1.8	2
% Asphalt (by weight of aggregate)	7.8	7.6
LA Rattler (loss at 100)	9.1 (10% max)	
LA Rattler (loss at 500)	35.5 (40% max)	
Sand Equivalent	64 (50 min)	
Hveem Stability	29	28
VMA, %	19.9	19.6
Air Voids, %	3.1	3.5

2.4.3 Asphalt Plant and Construction Equipment

The RAC-G mix was produced by Vulcan Materials in a dryer-drum plant located near Saticoy, CA. FNF Construction produced the asphalt rubber binder at the Saticoy plant, and placed and compacted the RAC-G mix on Route 150. The paving equipment utilized on the project is shown in Table 2.10.

Table 2.10 Ventura RAC Paving Equipment

Make	Type	Model
Merle Husky/Cat	Vibratory Paver	Model AP 1055B
Caterpillar	Steel Wheel Vibratory Roller (25,800 lbs)	Model CAT 634C
Ingersoll Rand	Steel Wheel Vibratory Roller (23,400 lbs)	Model DA110
Teamstar	2000 gal Tack Truck	

2.4.4 QC/QA Data

FNF's quality control plan for the test strip included the following testing: for aggregates, gradation, sand equivalent and LA abrasion; for the RAC-G mix, asphalt rubber content (by ignition), Hveem stability and air void content. Quality control testing requirements for RAC production are summarized in Table 2.11. Available QC and QA data are included in Appendix B. Similarly, results of the limited materials testing conducted by MACTEC (formerly Law Crandall), including asphalt rubber binder viscosity, RAC gradation and theoretical maximum specific gravity, are also shown in Appendix B. The test results indicate aggregate gradation and asphalt rubber content generally conformed to mix design targets and respective tolerances.

Table 2.11 Ventura QC Testing

<table>
<tr><th>Test Parameter</th><th>Frequency</th></tr>
<tr><td>Fractured Face</td><td rowspan="4">1/day</td></tr>
<tr><td>Sand Equivalent</td></tr>
<tr><td>Bulk Density</td></tr>
<tr><td>Hveem Stability</td></tr>
<tr><td>Gradation</td><td rowspan="3">1/5000 tonnes</td></tr>
<tr><td>Max Theoretical Density</td></tr>
<tr><td>Asphalt Content (by ignition)</td></tr>
<tr><td>In-Place Density</td><td>continuous</td></tr>
</table>

2.4.5 Observations and Comments

The contractor had extensive experience with RAC paving such that other than the usual challenges associated with nighttime paving, construction generally went smoothly. However there were some recurring issues with RAC delivery that occasionally interfered with paving operations. Haul time from Vulcan's Saticoy plant ranged from 40 minutes to one hour, depending on traffic and route which varied according to paving location within the project site. At times, the trucks were observed to gang (i.e. cluster together) along the route, which caused occasional lags in RAC mix delivery and forced the paver to stop. Such clustering also caused groups of trucks to arrive at the same time, which meant that some trucks had to wait to unload. Lags in delivery are noted in Tables 2.7 and 2.8 for three of the six PESs.

As noted previously, difficulties with the California profilograph measurements occurred on the east end of the project including the foothill area. The lags in RAC-G mix delivery likely also contributed to problems with achieving smoothness.

On some nights, ambient temperatures dropped below 55ºF. Temperature measurements of the windrows and the mat behind the paver generally indicate relatively good temperature control within the PESs, but there were some deviations over the duration of RAC overlay placement that may have affected compaction at some locations.

Prior to construction, the Contractor had expressed concerns with the suitability of using RAC-G in on-street parallel parking areas. MACTEC has been informed that some scuffs and raveling have been reported in these areas, but does not have specific location information at this time. It should be noted that there was reportedly some standing water on the pavement in PES 6WB in front of the Capri Hotel when it was overlaid with RAC-G which may have interfered with bonding of the overlay at this location.

3.0 FRESNO COUNTY, HIGHWAY 33

3.1 PROJECT LOCATION

The Fresno RAC Warranty project (EA No. 06-343534) is a two-lane roadway located along State Highway 33 in District 6, Fresno County, between Mendota and Firebaugh, CA. The project extends 7.0 mi (11.3 km) from PM 62.4 (KP 100.4 near Bass Avenue) to PM 69.4 (KP 111.7 near Main Canal Bridge). The subject section of Highway 33 is located in an agricultural area and also serves as a farm-to-market route. The RAC overlay for this project was constructed in August 2003. Figure 3.1 is a vicinity map illustrating the layout of the project. Table 3.1 identifies the location and provides some basic information on the six PESs selected for this project.

Table 3.1 Location and Description of Six PESs Selected for Fresno County, Highway 33

PES ID	Begin KP	Begin PM	Deflection Level	Overlay or Mill/Fill
NB1	103.31	64.25	High	Overlay
NB2	106.37	66.15	Low	Overlay
NB3	109.50	68.10	Moderate	Overlay
SB1	110.07	68.45	Low	Overlay
SB2	107.49	66.85	High	Overlay
SB3	105.39	65.54	Moderate	Overlay

3.2 DESIGN CONSIDERATIONS

The project area is located within the Caltrans 'Central Valley' climatic area. Precipitation and temperature data [Caltrans, 2004a (Station #043257)] are shown in Table 3.2. Traffic [Caltrans, 2004b] in the vicinity of the project is characterized in Table 3.3.

Table 3.2 Fresno Temperature and Precipitation Data

Element	Annual Readings
Average Max Temp (°F)	76.4
Average Min Temp (°F)	50.2
Average Total Precipitation (in)	10.88
Average Total Snow Fall (in)	0.1
Average Snow Depth (in)	0.0

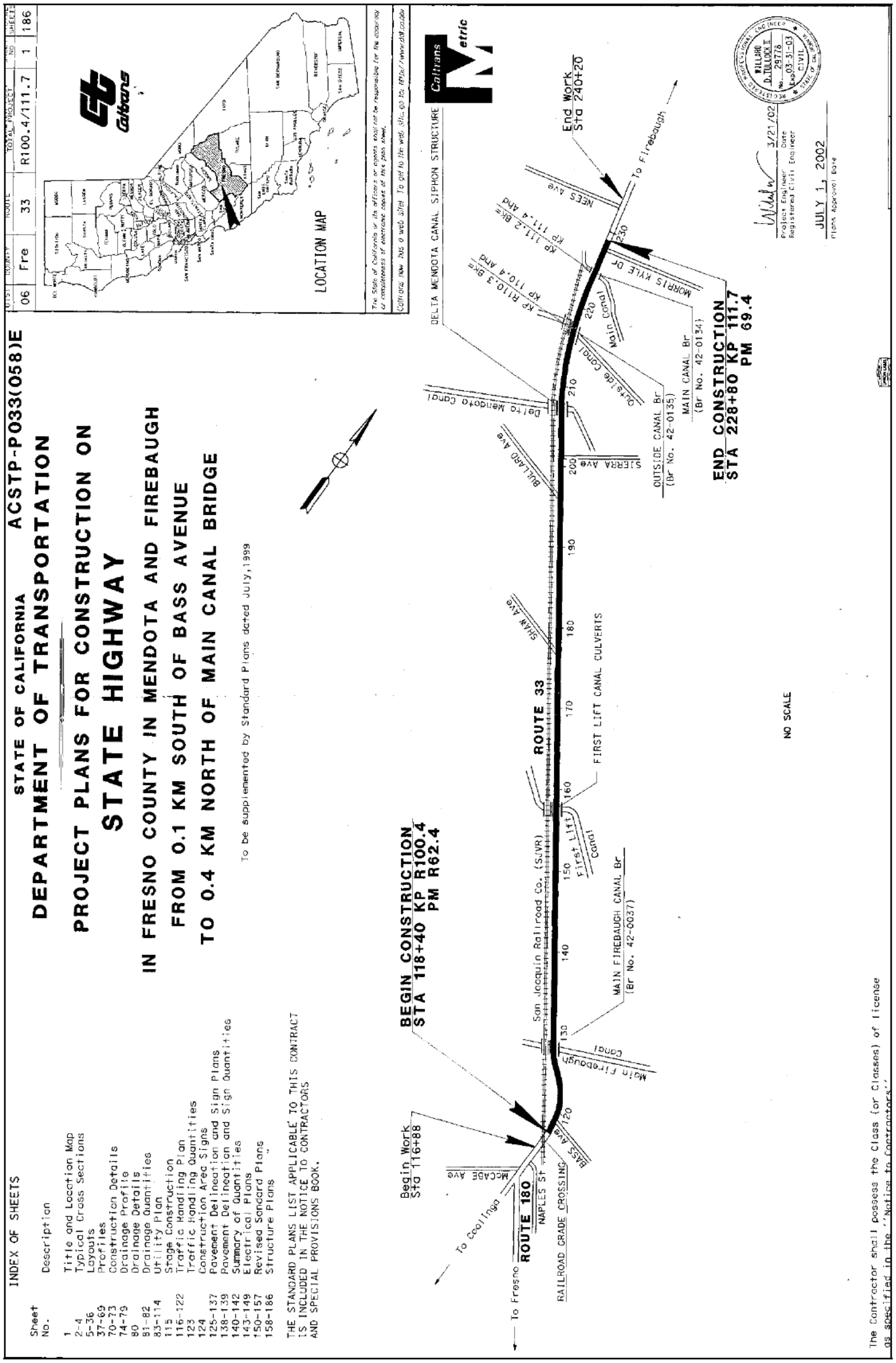

Figure 3.1 Fresno Project Location Plan

Table 3.3 Fresno 2003 Annual Average Daily Truck Traffic Data (AADT)

Post Mile	Kilo Post	LEG	Description	Vehicle AADT Total	Truck AADT Total	Truck % Total Vehicle	EAL 1-Way (1000)	Year Ver/Est
62.25	100.2	B	MENDOTA, JCT. RTE 180 EAST	5800	1682	29	394	01E
62.25	100.2	A	MENDOTA, JCT. RTE 180 EAST	6400	1280	20	138	01E
70.56	113.5	B	FIREBAUGH, 8^{TH} STREET	8700	1653	19	240	01V
70.56	113.5	A	FIREBAUGH, 8^{TH} STREET	7500	1425	19	207	01E

Ver=Verified; Est=Estimated

Although several design alternatives were considered, as shown in Table 3.4, a 60 mm gap-graded rubberized asphalt concrete (RAC-G) overlay was selected.

Table 3.4 Fresno Pavement Design Alternatives

<table>
<tr><td colspan="2">TRAVELED WAY RECOMMENDATIONS FOR A TEN-YEAR TI</td></tr>
<tr><td colspan="2">1. Design TI (TI) = 9.5
2. Average 80th percentile AC Pavement mm (inch) = 0.751mm (0.030)
3. Tolerable Percentile mm (in) = 0.356 (0.014)
4. Average AC thickness mm (in) 0.136 (0.45)</td></tr>
<tr><td>Alternate 1 - Cold Plane/DGAC Overlay Conduct a field-review and locate specific areas of severe distress such as rutting greater than 15 mm and/or loose or spalling pavement. Mill the existing AC pavement to remove the chip seal 30 mm (0.10 ft) deep and stockpile for future use. Dig out and repair the localized distressed areas and seal all cracks wider than 5 mm. Then: Place 120 mm (0.40 ft) of dense graded asphalt concrete (DGAC). This will increase the existing profile grade 90 mm (0.30 ft).</td><td>Alternate 2 - RAC-G Overlay Conduct a field-review and locate specific areas of severe distress such as rutting greater than 15 mm and/or loose or spalling pavement. Dig out and repair the localized distressed areas and seal all cracks wider than 5 mm. Then: Place 60 mm (0.20 ft) of rubber asphalt concrete-gap graded (RAC-G). This will increase the existing profile grade 60 mm (0.20 ft)</td></tr>
<tr><td rowspan="2">Alternate 3 - COLD-PIANE EXISTING, REPLACE WITH HRAC - Conduct a field review and locate specific areas of severe distress such as rutting greater than 15 mm and/or loose or spalling pavement. Mill the existing AC pavement to remove the chip seal 30 mm (0.10 ft) deep and stockpile this material for future use. Then mill an additional 45mm (0-15 ft) to reclaim asphalt pavement (RAP) for hot recycling. Dig out and repair the localized distressed areas and seal all cracks wider than 5 mm. Then: Place 150 mm (0.50 ft) of hot recycled asphalt concrete (HRAC). This will increase the existing profile grade 75 mm (0.25 ft).</td><td>Alternate 4 - COLD PLANE EXISTING, REPLACE WITH DGAC This alternative is especially useful to maintain grade at the structures. Conduct a field-review and locate specific areas of severe distress such as rutting greater than 15 mm and/or loose or spalling pavement. Mill 195 mm (0.65 ft) of the existing structural section and stockpile it for future use. Dig out and repair any remaining localized distressed areas. Then: Place 195 mm (0.65 ft) of DGAC. This will maintain the existing profile grade.</td></tr>
<tr><td>Remarks - Prior to choosing hot recycling as the planned alternative, a preliminary investigation must be made of the existing asphalt concrete pavement. Depending on the variation in the properties of the existing in-place material, recycling may not be appropriate. See Deputy Directive DD-17 dated November 17, 1993 on Recycling Asphalt Concrete.</td></tr>
</table>

3.3 PRE-CONSTRUCTION

Based upon the design drawings and verified from pre-construction coring, the existing roadway consisted of 136 mm of existing asphalt concrete (Type B) on 365 mm of base. As noted in the previous section, the contract work included a 60 mm RAC overlay of the existing roadway with new construction widening of the north bound lane. Additionally, a conventional asphalt concrete leveling blanket was planned on the south bound lane. The 60 mm RAC overlay design was based on a deflection study conducted in September 2000 by METS. A pavement condition survey made at the time of the deflection study revealed the presence of intermittent alligator cracking, rutting and pumping, and nearly continuous transverse and longitudinal cracking. A chip seal covered the entire project.

3.3.1 Deflection Testing and PES Selection

Pre-construction deflection testing was conducted in mid-March 2003 using a Falling Weight Deflectometer (FWD). Based upon the FWD data and pavement condition, six performance monitoring sections along State Highway 33 were selected, as shown in Figures 3.2 and 3.3. Based upon the average deflections, two sections were selected within each range: low (between 9 and 11 mils), medium (between 14 and 17 mils) and high (between 22 and 27 mils). Table 3.5 identifies the location and average deflections within each PES.

Table 3.5 Fresno Recommended Evaluation Section Locations

PES ID	Begin Kilo Post	Begin Mile Post	Avg. Deflection (mils)	Stationing
NB1	103.377	64.249	27.2 (high)	148+17 to 149+69
NB2	106.434	66.149	10.5 (low)	178+75 to 180+27
NB3	109.570	68.098	14.7 (med)	210+13 to 211+65
SB1	110.133	68.448	9.2 (low)	214+24 to 215+76
SB2	107.558	66.848	22.6 (high)	188+48 to 190+00
SB3	105.462	65.545	16.9 (med)	167+50 to 169+02

3.3.2 Pavement Condition Surveys and Surface Preparation

Pre-construction manual distress surveys were completed on each PES in July 2003. Results are detailed in Appendix C and summarized in Table 3.6. Transverse cracking and large areas of patching were observed within the project limits. Also evident was wheel path and non-wheel path longitudinal cracking, though the majority of cracks were sealed. Prior to the RAC overlay a conventional dense-graded asphalt concrete leveling blanket was placed on the south bound lane. The pre-overlay preparation work was completed in July 2003.

Table 3.6 Fresno Pre-Overlay Roadway Condition

PES	Station	General Condition
NB1	148+17 to 149+69	Large areas of patching
NB2	178+75 to 180+27	Sealed transverse cracking
NB3	210+13 to 211+65	Sealed longitudinal and transverse cracking
SB1	214+24 to 215+76	No visible distress
SB2	188+48 to 190+00	Right wheel path flushing, left wheel path patching, with water pumping evident.
SB3	167+50 to 169+02	Flushing, water pumping and patching with sealed block cracking

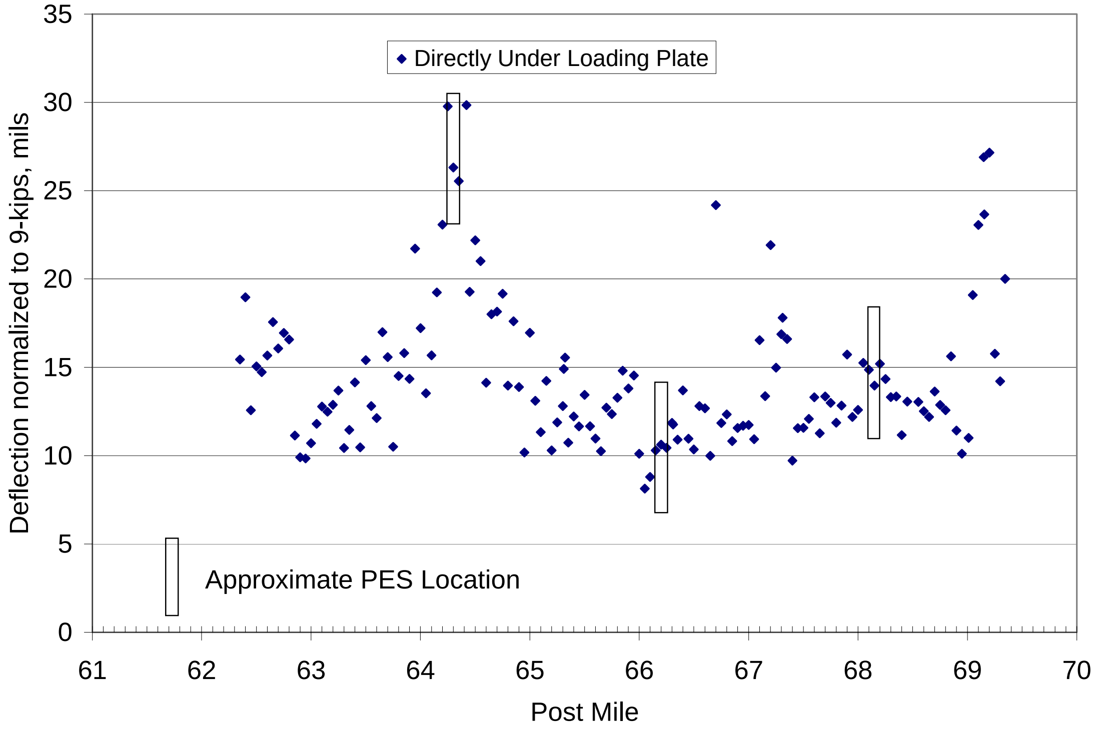

Figure 3.2 Fresno Northbound Deflection Profile and PES Location

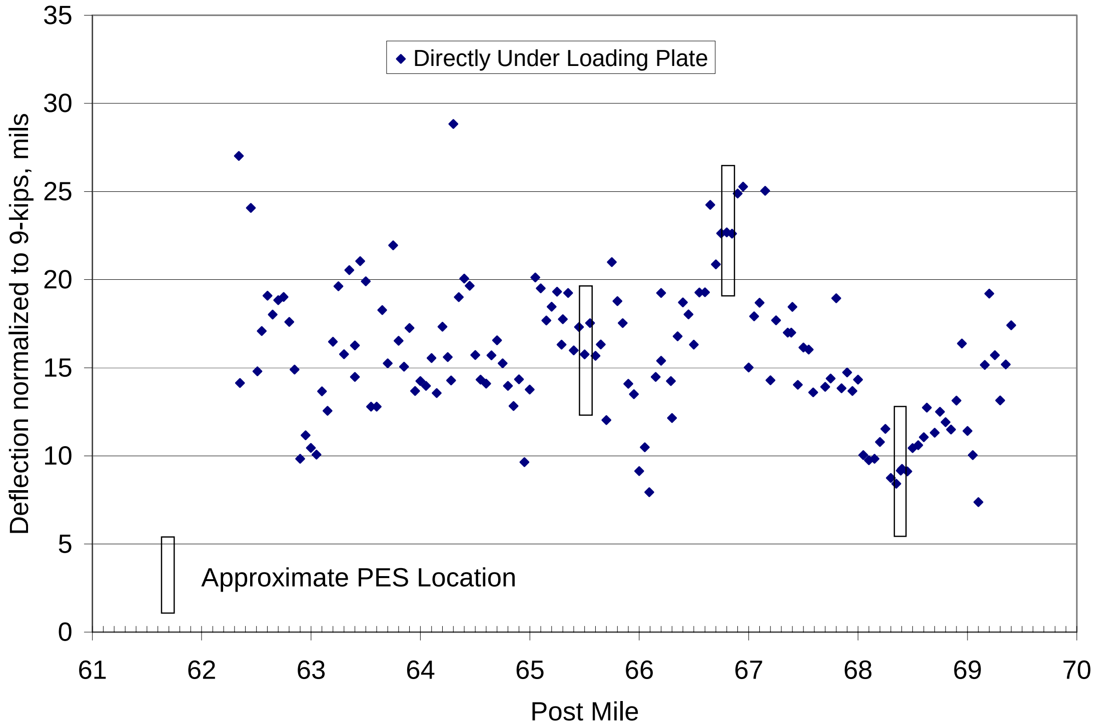

Figure 3.3 Fresno Southbound Deflection Profile and PES Location

3.4 CONSTRUCTION

3.4.1 General

RAC paving was done during the day between 11 and 21 August 2003. The range in ambient air temperature was 33ºC to 38ºC. The range in pavement surface temperature was 49ºC to 60ºC.

A pre-construction meeting was held at the District 6 office in Lemoore, CA on 7 August 2003 to discuss the data collection needs. In attendance were the following:

Jim Wilson	Caltrans, RE
Del Bains	Caltrans Sr. Engineer
Sarbjit Deol	Caltrans Inspector
Lee McClatchey	Lees Paving (Contractor)
Clifford Curry	Curry Group (Contractor)
Chris Antonucci	LAW Crandall
Mark Potter	LAW Crandall

Highlights of the meeting were as follows:

- Bains approved McClatchey's request to use the same mix design as that used for the Menefee project.
- McClathchey informed Wilson that BSK Labs would be employed for quality control, specifically to check temperatures, thickness, rolling patterns, and collect samples. Also, he indicated that test results would be reported to the RE within 4 days of sampling, though he did not indicate what testing would be performed.
- Bains informed the group that the District 6 laboratory would be conducting tests comparable to that required for a "QC/QA" project.

The first load of RAC hot mix arrived on-site about 0830 on 11 August 2003. The contractor spread tack at approximately 0.19 liter per meter^2 then began paving in the south bound lane, and shoulder (paving to the north). Paving equipment consisted of two paving machines, one each for the mainline and shoulder, and two steel drum vibratory rollers, one per paver. A tandem static steel roller was used for finish rolling of the shoulder and mainline. The rolling pattern for the mainline and shoulder consisted of five passes in vibratory mode, and one-full coverage with the static roller.

The paving operation went smoothly, with windrow temperatures reported to be approximately 127ºC to 130ºC. After paving approximately 1,021m the paving operation began paving in the north bound lane and shoulder (paving to the north) to even the paved lanes at the end of the day's construction. Tables 3.7 and 3.8 include paving highlights of the PESs.

3.4.2 Materials and Mix Design

The asphalt rubber binder was produced by FNF Construction, Inc. and consisted of 18% crumb rubber (75% scrap tire and 25% high natural rubber) and 2.5% extender oil by weight of total binder. The base asphalt cement was an AR-4000 from San Joaquin refinery. Physical properties of the asphalt rubber binder and blend viscosities as well as crumb rubber gradations are summarized in Appendix C. Table 3.9 includes results of tests on the 19 mm RAC-G mix performed by Caltrans District 6 Materials staff.

Table 3.7 Fresno PES NB1, NB2 and NB3 Associated Paving Details

<table>
<tr><th colspan="3">PES NB1</th><th colspan="3">PES NB2</th><th colspan="3">PES NB3</th></tr>
<tr><td colspan="3">Paved August 13, 2003

Daily paving started 08:50 hrs
PES Paved 14:00 hrs.

Three boxes of RAC samples, about 75 lb, were obtained at station 148+90.</td><td colspan="3">Paved August 15 & 18, 2003

This Performance Evaluation Section is 170 meters north of Shaw Road intersection. The contractor paved the taper for the Shaw road turn out, and stopped 29 meters into PES at Sta. 179+07 at 13:15 hrs., then backed up to begin paving the south bound lane, paving to the north. No samples taken.

Aug 18 at 08:30 beginning at station 179+07, 29 m into PES. Four boxes of RAC samples were collected at station 179+ 72.

There was a 30 minute wait for a haul truck at station 189+20. Paving of SB 2 was completed at 16:40 hrs</td><td colspan="3">Paved August 20, 2003

First truck onsite at 09:05 hrs.

Began paving at STA 207+40 NB

09:30 hrs. began paving shoulder of PES, and began main line paving in NB3 at 09:45 hrs.

Four boxes of RAC samples collected at 10:00 hrs at Sta 211+00.

Paving completed on PES at 10:15 hrs.</td></tr>
<tr><td>Air Temp</td><td>Mat Temp @ Roller</td><td>Windrow Temp</td><td>Air Temp</td><td>Mat Temp @ Roller</td><td>Windrow Temp</td><td>Air Temp</td><td>Screed Temp</td><td>Windrow Temp</td></tr>
<tr><td>33^{0}C
38^{0}C</td><td>90-125^{0}C</td><td>>125^{0}C</td><td>33^{0}C
38^{0}C</td><td>90-125^{0}C</td><td>90-125^{0}C</td><td>33^{0}C
38^{0}C</td><td>65^{0}C
71^{0}C</td><td>82^{0}C
85^{0}C</td></tr>
<tr><td colspan="3">Windrow Length 92-100 m
Average one-way haul time 1-2 hrs
Weather, Clear, dry with a slight breeze</td><td colspan="3">Windrow Length 31-61 m
Breakdown Roller from Paver 16-76m
Average one-way haul time 1-2 hrs
Weather, Clear with a slight breeze</td><td colspan="3">Air Voids 6-10% in mat
Oil Content 6.5-7.5%
Stabilities 25, 27</td></tr>
<tr><td colspan="9">Paving Equipment Setup

Tack Speed @ 0.18925 per m^{2}
Paver Spread rate = 12 mm
SKI Length – 2 @ 9.1 m
Paver installed with Joint Matcher
Dynapac 13 Ton - C522 frequency set to High – reading @ 58
5 Rolling passes in vibratory mode in both directions.</td></tr>
</table>

Table 3.8 Fresno PES SB1, SB2 and SB3 Associated Paving Details

<table>
<tr><td colspan="3">PES SB1</td><td colspan="3">PES SB2</td><td colspan="3">PES SB3</td></tr>
<tr><td colspan="3">Paved August 20 2003

12:50 hrs an ambulance drove on the hot mat in the northbound lane adjacent to the PES SB1.

15:00 hrs began paving shoulder on PES SB1.

Four boxes of RAC samples were collected on SB1 15:30 hrs at STA 215+00.

This section was completed at 16:00 hrs.</td><td colspan="3">Paved August 18, 2003

Collected four boxes of RAC samples 15:50 hrs at STA 188+95

There was a 30 minute wait for a haul truck at station 189+20.

Paving of SB2 was completed at 16:40 hrs</td><td colspan="3">Paved August 15, 2003

Paved at 14:00 hrs.

4 boxes of RAC, about 100lb, were collected within the section limits at STA 168+18.

Contractor completed the paving of this section at 14:28 hrs.

Two pavers–mainline and shoulder.

One vibratory roller per.</td></tr>
<tr><td>Air Temp</td><td>Mat Temp @ Roller</td><td>Windrow Temp</td><td>Air Temp</td><td>Mat Temp @ Roller</td><td>Windrow Temp</td><td>Air Temp</td><td>Mat Temp @ Roller</td><td>Windrow Temp</td></tr>
<tr><td>33^0C
38^0C</td><td>$90\text{-}125^0C$</td><td>$90\text{-}125^0C$</td><td>33^0C
38^0C</td><td>$90\text{-}125^0C$</td><td>$90\text{-}125^0C$</td><td>33^0C
38^0C</td><td>$90\text{-}125^0C$</td><td>$90\text{-}125^0C$</td></tr>
<tr><td colspan="3"></td><td colspan="3">Windrow Length 31-61 m
Breakdown Roller from Paver 16-76 m
Average one-way haul time 1-2 hrs
Weather, Clear with a slight breeze</td><td colspan="3"></td></tr>
<tr><td colspan="9">Paving Equipment Setup

Tack Speed @ 0.18925 per m^2
Paver Spread rate = 12 mm
Ski length – 2 @ 9.1 m
Paver installed with Joint Matcher
Dynapac 13 Ton - C522 frequency set to High – reading @ 58
5 Rolling passes in vibratory mode in both directions.</td></tr>
</table>

Temperatures are surface measurements obtained by infrared device operated by others. Although the values listed in Tables 3.7 and 3.8 may not accurately represent the temperature inside the windrow or under the mat surface, these measurements indicate that the mix had cooled considerably from the consistent 150 to 152ºC surface temperature measured in the haul trucks. Surface cooling creates temperature segregation that results in differential compaction. The reported mat surface temperatures are low, which would also be expected to interfere with achieving adequate compaction.

Table 3.9 Fresno Mix Design Data

Aggregate Gradation			Specimen Characteristics				
Sieve Size (mm)	Target Value	Contract Compliance	Detail	Result			
25.4	100	100	Percent Oil Content	7.0	7.5	8.0	8.5
19	99	99-100	Hveem Stabilometer	36	40	54	46
12.5	84	79-89	VMA %	17.3	18.5	18.6	18.2
9.5	66	61-71	Air Voids %	3.6	4.04	3.05	1.62
4.75	34	29-39	Swell (mm) Kc	1.0			
2.36	21	18-26	Swell (mm) Kf	1.0			
0.6	11	6-14	Recommended Bitumen Content 7.2 - 7.5 %				
0.075	2	2-7					

Aggregate Quality Tests			Percent of Crushed Particles			
Test	Result	Spec.	Sieve Size (mm)		%	Aggregate Type
Crushed Coarse %	98	90	Bin 5	19mm	21	Coarse
Crushed Fine %	100	90	Bin 4	12.5mm	23	
LA Rattler (100 revs)	-	10	Bin 3	9.5mm	32	
LA Rattler (500 revs)	21	40	Bin 2	Dust	10	
Sand Equivalent, 50 min.	83	50	Bin 1	Sand	14	Fine
Test Number 6-03-046, 30 May 2003						

3.4.3 Asphalt Plant and Construction Equipment

The equipment utilized is listed in Table 3.10. The RAC-G mixture was supplied by Vulcan Materials' Friant AC drier-drum plant. An example of Caltrans plant inspection reports is shown in Table 3.11.

Table 3.10 Fresno RAC Paving Equipment

Make	Type	Model
Ingersoll Rand Blaw Knox	Paver with CMI Pickup Machine (3.7 m mainline paving)	Model 5510
Ingersoll Rand Blaw Knox	Paver with Lincoln Pickup Machine (2.4 m shoulder paving)	Model 4410
Dynapac	13 Ton Tandem Roller	Model C522
Dynapac	10 Ton Tandem Roller (shoulder paving)	Model C232
Hyster	10 Ton Tandem Static Roller (Finish rolling shoulder and mainline)	
Various	33 Double Trailer Belly Dumps	

Table 3.11 Fresno Summary AC Plant Production Data

Base Asphalt Grade	Asphalt Modifier	Scrap Tire CRM	High Natural
79.95% AR400	2.05%	13.86%	4.14%
Plant Production Report Items			
Date	Details		Recording
August 11, 2003	Asphalt Oil Temp		204^{0}C (400^{0}F)
	Viscosity Tube		2600, 2800, 3800 cPa
	AC Batching Started		07:00 am
	AC Daily production		1970 Tonnes
	Production rate		325 Tonnes/hr
	Oil %		7.5 %
	Mix Temp		156^{0}C (314^{0}F)
August 18, 2003	Truck Mix Temps from 08:19 hr to 12:45 hr		152-156^{0}C
	Rate of AR Blend		20 Tonnes/hr
		AR Blend wet	6.8%
	Bin 5	19mm Aggregate	29%
	Bin 4	12.5mm Aggregate	22%
	Bin 3	9.5mm Aggregate	25%
	Bin 2	Rock-dust	10%
	Bin 1	Sand	14%
August 20, 2003	Rate of AR Blend		20 Tonnes/hr
		AR Blend wet	6.8%
	Bin 5	19mm Aggregate	22%
	Bin 4	12.5mm Aggregate	25%
	Bin 3	9.5mm Aggregate	29%
	Bin 2	Rock-dust	10%
	Bin 1	Sand	14%
	Truck Mix Temps from 07:45 hr to 14:45 hr		150-152^{0}C

** Data extracted from Caltrans Plant Inspection Report notes.*

3.4.4 QC/QA Data

BSK Laboratories performed quality control sampling and testing, as well as construction monitoring. BTC collected and split samples with District 6 lab for purposes of quality assurance testing. Material testing results are included in Appendix C. Table 3.12 presents the available test results.

Target asphalt rubber binder content was 7.5% by weight of dry aggregate. Results of tests performed by Caltrans and presented in Table 3.12 yielded asphalt rubber binder contents that ranged from 5.03 to 8.04% (average 7.03% for 31 tests). Corresponding gradation results could not be located. QC test results from BSK Laboratories show a narrower range of binder contents, from 5.90 to 7.59%, with an average of 6.9% for 30 tests. Very few individual test results were higher than the mix design target. However 19 of the total 61 test results reviewed yielded asphalt rubber binder contents less than 6.9%, which raises concerns about potential for raveling and long-term durability. The minimum asphalt rubber binder content for RAC-G is set at 7.0% by dry weight of aggregate because RAC-G pavements with lower binder contents reportedly tend to ravel and have not performed well.

Six sets of two cores each (1A-B through 6A-B) were tested for in-place air voids content. Compaction of sets 1, 2, and 3 was good, with air voids contents ranging from 6.1 to 7.0%. However sets 4 and 5 yielded relatively high in-place air voids contents ranging from 10.3 to 11.8%, which may be a function of low placement and compaction temperatures. Core set 6 had marginal air voids contents of 9.2 and 9.8%.

Table 3.12 Fresno Daily Test Result Summaries

Characteristic	Daily Test Results								
	Aug 11		Aug 12	Aug 13	Aug 14	Aug 15	Aug 16	Aug 18	Aug 20
				PES Paving		PES Paving		PES Paving	PES Paving
Sieve Size (mm) 25.0 19.0 12.5 9.5 4.75 2.36 1.18 0.600 0.300 0.150 0.075	 100 100 88 71 37 23 17 11 7 5 3.8	 **100** **99** **83** **65** **32** **21** **15** **9** **6** **4** **3.1**							
Bitumen (CT 382)	7.98 7.41 7.53		7.33 7.56 7.58	7.35 6.99 6.10 7.30	6.53 7.36 7.00 6.96	7.20 6.42 6.99 7.21 7.40		5.03 6.12 7.03 6.41 7.70 7.27	6.96 5.54 7.58 7.03 8.04 7.06
	6.63 7.40 7.56		**7.02 6.80**	**5.96 6.82**	**7.20**	**7.03 7.30**	**7.37**	**6.84 6.06**	**6.37 7.59**
CT 382	**6.57 7.46 7.50**		**6.96 6.74**	**5.90 6.76**	**7.14**	**6.97 7.24**	**7.31**	**6.78 6.00**	**6.31 7.53**
Specific Gravity Briq. (CT 308)	2.33 2.33 2.31		2.32 2.34 2.35	2.31 2.32 2.28 2.34	2.25 2.28 2.29 2.33	2.30 2.30 2.30 2.29 2.33		2.32 2.32 2.33 2.31 2.32 2.32	2.33 2.29 2.32 2.30 2.34 2.33
	2.33								
RICE Theo. BSG ASTM 2041	**2.402**		**2.418**						
Stabilometer	20 24 27		33 23 20	38 40 37 34	47 51 48 36	38 40 37 35 37		42 40 34 37 29 21	42 50 25 49 12 31
	25		**27**	**37**	**40**	**45**	**37**	**40**	**-**
Air Voids	1.40 2.06 2.78		2.37 1.47 1.01	2.98 2.97 5.71 1.74	6.44 4.20 4.22 2.58	3.56 4.49 3.81 3.98 2.06		5.34 4.01 2.51 4.01 2.15 2.64	2.58 5.95 2.27 3.77 0.93 2.47

*Results extracted from Caltrans Test reports TL-0302
Contractor Lab BSK results report in bold font

3.4.5 Observations and Comments

RAC construction appeared to run smoothly. However, if the typical windrow and mat surface temperatures of 90-125ºC reported for the PESs are correct, then the RAC-G mix was placed and compacted at excessively low temperatures in spite of the relatively high ambient and pavement temperatures. Caltrans specifies a minimum spread temperature of 138ºC, minimum breakdown compaction temperature of 135ºC, and completion of breakdown compaction before the mix temperature drops below 121ºC. Windrow temperature readings of 82ºC and 85ºC for PES NB3 are likely erroneous. At such low temperatures, the RAC-G mix would be very stiff and difficult to spread; workability would be poor at best and compaction difficult to achieve.

Asphalt rubber binder content results indicate a wide range of contents, nearly one-third of which fell below the SSP minimum requirement of 7.0% by weight of dry aggregate. This could have major impacts on performance of the resulting RAC-G pavement. Areas with low binder contents may ravel relatively quickly, particularly if in-place air voids contents are high. Only two tests yielded binder contents more than 0.4% higher than the 7.5% design target. The relatively low binder content results do not indicate potential for flushing or bleeding of the RAC-G mix, which are not typical distresses for RAC-G pavements. However 18 of 31 laboratory-compacted specimens had mixture voids below 3.0% which raises some concerns about potential for flushing or bleeding in the overlay.

During performance monitoring, binder content and in-place air voids content should be considered as factors in the RAC evaluation. The low compaction in some areas of the project is likely to affect long-term pavement performance, and may increase potential for rutting (primarily as further consolidation under traffic) and decrease resistance to moisture damage. Areas with good compaction and sufficient binder would be expected to perform better and to be less likely to ravel.

4.0 MERCED COUNTY, HIGHWAY 140

4.1 PROJECT LOCATION

The Merced RAC Warranty project (EA No. 10-0A5804) is a two-lane roadway located along State Highway 140 in District 10, Fresno County, near Merced, CA. The project extends 3.2 miles (5.2 km) from PM 27.0 (KP 43.4) near McSwain Road to PM 30.2 (KP 48.6), 0.8 mi (1.2 km) east of Applegate Road. The RAC overlay for this project was constructed in September 2003. Figure 4.1 is a vicinity map illustrating the layout of the project. Table 4.1 identifies the location and provides some basic information on the six PESs selected for this project.

Table 4.1 Location and description of six PESs selected for Merced County, Highway 140

PES ID	Begin KP	Begin PM	Deflection Level	Overlay or Mill/Fill
WB1	47.737	29.69	High	Overlay
WB2	46.931	29.19	Moderate	Overlay
WB3	44.759	27.84	Low	Overlay
EB1	44.221	27.50	Low	Overlay
EB2	45.258	28.15	High	Overlay
EB3	45.894	28.54	Moderate	Overlay

4.2 DESIGN CONSIDERATIONS

The project area is located within the Caltrans 'Central Valley' climatic area. Precipitation and temperature data [Caltrans, 2004a (Station #045532)] are shown in Table 4.2. Traffic [Caltrans, 2004b] in the vicinity of the Merced RAC project is characterized in Table 4.3.

Table 4.2 Merced Temperature and Precipitation Data

Element	Annual Readings
Average Max Temp (°F)	76.4
Average Min Temp (°F)	47.3
Average Total Precipitation (in)	12.36
Average Total Snow Fall (in)	0.0
Average Snow Depth (in)	0.0

Table 4.3 Merced 2003 Annual Average Daily Truck Traffic Data (AADT)

Post Mile	Kilo Post	LEG	Description	Vehicle AADT Total	Truck AADT Total	Truck % Total Vehicle	EAL 1-Way (1000)	Year Ver/Est
16.22	26.1	B	JCT. RTE. 165	3400	357	10.5	73	97E
16.22	26.1	A	JCT. RTE. 165	3300	383	11.6	95	97V
35.78	57.6	B	MERCED, JCT. RTES. 99/59	9800	392	4	80	98V
35.79	57.6	A	MERCED, JCT. RTES. 99/59	16500	990	6	167	98V

Ver=Verified; Est=Estimated

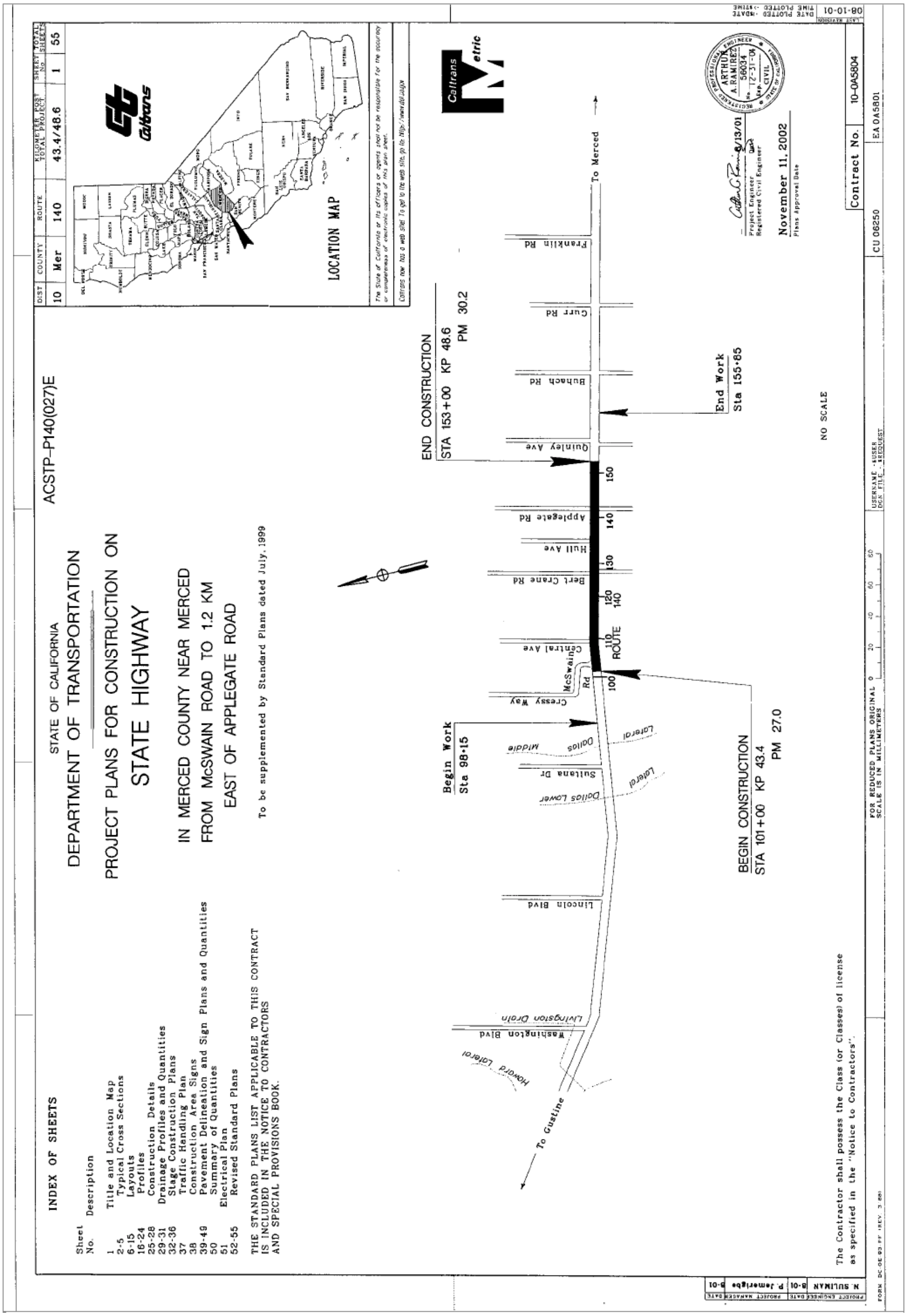

Figure 4.1 Merced Project Location Plan

Although several design alternatives were considered by District 10 staff, as shown in Table 4.4, a 60 mm rubberized asphalt concrete (RAC-G) overlay was selected.

Ten-year design recommendations for a TI = 9.5 were based on the deflection study conducted in July 2000. Additionally, pavement condition survey (PCS) data, photo logs and longitudinal profile data (International Roughness Index of 108) were considered. Records indicate that an approximate 30 mm AC overlay had been placed on the project in late 1997 or early 1998. Cracks reflected through this overlay within 2 years. A distress survey conducted at the time of the deflection study indicated the presence of intermittent alligator, transverse and longitudinal cracking with occasional pumping and rutting.

Table 4.4 Merced Pavement Design Alternatives

10 YEAR REHABILITATION RECOMMENDATIONS	
Alternative I Dense Graded Asphalt Concrete (DGAC) Plus Rubberized Asphalt Concrete (Warranty) Overlay – Conduct field review and locate specific areas of severe distress such as rutting greater than 15 mm and/or loose or spalling pavement. Repair the localized distressed areas and seal all cracks wider than 5 mm. Then: Place 45 mm of dense graded AC 1. Place 45 mm of rubberized asphalt concrete (Warranty) 2. This alternative will increase the existing profile grade 90 mm	Alternative 2 Rubberized Asphalt Concrete (Warranty) Overlay - Conduct a field review and locate specific areas of severe distress such as rutting greater than 15 mm and/or loose or spalling pavement. Repair the localized distressed areas and seal all cracks wider than 5 mm. Then: 1. Place 60 mm of rubberized asphalt concrete (Warranty). 2. This alternative will increase the existing profile grade 60 mm.

4.3 PRE-CONSTRUCTION

Based upon pre-construction coring the existing pavement structure consisted primarily of 179 mm of AC over 195 mm of aggregate base (AB). Core photographs are shown in Appendix D.

4.3.1 Deflection Testing and PES Selection

Prior to construction FWD testing was undertaken in June 2003 as part of the PES selection process. Deflection data are included in Appendix D. Figures 4.2 to 4.5 illustrate the variation in deflection along the project route. Figures 4.2 and 4.3 provide deflection profile plots for the EB and WB lanes in stationing (meters), whereas Figures 4.4 and 4.5 provide similar data in kilo-post (KP) units. The allowable limits reflect a range of relatively uniform deflections within which the PES was chosen. Tables 4.5 shows the locations of the PESs selected.

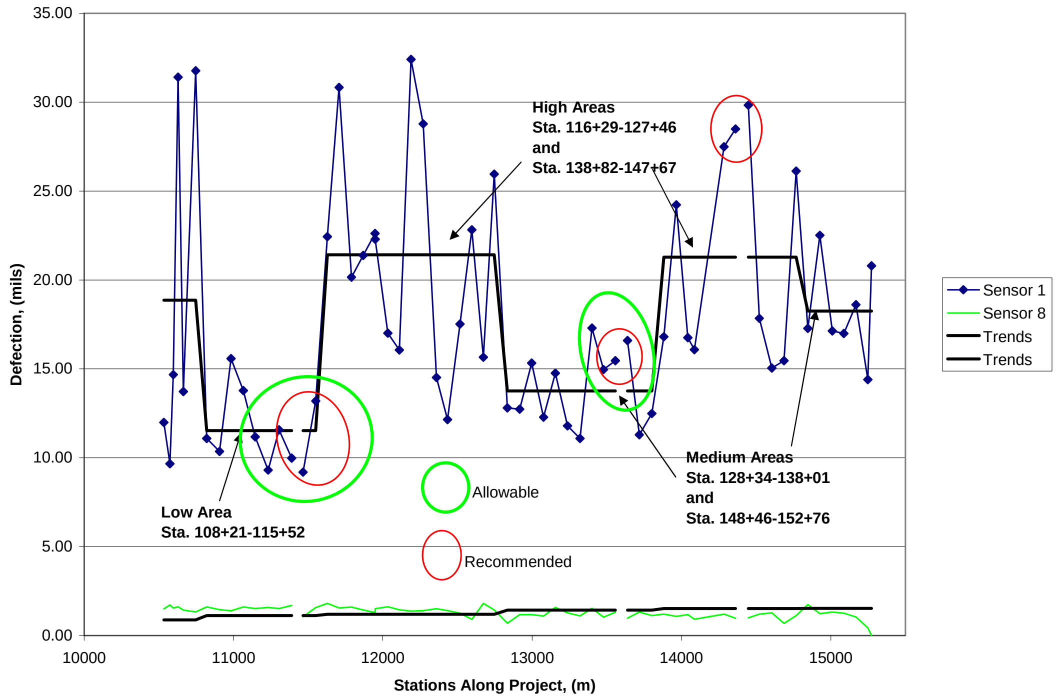

Figure 4.2 Merced West Bound Evaluation Section Locations (stations)

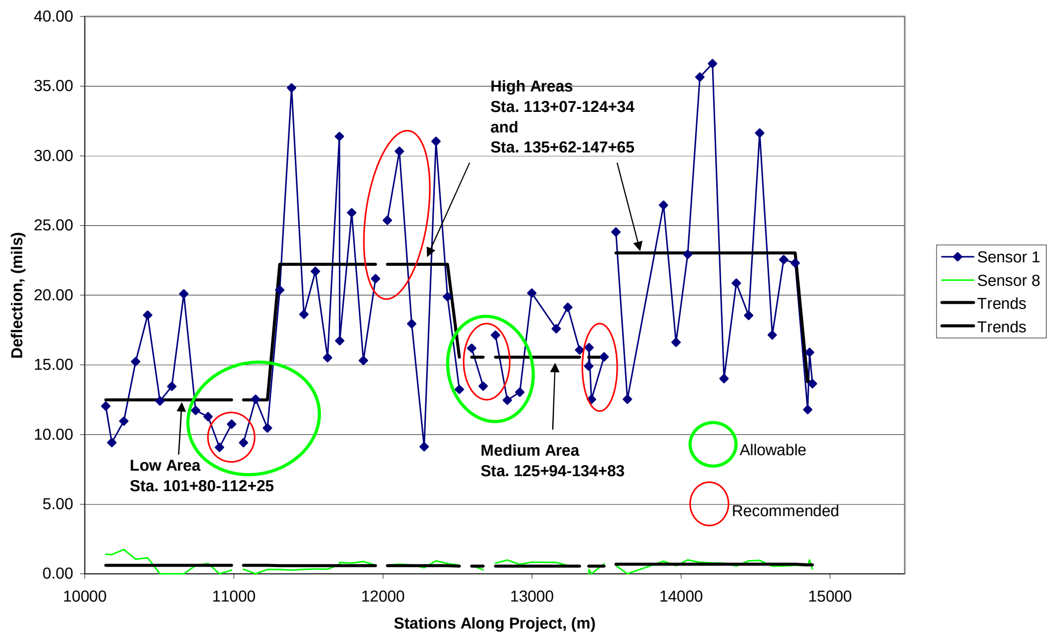

Figure 4.3 Merced East Bound Evaluation Section Locations (stations)

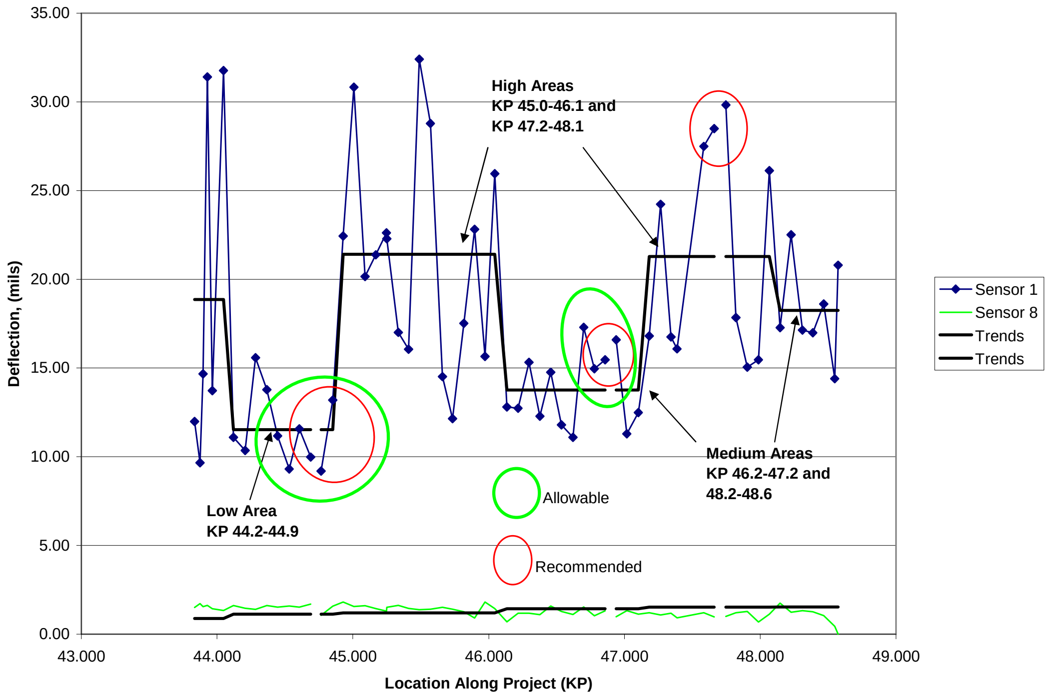

Figure 4.4 Merced West Bound Evaluation Section Locations (KP)

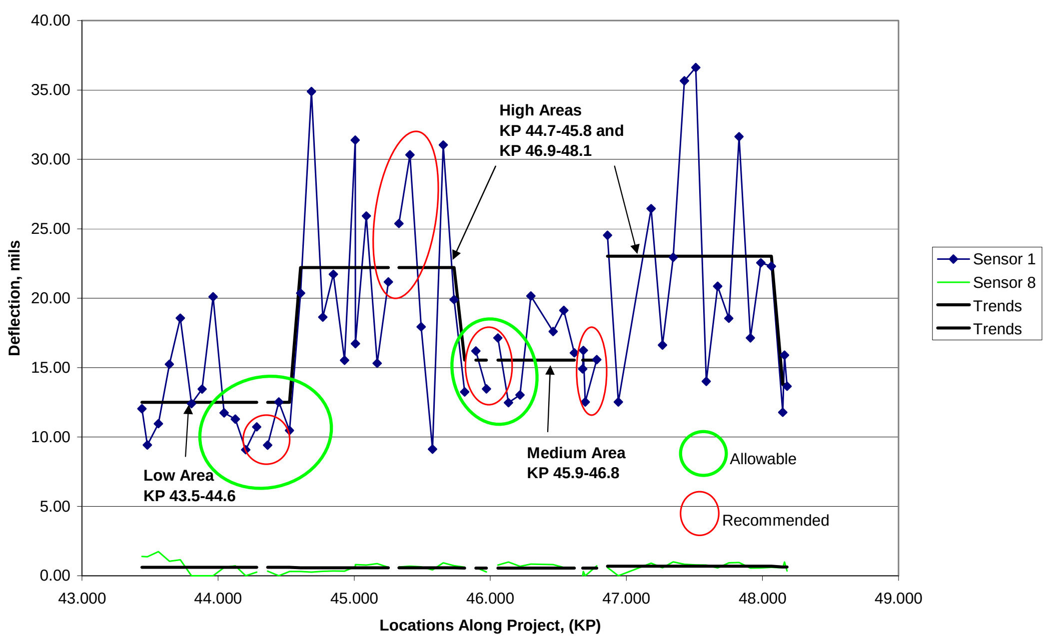

Figure 4.5 Merced East Bound Evaluation Section Locations (KP)

Table 4.5 Merced PES Deflection Data Summary

Section ID #	Deflection Level & Mean Value	Section Location
WB1	High (28.0 mils)	Station 144 + 37 to 142 + 85
WB2	Medium (16.0 mils)	Station 136 + 31 to 134 + 79
WB3	Low (11.0 mils)	Station 114 + 58 to 113 + 06
EB1	Low (10.0 mils)	Station 109 + 20 to 110 + 72
EB2	High (26.0 mils)	Station 119 + 57 to 121 + 09
EB3	Medium (16.0 mils)	Station 125 + 94 to 127 + 46

4.3.2 Pavement Condition Surveys and Surface Preparation

As noted previously, the most recent Caltrans pavement condition survey was completed in July 2000 at which time the distress observed included intermittent alligator, transverse and longitudinal cracking with occasional pumping and rutting. There are no records available as to the extent of surface preparation undertaken, which included repair of localized areas of cracking and rutting; grade adjustment; crack sealing, etc. A conventional DGAC leveling course of varying thickness was placed prior to RAC construction. Limited pre-construction photos are included in Appendix D.

4.4 CONSTRUCTION

4.4.1 General

A pre-construction meeting was held 12 September 2003 to discuss the data collection needs. In attendance were the following:

Kewal Virk	Caltrans, RE
Sam Sirang	Caltrans Inspector
Dave Bracy	Caltrans Plant Inspector
Mike Erickson	W. Jackson Baker (Contractor)
Clifford Curry	Curry Group (Contractor)
Andrew Brigg	LAW Crandall
Mark Potter	LAW Crandall

Highlights of the meeting were as follows:

- It was agreed that data collection would be overseen by Kewal Virk for distribution to LAW Crandall.
- Coring by the Curry Group would be done immediately after the construction in coordination with onsite Caltrans staff.
- PESs limits would be marked by LAW Crandall with wooden stakes.

RAC production for the PESs began on 12 September 20003. Since the plant ran short of binder after having produced only 175 tonnes, the test strip quantity was reduced from its original 200 tonnes to 150 tonnes. RAC paving began on 15 September 2003 with the arrival seventeen (17) double trailer belly dump trucks hauling RAC mix from the Baker’s LeGrand asphalt plant, about 32 miles from the project site. Highlights from plant inspection summaries and PESs paving are shown in Tables 4.6 to 4.8. RAC paving was completed on 19 September 2003.

Table 4.6 Merced Caltrans Plant Inspection Summary

September 15, 2003	
Time	Detail
7:20	Asphalt plant was fired up, with the early mix being wasted
7:35	Asphalt production Mix Temperature 163°C (375°F) Cold feed settings used for test strip produced aggregate that was out of spec on 19 mm screen Bin settings Bin 5 (19mm)-8% Bin 4 (12.5mm)-18% Bin 3 (9.5mm)-47% Bin 2 (dust)-22% Bin 1 (sand)-5%.
8:00	An aggregate sample was taken at 0800 with 60 Tonnes made to check new cold feed settings.
12:00	Sample found out of spec on the 19 mm. The sample was split. Cold feed settings were changed to Bin 5 -9%; Bin 4 -24%; Bin 3 – 42%; Bin 2 -19%; and Bin 1 -5%.
12:45	Sample was taken - AC plant and binder plant appear to be running smoothly. Total output was 75 loads and 1770 Tonnes (1951 tons). Plant ran smoothly throughout the day and no discrepancies were noted.
5:30	Two batches (1000 gallons) of binder had been made. Viscosities were checked 45 minutes after core temp (163°C) had been reached. Viscosities (centipoise, cPs) were 2500 and 3400. Mix design spec 78% AR-4000, 15% CRM, 5% high-natural rubber and 2% extender oil. Recipe being used for blending was 79.5% AR-4000, 14% CRM, 4% high-natural rubber and 2.5% extender oil. Viscosity of batch 3 was 1900, batch 4 – 2600 cPs, batch 5 – 2200, and batch 6 – 2300. Blending operations proceeded smoothly and no discrepancies were noted. A total of 10 batches (40,000 gallons) were blended. 10,000 gallons of binder remained at the end of the day.
15:59	The last truck loaded

September 16, 2003	
Time	Detail
6:00	AC plant fired up and began keeping mix at 0620. Early material was wasted and silos were cleaned out.
629	First truck was loaded at 0629. Cold feed settings were bin 5 (7/8)-10; bin 4 (-1/2)-22%; bin 3 (3/8)-45%; bin 2 (dust)-18% and bin 1 (sand)-5%. 7% binder was being used. Plant ran continuously throughout Tuesday. No discrepancies were noted. Contract tester took 5 aggregate samples. Total output was 88 loads and 2104 Tonnes (2319.5 tons).
	Rubber plant began day with 10,000 gallons of binder in two tanks. After cure time at 163°C (375°F) viscosity in each tank was 2,000. Recipe is 79.5% AR-4000, 14% CRM, 4% high-natural rubber and 2.5% extender oil. Blending proceeded smoothly and supplied all the binder needed by the AC plant. The viscosity of batch 3 was 2000 and of batch 4 was 2000. A total of 9 batches (36,000 gallons) were blended. No binder remained at the end of the day. One binder sample and one extender oil sample was taken.
15:59	The last truck loaded

Table 4.6 Merced Caltrans Plant Inspection Summary (Cont.)

September 17, 2003	
Time	Detail
6:10	Plant fired up. Early material was wasted and silos were cleaned out. Mix was kept until 06:20
6:24	First truck was loaded. New cold feed settings were used. They were bin 5 (7/8)-10%; bin 4 (1/2)-22%; bin 3 (3/8)-43%; bin 2 (dust)-20%; and bin 1 (sand)-5%. Change was made to add more #200 particles to the mix. 7% binder was being used. Plant ran continuously throughout Tuesday and no discrepancies were noted. Total output was 87 loads and 2034 Tonnes (2242 tons). Rubber plant began blending with no binder carried over from the previous day. Recipe being used is 79.5% AR-4000; 14% CRM; 4% high-natural rubber and 2.5% extender oil. Viscosities were checked before any binder was used. A total of 11 batches (45,000 gallons) were blended. The viscosity of batch 1 was 2500; batch 2 – 2700; batch 3 – 2300; batch 4/5 – 2500; batch 6/7 – 2500 and batch 8/9 – 2900. Blending operations proceeded smoothly and no discrepancies were noted. Total output was 87 loads and 2034 Tonnes (2242 tons).
1600	The last truck was loaded

September 18, 2003	
Time	Detail
6:53	Plant fired up. Early material was wasted and silos were cleaned out. Mix was kept until 0620
7:18	First truck was loaded Transfers were being used. Cold feed settings were bin 5 (7/8)-10%; bin 4 (1/2)-22%; bin 4 (1/2)-22%; bin 3 (3/8)-43%; bin 2 (dust)-20%; and bin 1 (sand)-5%. 7% binder was being used. Plant shut down at 0910 with full silo. Total output was 24 loads and 534.4 Tonnes (589 tons). No binder was held over from the previous day. Two batches were blended and combined for reaction. The viscosity was 2000. This was enough binder to meet the need of the AC plant for today. One binder sample was taken.
15:28	The last truck was loaded

Table 4.7 Merced PES Paving Associated Activities and Events (WB)

<table>
<tr><th colspan="3">PES WB1</th><th colspan="3">PES WB2</th><th colspan="3">PES WB3</th></tr>
<tr><td colspan="3">Paved Monday September 15, 2003

Contractor began paving PES WBI (144+37 to 142+85) @ 10:20

Completed paving of PES WBI (144+37 to 142+85) @ 10:34

RAC lay down temp recorded with contractor infrared device

One five (5) gallon bucket of RAC material collected from windrow within PES limits.</td><td colspan="3">Paved Monday September 15, 2003

Contractor began paving PES WB2 (136+31 to 134+79) @ 11:30

Completed paving PES WB2 (136+31 to 134+79) @ 11:45

One five (5) gallon bucket of RAC material collected from windrow within PES limits.

Contractor decided to raise RAC mix temperature at the plant. Delivery temp recorded @ 152^{0}C

Caltrans Plant Inspector indicated that QC checks on the 9.5 mm (3/8") aggregate showed material was out of spec.

Plant production stated as 280 Tonnes of RAC per hour. West bound (126+20) mat sanded and opened to traffic.

Contractor paving @ Applegate road intersection @ 14:30

PES RAC mix samples from WBI and WB2 labeled and loaded for shipment to METS TransLab @ 15:00

Lay-down paving production ended @ 16:40 (126+20), excluding roller work.</td><td colspan="3">Tuesday, September 16, 2003

First RAC load onsite @ 07:15 17 double trailer belly dump trucks hauling the RAC mix.

Haul time of approximately 45 minutes

Contractor applied tack and began paving west bound lane

Paving PES WB3 (114+58 to 113+06) @ 09:23

Average ground pavement temp 30^{0}F

One five (5) gallon bucket RAC mix collected from the windrow (113+80)

Completed paving PES WB3 @ 09:30

Sanded and open to traffic 12:00</td></tr>
<tr><td>Air Temp</td><td>Mat Temp @ Roller</td><td>Windrow Temp</td><td>Air Temp</td><td>Mat Temp @ Roller</td><td>Windrow Temp</td><td>Air Temp</td><td>Screed Temp</td><td>Windrow Temp</td></tr>
<tr><td>27^{0}C</td><td>103^{0}C</td><td>139^{0}C</td><td>27^{0}C</td><td>116-136^{0}C</td><td>152^{0}C</td><td>31^{0}C</td><td>127^{0}C</td><td>140^{0}C</td></tr>
<tr><td colspan="3">Mat temp behind paver screed 127^{0}C

Breakdown roller mat temp 116^{0}C

Breakdown roller operating approximately 10m behind Paver.</td><td colspan="3">Distance from breakdown roller to paving screed approx 10m

Average one-way haul time 45 min

Finishing Roller @ PES WB2 (Mat temp. 52^{0}C</td><td colspan="3">Average breakdown roller temp, 104^{0}C

Distance from breakdown roller to paving screed approx 10m

Finish roller operator stated that the temperature range of the mat during finish rolling targeted between 66^{0}C and 82^{0}C</td></tr>
</table>

Mat temperature for PES WB1 is very low, and may have interfered with compaction. The compaction temperatures for PES WB2 varied and finish rolling temperature is very low; compaction may also be an issue for this evaluation section. Table 4.8 indicates similar temperature issues for PES EB1-EB3.

Table 4.8 Merced PES Paving Associated Activities and Events (EB)

<table>
<tr><th colspan="3">PES EB1</th><th colspan="3">PES EB2</th><th colspan="3">PES EB3</th></tr>
<tr><td colspan="3">Tuesday, September 16, 2003

Started paving PES EBI
(109+20 to 110+72) @ 14:00

One five (5) gallon bucket of the RAC material collected from windrow (110+00)

Completed paving @ 14:15 Section 110+00 sanded and opened to traffic 14:50

Project level and PES digital photos taken and logged off construction operations.

Contractor completed mainline paving and began paving east bound shoulder at Bert Crane intersection (paving eastbound) @ 15:30</td><td colspan="3">Tuesday, September 16, 2003

Paving PES EB2
(119+57 to 121+09) @ 12:10

One five (5) gallon bucket of the RAC material collected from the windrow (120+40)

Completed paving PES EB2 @ 12:20

This section (120+40) was sanded and opened to traffic @ 14:50</td><td colspan="3">Tuesday, September 16, 2003

Start paving the east bound lane (127+31) @ 11:44

37m section of PES EB3
(125+94 to 127+46) paved

Monday, September 15, 2003.
Construction joint located @ PES.0+15

Contractor paved remaining 15 meters of P.E.S within approx. 2 min.

One five (5) gallon bucket of RAC material sampled from windrow (126+01).

Breakdown roller operating approx 30m behind paving screed

Pavement @ 126+01 sanded and opened to traffic 16:40</td></tr>
<tr><td>Air Temp</td><td>Mat Temp @ Roller</td><td>Windrow Temp</td><td>Air Temp</td><td>Mat Temp @ Roller</td><td>Windrow Temp</td><td>Air Temp</td><td>Screed Temp</td><td>Windrow Temp</td></tr>
<tr><td>31^{0}C</td><td>107^{0}C</td><td>142^{0}C</td><td>31^{0}C</td><td>114^{0}C</td><td>141^{0}C</td><td>31^{0}C</td><td>127^{0}C</td><td>143^{0}C</td></tr>
<tr><td colspan="3">Average RAC mat temp behind paving screed 129^{0}C

Average existing pavement ground temp. 53^{0}C

Mat temp during the finish rolling 68^{0}C

Average temp. @ Breakdown roller
Distance from breakdown roller to paving screed approximately 28m.</td><td colspan="3">Average existing pavement ground temp. 50^{0}C

Average temp, RAC mat behind the paving screed 129^{0}C

Distance of breakdown roller 30m behind paving screed</td><td colspan="3">Existing pavement ground temp. 113^{0}C

RAC mat temp behind paving screed
Average temp @ breakdown roller 98^{0}C</td></tr>
</table>

4.4.2 *Materials and Mix Design*

The asphalt rubber binder for the RAC mix was produced by Greka Oil. The binder included 15% scrap tire crumb rubber, 2% high natural crumb rubber, and 5% extender oil. The design binder content was 7.0% (by dry weight of aggregate). The target values for the aggregate gradation of the 12.5 mm maximum RAC-G mix are shown in Table 4.9.

Table 4.9 Merced Mix Design Characteristics

Aggregate Gradation			Specimen Characteristics				
Sieve Size (mm)	Target Value	Contract Compliance	Detail		Result		
25	100	100	Percent Oil Content		7		
12.5	95	79	Hveem Stabilometer		36		
9.5	81	69	VMA %		15.8		
4.75	37	53	Air Voids %		4.2		
2.36	22	33	Swell (mm) Kc		1.1		
0.6	13	21	Swell (mm) Kf		1.1		
0.075	5.1	5					
0.075	3.3	0-8					
Aggregate Quality Tests			Percent Of Crushed Particles				
Test	Result	Spec.	Sieve Size (mm)		%	Aggregate Type	
Crushed Coarse %	97	90	Bin 5	19mm	8		
Crushed Fine %	93	90	Bin 4	12.5mm	18		
LA Rattler (100 revs)	4	10	Bin 3	9.5mm	47		
LA Rattler (500 revs)	19	40	Bin 2	Dust	22	Coarse	
Sand Equivalent,50 min.	61	50	Bin 1	Sand	5	Fine	

4.4.3 Asphalt Plant and Construction Equipment

The equipment utilized is listed in Table 4.10.

Table 4.10 Merced RAC Paving Equipment

Make	Type	Model
Barber Green	Paving Machine	Model # BG 260B
Lincoln	Pickup Machine	Model #31004
Ingersoll Rand	12 Ton Tandem Vibratory Roller	Model # DD 11 OHF
Hypac	12 Ton Tandem Static Roller	Model #C778A
Terra Gator	Sanding Truck	1603T
Asphalt Trucks	17 Double Trailer Belly Dump Trucks	Various
Tack Truck	Tandem Axle	Unknown

4.4.4 QC/QA Data

RAC loose mix (12 5-gallon buckets) and binder samples (1 quart to 1 gallon) were taken at the plant between 15 and 19 September 2003 and sent to METS TransLab for testing at a later date. Upon completing the shoulder paving on 17 September 2003, all PESs limits and coring locations were re-marked. The Curry Group extracted cores on 19 September 2003 and backfilled with a high strength PCC product. Twelve (12) cores were extracted, 2 per PES. Table 4.11 includes the core log data, but no test data were provided for evaluation of in-place air voids. Construction photos are located in Appendix D. The lack of typical QC and QA data reflect the difference in the approach to this warranty project. MACTEC was not authorized to perform any mix testing for information. We have not located any materials characterization information to use in evaluating the performance of the RAC mix placed at this site, and urge Caltrans to retain their loose mix samples in case such testing may be needed in the future.

Table 4.11 Merced Core Log Data

PES Section	Stationing	Core ID	Core Location	Total Thickness (mm)
WB1	144+37 to 142+85	WB1A	144+67	253
WB2	136+31 to 134+79	WB2A	136+66	365
WB2	136+31 to 134+79	WB2B	134+49	254
WB3	114+58 to 113+06	WB3A	114+88	278
WB3	114+58 to 113+06	WB3B	112+76	293
EB1	109+20 to 110+72	EB1A	109+50	321
EB1	109+20 to 110+72	EB1B	110+42	335
EB2	119+57 to 121+09	EB2A	119+87	238
EB2	119+57 to 121+09	EB2B	120+79	308
EB3	125+94 to 127+46	EB3A	126+24	393
EB3	125+94 to 127+46	EB3B	127+16	306

4.4.5 Observations and Comments

Overall, the RAC paving operation appeared to have run smoothly and continuously, however it appears that there were some issues with relatively low mix temperatures during compaction. The primary delay in the paving operations was associated with base preparation, i.e., quantity of the conventional DGAC leveling course mix and the RAC overlay. The delay was related to contractual issues of measurement and pay. The contractor's experience with RAC was obvious and led to a smooth operation but temperature control issues may have adverse effects on performance of the resulting RAC-G pavement. No test results are available for gradation, binder content, mixture voids, or in-place air voids contents to incorporate in the performance evaluation.

5.0 SAN DIEGO COUNTY, HIGHWAY 75

5.1 PROJECT LOCATION

The San Diego RAC Warranty project (EA No. 11-230104) is located along the two southbound lanes and shoulders of State Highway 75, District 11, San Diego County, between Coronado and Imperial Beach, CA. The project extends 6.4 mi (10.3 km) from PM 11.0 (KP 17.7) to PM 17.4 (KP 28.0). This portion of State Route 75 begins at Rainbow Dr in the city of Imperial Beach and ends at the Naval Amphibious Base Gate 4 in the city of Coronado. There is a cross street with a left turn lane and an under-crossing within the project limits at approximately station 235+80. The RAC overlay for this project was constructed between April 21 and May 15, 2003. Figure 5.1 is a vicinity map illustrating the layout of the project. Table 5.1 identifies the location and provides some basic information on the four PESs selected for this project after the RAC-G was placed.

Table 5.1 Location and description of four PESs selected for San Diego County, Highway 75

PES ID	Begin KP	Begin PM	Deflection Level	Overlay or Mill/Fill
SB-1	26.50	16.48	Low	Overlay
SB-2	23.07	14.35	High	Overlay
SB-3	20.48	12.74	Moderate	Overlay
SB-4	18.81	11.70	Moderate	Overlay

5.2 DESIGN CONSIDERATIONS

The project area is located within the Caltrans "South Coast" climatic area. Precipitation and temperature data [Caltrans, 2004a (Station #047740)] are shown in Table 5.2. Traffic [Caltrans, 2004b] in the vicinity of the San Diego RAC project is characterized in Table 5.3.

Table 5.2 San Diego Temperature and Precipitation Data

Element	Annual
Average Max Temp (ºF)	69.9
Average Min Temp (°F)	56.4
Average Total Precipitation (in)	10.22
Average Total Snow Fall (in)	0.0
Average Snow Depth (in)	0.0

Table 5.3 San Diego 2003 Annual Average Daily Truck Traffic Data (AADT)

Post Mile	Kilo Post	Leg	Description	Vehicle AADT Total	Truck AADT Total	Truck % Total Vehicle	EAL 1-Way (1000)	Year Ver/Est
9	14.5	A	SD JCT RTE 5	71000	2130	3	151	85V
18.47	29.7	B	CORONADO POMONA AVE	30000	570	1.9	51	86E
19.586	31.5	B	JCT RTE 282	32000	768	2.4	46	84V
19.586	31.5	A	JCT RTE 282	26000	884	3.4	81	86E

Ver=Verified; Est=Estimated

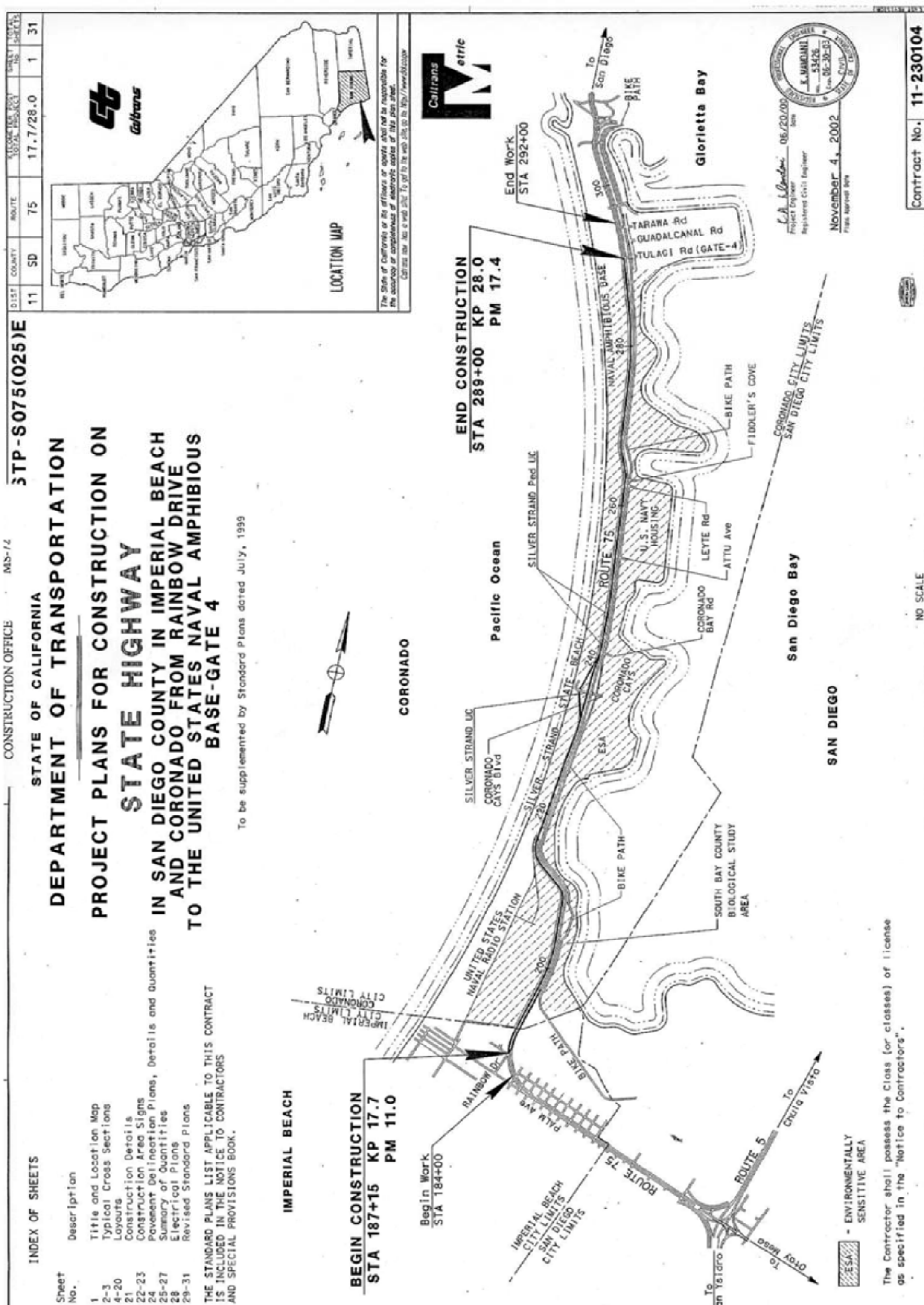

Figure 5.1 San Diego Project Location Plan

Although several design alternatives were considered by District 11 staff, as shown in Table 5.4, a 60 mm gap-graded rubberized asphalt concrete (RAC-G) overlay was selected.

Table 5.4 San Diego - Caltrans Pavement Design Alternatives

<table>
<tr><td colspan="3">TRAVELED WAY RECOMMENDATIONS FOR A 10-YEAR TI</td></tr>
<tr><td colspan="3">1. 10 yr TI = 8.5
2. Average AC Depth = 88 mm / 150 mm cement treated base
3. Average 80th % deflection = 0.254 mm
4. Tolerable deflection = 0.330 mm
5. Reflective depth requirements governs the design</td></tr>
<tr><td>Alternate 1 - Mill 105 mm of the existing AC and cement treated base; Remove and replace any failed areas; Clean and seal cracks equal to or wider than 6 mm (1 /4"); Place 105 mm DGAC.</td><td>Alternate 2 - Remove and replace any failed areas; Clean and seal cracks equal to or wider than 6 mm (1 /4"); Overlay with 105 mm DGAC.</td><td>Alternate 3 - Mill 45 mm of the existing AC; Remove and replace any failed areas; Clean and seal cracks equal to or wider than 6 mm (1 /4"); Place 60 mm RAC-Type G (Rubberized Asphalt Concrete).</td></tr>
<tr><td colspan="3">Design Notes - Rutting greater than 13 mm and/or loose pavement identifies locations of specific areas of severe failure. Dig out and repair these localized areas and seal all cracks wider than 6 mm.

1. For Alternate 1, the shoulder section should be as follows: Mill 30 mm of the existing AC and replace with 30 mm DGAC. For Alternate 2, the shoulder section should be the same as the traveled way recommendation. For Alternate 3, the shoulder section should be as follows: Mill 30 mm of the existing AC and replace with 30 mm RAC.
2. The alternates are equal sections and are in no order of preference. Alternate 2 may require shoulder backing.
3. The recommended aggregate grading for DGAC is Type A (19 mm maximum, medium).
4. RAC is Type G Rubberized Asphalt Concrete and should conform to the requirements specified for Type A Asphalt Concrete in Section 39, "Asphalt Concrete", of the Standard Specifications and the most current SSP.
5. The recommendations in this report are valid for a period of 18 months prior to PS&E.
6. Locations of dig outs should be determined 6 to 9 months before construction. The locations and quantities should be determined by the Project Engineer, Maintenance, or the District Materials Lab.</td></tr>
</table>

5.3 PRE-CONSTRUCTION

The 60 mm RAC overlay design was based on a June 2002 deflection study (Dynaflect JILS-1313) conducted by the Office of Materials Engineering & Testing Services personnel. Manual distress data gathered in conjunction with the deflection testing of 2002 revealed a pavement in poor condition with continuous transverse cracking and intermittent longitudinal and alligator cracking. A chip seal had been applied, though the date of its application could not be confirmed. The average thickness of the existing AC, as determined from pavement cores, was 88 mm over a cement treated base. Although the design plans indicated that there was 100mm class II base over 457mm of select fill, the contractor found that there was no Class II base between stations 187+78 to 188+82 and 191+91 to 194+23. Also, the contractor noted the presence of portland cement concrete about 2000ft north of Rainbow Dr and near station 239+15. Pavement condition and core photos may be found in Appendix E.

5.3.1 Deflection Testing and PES Selection

Ideally, FWD testing and a pavement condition survey would have been done immediately preceding construction to establish the location of the PESs. Unfortunately, due to staffing and budget constraints as well as construction scheduling, these two critical tasks did not occur in a timely manner. Instead, post-construction FWD test data collected in February 2005 and summarized in Figure 5.2 were used to select the 4 PESs as previously shown in Table 5.1.

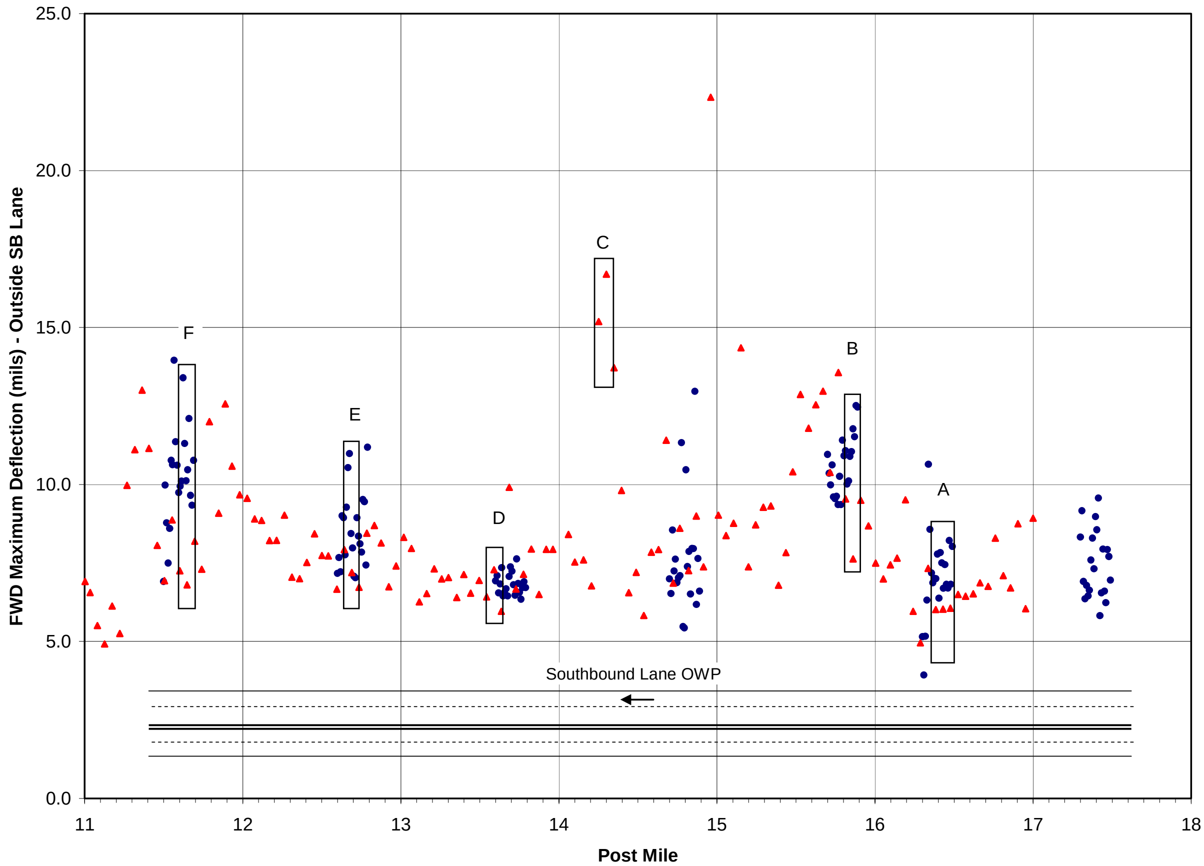

Figure 5.2 San Diego Deflection Evaluation Plot

5.3.2 Pavement Condition and Surface Preparation

As noted previously, pavement condition survey data were limited to that gathered in June 2002. Dig-outs and cold milling were done during the first two weeks in April 2003. Information with regard to dig-out locations or extent of milling operation was not available.

5.4 CONSTRUCTION

5.4.1 General

Paving was completed in 18 production days within a 25-day window from 21 April 2003 to 15 May 2003. The cold plane-grinding operation ran ahead of the paving operation, with the length removed each production cycle being paved that day. Shoulder paving was done in the same mode. Temperatures recorded during the day-time paving operation ranged from a morning low of 12^{o}C to late afternoon high of 19^{o}C. Traffic was controlled with the use of 2 flag personnel and a pilot car. RAC lift thickness ranged from 45 mm to 60 mm, 3.4 meters wide. The material was generally placed at temperatures above 152^{o}C.

5.4.2 Materials and Mix Design

The asphalt rubber binder was an AR-4000 (Valero Refining, Wilmington, CA) with 20% CRM (75% scrap tire and 25% high natural) from First Nation Recovery, Mecca, CA, and 3% extender oil (Raffex 170 ACB, Tricor Refining, Oildale, CA). Hanson Industries provided both the coarse and fine aggregate from its Carroll Canyon and Pala sources, respectively. The asphalt rubber binder was produced by FNF Construction, Fullerton, CA, and the mix design was developed by Kleinfelder, Inc. San Diego, CA. The design target values for the 12.5 mm maximum RAC-G mix are shown in Table 5.5.

Table 5.5 San Diego Mix Design Characteristics

Aggregate Gradation			Specimen Characteristics			
Sieve Size (mm)	Target Value	Contract Compliance	Detail			Result
25.4	100	100	Percent Oil Content			7.4
19	99	99-100	Hveem Stabilometer			31
12.5	86	79-93	VMA %			19.2
9.5	66	59-73	Air Voids %			5.1
4.75	33	26-40	Swell (mm) Kc			1.1
2.36	21	16-26	Swell (mm) Kf			1.1
0.6	12	7-17				
0.075	3.3	0-8				
Aggregate Quality Tests			Percent Of Crushed Particles			
Test	Result	Spec.	Sieve Size (mm)		%	Aggregate Type
Crushed Coarse %	98.8	90	Bin 5	19	13	Coarse
Crushed Fine %	99.5	90	Bin 4	12.5	20	
LA Rattler (100 revs)	4.1	10	Bin 3	9.5	21	
LA Rattler (500 revs)	18.9	40	Bin 2	Dust	12	
Sand Equivalent,50 min.	54	50	Bin 1	Sand	12	Fine

5.4.3 Asphalt Plant and Construction Equipment

RAC was produced at the CCAC, Otay, CA drum plant. A test strip was placed on 10 April 2003 on the northbound side between stations 187+150 and 198+645. The equipment used on the project is listed in Table 5.6.

Table 5.6 San Diego RAC Paving Equipment

Make	Type	Model
Merle Husky/Cat	Vibratory Paver	Model AP 1055B
Caterpillar	Steel Wheel Vibratory Roller	Model CAT 364C
Ingersoll Rand	Steel Wheel Vibratory Roller	Model DD110
Teamstar	2000 gal Tack Truck	
Terra Gator	Sanding Truck	1603T
	R/T Backhoe w/ Spreader Box	
Brace	Brace Broom	BD250B

5.4.4 QC/QA Data

Kleinfelder, Inc. performed extensive QC sampling, testing and construction monitoring. Daily QC test results are may be found in Appendix E. Results of tests for gradation, asphalt rubber binder content and relative compaction complied with mix design targets and tolerances with only a few relatively minor exceptions. Results from the test trip are summarized below in Table 5.7.

Table 5.7 San Diego Test Strip Production Evaluation Summaries

Characteristic	Results of QC Tests	Spec Limits
Sand Equivalent	62	> 50
Stability	34	> 25
Air Voids (%)	4	7-Mar
Binder Content	6.9	6.9-7.9
Gradation (% passing)		
19mm	97.7	90-100
9.5mm	68.3	59-73
4.75mm	30.7	24-40
2.36mm	18	16-26
0.6mm	9.7	7-17
0.075mm	1.4	0-8
RC (%)	94.3	> 94

5.4.5 Observations and Comments

Due to staffing and budget constraints as well as construction scheduling, no onsite details of PES paving are available. Although no materials sampling and testing was performed by Caltrans, the Contractor’s QC results do not indicate any apparent materials problems. A review of Caltrans daily inspection diaries indicated no unusual occurrences during the paving operation.

6.0 LASSEN COUNTY, HIGHWAY 395

6.1 PROJECT LOCATION

The Lassen RAC Warranty project (EA No. 02-258504) is a two-lane roadway located along State Highway 395 in District 2, Lassen County, near Doyle, CA. The project extends 13.0 mi (20.9 km) from PM 11.8 (KP 19.0) to PM 24.8 (KP 39.9). Figure 6.1 is a vicinity map illustrating the layout of the project. Table 6.1 identifies the location and provides some basic information on the nine PESs selected for this project. The modified binder dense-graded asphalt concrete (MB-D) overlay was constructed in August 2004. Although paved with the same material, i.e., a 60 mm lift of 19 mm MB-DGAC, the section between PM 17.6 and PM 22.5 is not covered by the warranty.

Table 6.1 Location and Description of Nine PESs Selected for Lassen County, Highway 395

PES ID	Begin KP	Begin PM	Deflection Level	Overlay or Mill/Fill
NB-1*	24.89	15.48	Low	Overlay
NB-2*	27.48	17.09	Moderate	Overlay
NB-3	33.91	21.09	High	Overlay
NB-4	34.72	21.59	Moderate	Overlay
NB-5	35.52	22.09	Low	Overlay
NB-6*	36.23	22.53	Moderate	Overlay
NB-7*	37.92	23.58	High	Overlay
SB-8*	38.06	23.67	High	Overlay
SB-9	28.43	17.68	High	Overlay
* covered by warranty				

6.2 DESIGN CONSIDERATIONS

The project is located within the Caltrans "High Desert" climatic area. Precipitation and temperature data [Caltrans, 2004a (Station #042504)] are shown in Table 6.2. Traffic [Caltrans, 2004b] in the vicinity of the project is characterized in Table 6.3.

Table 6.2 Lassen Temperature and Precipitation Data

Element	Annual
Average Max. Temp (°F)	67.1
Average Min. Temp (ºF)	34.0
Average Total Precipitation (in)	11.47
Average Total Snow Fall (in)	22.1
Average Snow Depth (in)	0.0

Table 6.3 Lassen 2003 Annual Average Daily Truck Traffic Data (AADT)

Pm	Kp	Leg	Description	Vehicle AADT Total	Truck AADT Total	Truck % Total Vehicle	Eal 1-Way (1000)	Year Ver/Est
4.615	7.4	B	JCT RTE 70 West	9400	975	10.4	226	02E
4.615	7.4	A	JCT RTE 70 West	6100	915	15.0	223	02E
29.84	48.0	A	Garnier Rd	4500	963	21.4	254	02E

Ver=Verified; Est=Estimated

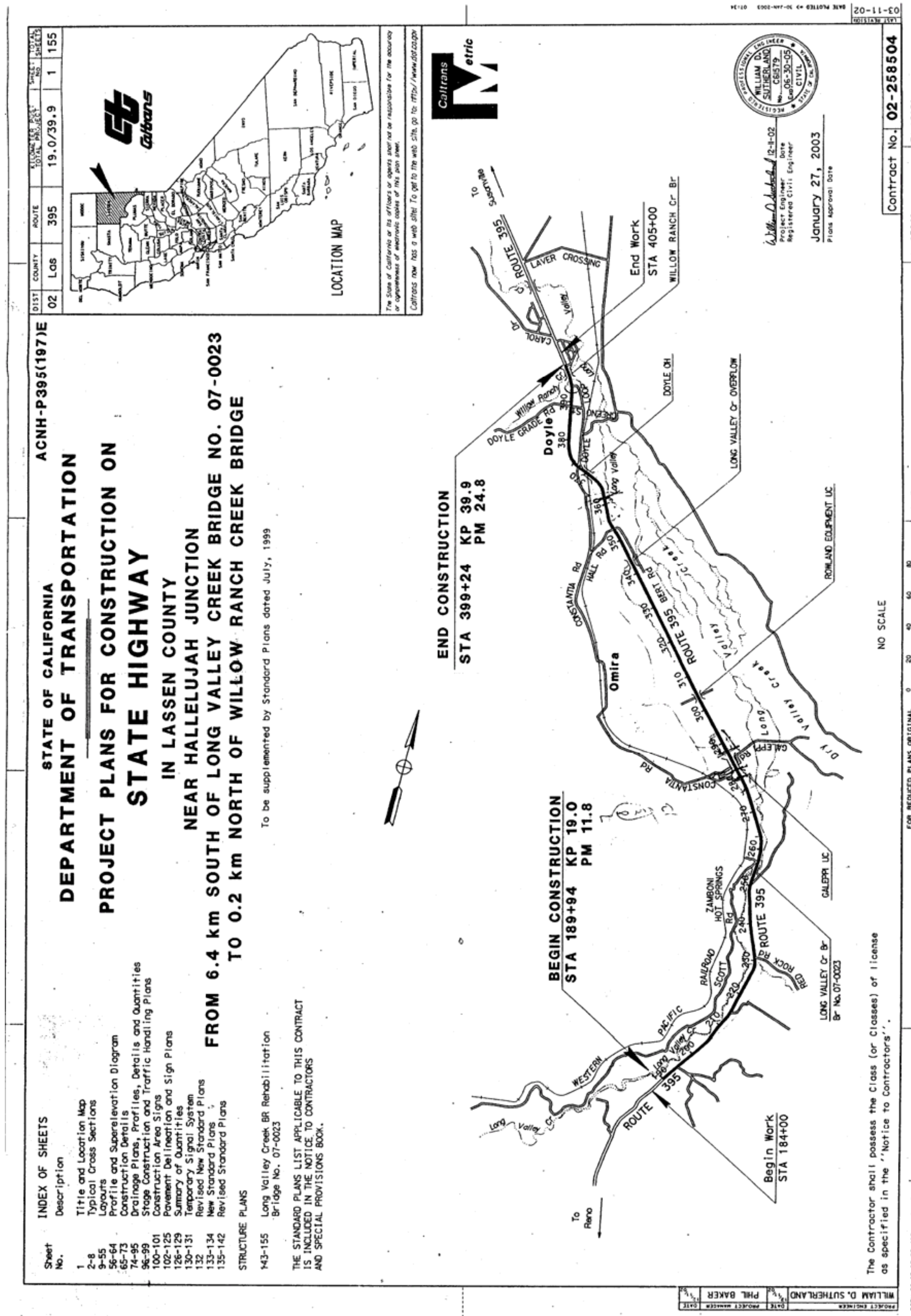

Figure 6.1 Lassen Project Location Plan

6.3 PRE-CONSTRUCTION

The basis for the 60 mm overlay design is assumed to be the deflection testing (Dynaflect) conducted on in September 2000 between KP 19.0 and KP 39.1. There was no deflection testing conducted after surface repair and preparation was completed. In July 2004, the Office of Pavement Rehabilitation conducted deflections testing (FWD) test prior to the placement of the MB-D overlay on the non-warranted section. Deflection data and photos showing pre-overlay pavement condition are provided in Appendix F.

6.3.1 Deflection Testing and PES Selection

Nine PES sections were established based upon analysis of deflection studies noted in the preceding section. As shown in Figure 6.2, only five sections are covered by the RAC warranty.

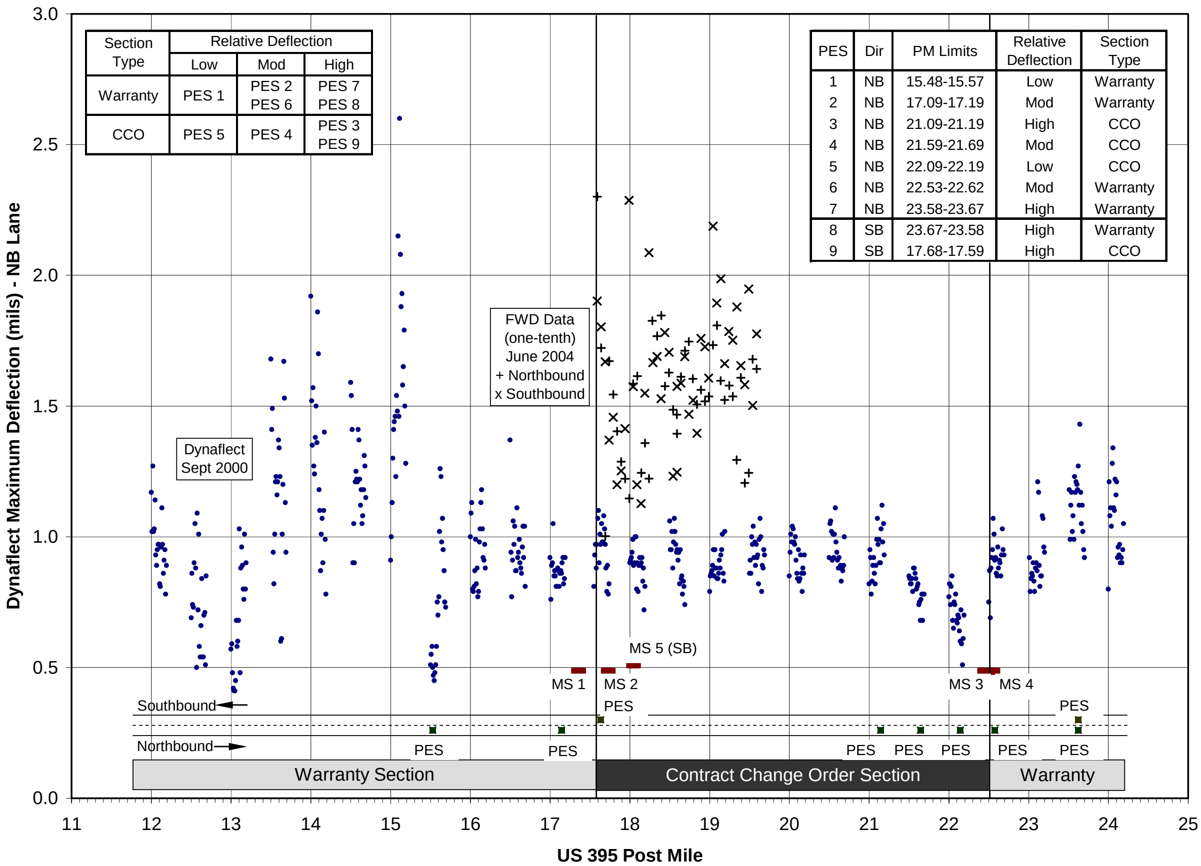

Figure 6.2 Lassen Deflection Data Evaluation and Section Locations

6.3.2 Pavement Condition Surveys and Surface Preparation

Prior to placing the RAC warranty overlay, the contractor placed a scrub seal using a Polymerized Asphalt Surface System (PASS) in October 2003. The PASS scrub seal was part of the contractor's original repair strategy to seal cracks, prevent reflective cracking, and rejuvenate the existing pavement surface. Note that the PASS scrub seal was placed only on the warranted sections of the project. With warm weather in early 2004, the scrub seal bled and created a slippery surface with low skid numbers. To remedy the problem, the contractor opted to place a “Type A” 12.5 mm thin blanket AC overlay using a PBA binder over the entire scrub seal area. The AC overlay was to serve two purposes: to temporarily enhance frictional resistance and to act as a leveling course prior to placing the RAC overlay.

As noted previously, an 8-kilometer section (KP 28.3 to KP 36.3) of this project was also overlaid with RAC but is not covered by the warranty. District 02 decided to have the contractor overlay the section “AS IS” by Contract Change Order (CCO). The section was excluded from warranty since there was no repair done to the existing pavement prior to placing the overlay.

6.4 CONSTRUCTION

6.4.1 General

Based on the test strip placed 28 June 2004 the contractor reduced the binder content from 5.3% to 5.1%. Paving was done between 3:00 p.m. and 5:00 a.m, starting on 7 June and was completed on 7 August 2004. Ambient temperatures at the time of paving, ranged from 90°F in the late afternoon to 50°F in the early morning hour. Traffic control setup included two changeable message signs (CMS), two flag personnel, and one pilot car. Paving was from south to north with the sequence as follows: NB mainline, NB shoulders, SB mainline, and SB shoulders. Mainline paving widths varied from 3.5 m to 3.8 m and shoulder widths varied from 2.4 m to 2.7 m. Payment for the RAC warranty sections was per square meter and the non-warranty section was per tonne. Total RAC warranty and non-warranty tonnes placed were 24,644 and 14,048, respectively.

6.4.2 Materials and Mix Design

Valero Refining provided the AR-4000 binder modified with 15% crumb rubber as a terminal blend. The laboratory report and certified batch blend record are found in Appendix F. The source of the aggregate was the Martin Marietta Pit in Sparks, NV. Lime slurry marination of the aggregate was required. The worksheet is included in Appendix F. The dense-graded mix design was performed by CGI and verified by Caltrans District 02 Materials Lab. Target values of the job mix formula and verification data are listed in Table 6.4. The Contractor’s target values for aggregate gradation generally conform to requirements for Caltrans Type A 19-mm Maximum, Coarse except that the target value for percent passing the 4.75 mm (No. 4) sieve size falls outside the gradation limits presented in Section 39 of the Caltrans Standard Specifications. The gradation used in verification is finer on most sieve sizes and conforms more closely to the Caltrans 19-mm Maximum, Medium gradation limits.

6.4.3 Asphalt Plant and Construction Equipment

Atlas Contractors, Inc. supplied the rubberized asphalt concrete from its batch plant in Sparks, NV. Haul distance from the plant to the project site was approximately 50 miles and haul time was approximately 1½ hours. As expected, rush hour traffic tended to increase the haul time. The paving equipment used on the project is shown in Table 6.5.

Table 6.4 Lassen Mix Design Characteristics

MIX GRADATION			
Sieve Size (mm)	Contractor Mix Design Target	Caltrans Verification	Contractor Mix Design (Modified)
19	100	100	
12.5	78	79	
9.5	67	69	
4.75	51	53	
2.36	34	33	
0.6	17	21	
0.075	4.9	5	
Mix Properties			
OBC, BDWA, %	5.3	5.3	5.1
Stability, 37 min.	42	46	
VMA,%	15.8		
% Air Voids	4.0	5.2	
Swell	0.12	0.001	
Kc	1.1		
Kf	1.1		
Aggregate Properties			
Crushed Coarse, 90% min.	100	100	
Crushed Fine, 90% min	100	100	
LA Rattler			
@ 100 rev, 10% max.	4	5	
@ 500 rev, 25% max.	18	23	
Sand Equivalent, 50 min.	67	75	
Bin Proportioning			
Sieve Size (mm)			
19	30	30	33
12.5	13	13	14
9.5	10	10	10
Dust	22	22	22
Sand	25	25	21

Table 6.5 Lassen Paving Equipment

Terex/Cedarapids 552 Paver
Terex/Cedarapids MS 2 pick-up machine
Ingersoll-Rand DD130 (13 metric ton) steel-wheel tandem vibratory roller
Ingersoll-Rand DD110HF (11.4 metric ton) steel-wheel tandem vibratory roller
BearCat 2000-gallon tack distributor truck
Single and double belly-dump trucks

6.4.4 QC/QA Data

Quality control sampling, testing and construction monitoring was subcontracted to CGI. RAC samples were collected behind the paver and split with Caltrans using sample splitters. The tests run by CGI included gradation, stability, binder content, air void content, sand equivalent, and density. The QC results in Appendix F indicate that gradation and binder content were, with few exceptions, consistently within tolerance of the mix design targets. Mixture voids during MB-D mix production were somewhat low, ranging from 2.2 to 3.3%. It is not clear if the relative compaction results listed are based on the mix design air voids target or air voids contents measured during production. The former would yield about 5 to 8% in-place air voids, the latter about 3 to 4.5% in-place air voids. In-place air voids contents of 3% or less may indicate increased potential for rutting. Limited stability test results ranged from 28 to 33, which exceeds the RAC-G minimum of 23, but is low for a dense-graded mix. Since this was not a “QC/QA” project Caltrans performed similar “shadow” testing. Also, CGI used the California Profilograph to assess ride quality, i.e., smoothness, as part of construction QC.

6.4.5 Observations and Comments

During construction of the test strip on 28 June 2004, tearing of the mat was observed. Furthermore, within six hours of compaction, wheel path rutting was observed that indicates a “tender” mix. This type of behavior corresponds with the observed low mixture voids and stability values and relatively high compaction. Because of the warranty strategy, as opposed to a “Section 39” project, the RE was not permitted to take action.

Although the new Cedar Rapids paver was equipped with automated screed control, the contractor chose to operate it manually because of unspecified difficulties. Additionally, the paving crew did not seem to communicate effectively and work as “a team,” perhaps because they had not worked together previously. Insufficient haul trucks throughout construction made for a “stop and go” operation, which in some instances halted the paver for 30 to 45 minutes. “Stop and go” operation of the paver typically introduces “dips” in the pavement that adversely affect smoothness and ride quality. Moreover, prolonged “stops” of the paving operation allow the paving material to cool resulting in non-uniform and/or inadequate compaction. The RAC warranty specification did not include a smoothness requirement (CA Profilograph) since the lift thickness of single lift is less than 75 mm. However, the straightedge requirement in Section 39-6.03, “Compacting,” of the Standard Specifications was used.

Paving in low light conditions presented difficulty in visually assessing mix consistency. Fortunately, segregated mix observed in the windrow was removed prior to collection by the pick-up machine and subsequent transfer to the paver hopper.

Although aggregate gradation and binder content were in substantial conformance with mix design targets, the low mixture voids and relatively stability values raise concerns regarding resistance to rutting. However if the MB-D mixture does not rut, the low voids may be beneficial in improving resistance to fatigue and moisture damage

7.0 SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

7.1 SUMMARY

This report presents a compendium of the available information related to site conditions, design, materials, and construction of the individual subject RAC warranty projects. It is intended to provide information to supplement annual performance monitoring data and to help identify factors related to materials and/or construction that may affect the performance of the respective RAC pavements. However in spite of guidelines provided by METS, the warranty approach created some confusion regarding needs and responsibilities for sampling and testing. The warranty specifications did not include requirements for frequency of sampling and testing and thus available resources (which were typically limited) rather than guidelines governed how much testing was performed. As is evident in the test data included herein, there were considerable differences in the amount of sampling and testing performed for the respective pilot RAC warranty projects by Caltrans, Contractors, and their respective agents. As a result, there are gaps in the available data that may interfere with in-depth evaluation of RAC overlay performance for the respective warranty projects.

Compaction, in terms of in-place air voids content, has been shown to have significant effects on fatigue and rutting performance of RAC materials as well as conventional paving materials [Caltrans, 2003]. It is one of the factors that should be considered in performance evaluation. However, such testing was not required by either the RAC or warranty SSP and thus only limited data are available. Temperature (mix, ambient, and underlying pavement) is a critical factor in compaction. Temperature measurements from the Fresno project indicate low windrow and mat temperatures behind the paver; limited data indicates adversely affected compaction in the PESs.

Resistance to reflective cracking is a key performance element for RAC overlays, so the condition of the pavements overlaid with RAC is also an important factor in RAC performance evaluation. The RAC overlays applied in most of these projects were typically relatively thin lifts, with nominal thickness less than 75 mm, compared to the typical minimum requirement of 4 inches of DGAC to resist reflective cracking. Distress surveys were performed for most of the performance evaluation sections (PES) except for the San Diego project.

Mixture characterization also provides valuable information related to performance. Low mixture voids may indicate increased potential for rutting or flushing, but may provide benefits of increased resistance to fatigue and moisture damage. High mixture voids may indicate increased potential for rutting by further consolidation under traffic, moisture damage, and oxidative aging, along with reduced resistance to fatigue. Variations in gradation and binder content are typical causes for changes in void structure and related mix properties.

Performance evaluation for other than warranty purposes should therefore consider factors related to materials, construction, structural adequacy, and site conditions. For example, in Ventura County, two of the PESs are in areas on the west side of the project where the existing pavement structure was not as thick as it was believed to be. Although a leveling course was added, the structural cross-section in these areas remains thinner than that used for the overlay design and thus the overlay may not be able to provide the intended performance if the structure is not adequate. The Contractor for this project also raised concerns regarding the suitability of using RAC-G in on-street parallel parking areas, and some scuffing and raveling has been reported in some areas. Whether any of the distress locations correspond to the area where standing water was reportedly observed immediately before RAC placement has not been determined.

In Fresno, the windrow and mat temperatures measured were low, and in some cases, very low (Tables 3.7 and 3.8) which would be expected to interfere with compaction. Limited core data indicates that compaction varied from good to poor. Binder content fluctuated over a relatively wide range, with nearly one third of the samples yielding contents less than 6.9%. This raises concerns about potential for raveling and long-term durability that are directly related to mixture production issues.

For Merced County, PES information indicates issues with low mat temperatures during paving that likely affected compaction. However no other materials or compaction data are available to use in evaluating RAC performance.

District 11 staff reportedly considered the San Diego County project to be routine and the RAC overlay was completed before METS was informed. Therefore PES selection was based solely on post-construction FWD testing without benefit of the detailed survey of the condition of the underlying pavement. The QC results provided do not indicate any problems with the mixture or compaction, but no supporting QA data could be located.

The Lassen project included the only dense-graded RAC mix (MB-D) in this study, which was a change from original plans to use an MB-G mix. This mix would thus be expected to perform much like a conventional DGAC. Although aggregate gradation and binder content were in substantial conformance with mix design targets, the low mixture voids and relatively low stability values raise concerns regarding resistance to rutting.

Performance of the respective projects and PESs is to be evaluated over time. Annual monitoring will provide the performance information required for warranty enforcement. However a full evaluation of RAC-G performance requires consideration of materials characteristics (including but not limited to gradation, binder content, mixture voids, stability), construction factors including compaction, structural adequacy of the pavement section including subgrade and base courses, and site conditions including drainage. For some projects, the information needed for in-depth performance analysis is not available. If pavement distress does occur, additional sampling and testing may be required to identify the likely causes.

7.2 CONCLUSIONS

Due to circumstances already described, the RAC warranty projects were designed and constructed as individual Caltrans District projects. Data collection responsibilities and requirements were not included in either the RAC or Warranty SSPs, but were presented as guidelines that were not consistently followed by the respective projects. There are considerable differences in the amount and type of data available for each project. For some projects, the materials and construction information needed for in-depth performance analysis is not available.

7.3 RECOMMENDATIONS

It is recommended that performance monitoring for warranty enforcement should be performed according to the data collection guidelines. However the warranty periods are relatively short (3 to 5 years) and relatively little distress is expected to manifest over such limited periods. If pavement distress does occur on projects where only limited materials data are available, additional sampling and testing may be required to establish the likely causes.

For evaluation of overall RAC performance, the same type of condition monitoring is recommended throughout the life of the overlay. Limited District resources may extend the interval between condition surveys of PESs to several years, but long term performance documentation would be useful even if limited.

If Caltrans performs similar studies of any paving material in the future where sampling and testing are critical to the overall evaluation, it is recommended that the requirements for sampling and testing be included in the project special provisions to assure that they are followed.

8.0 REFERENCES

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