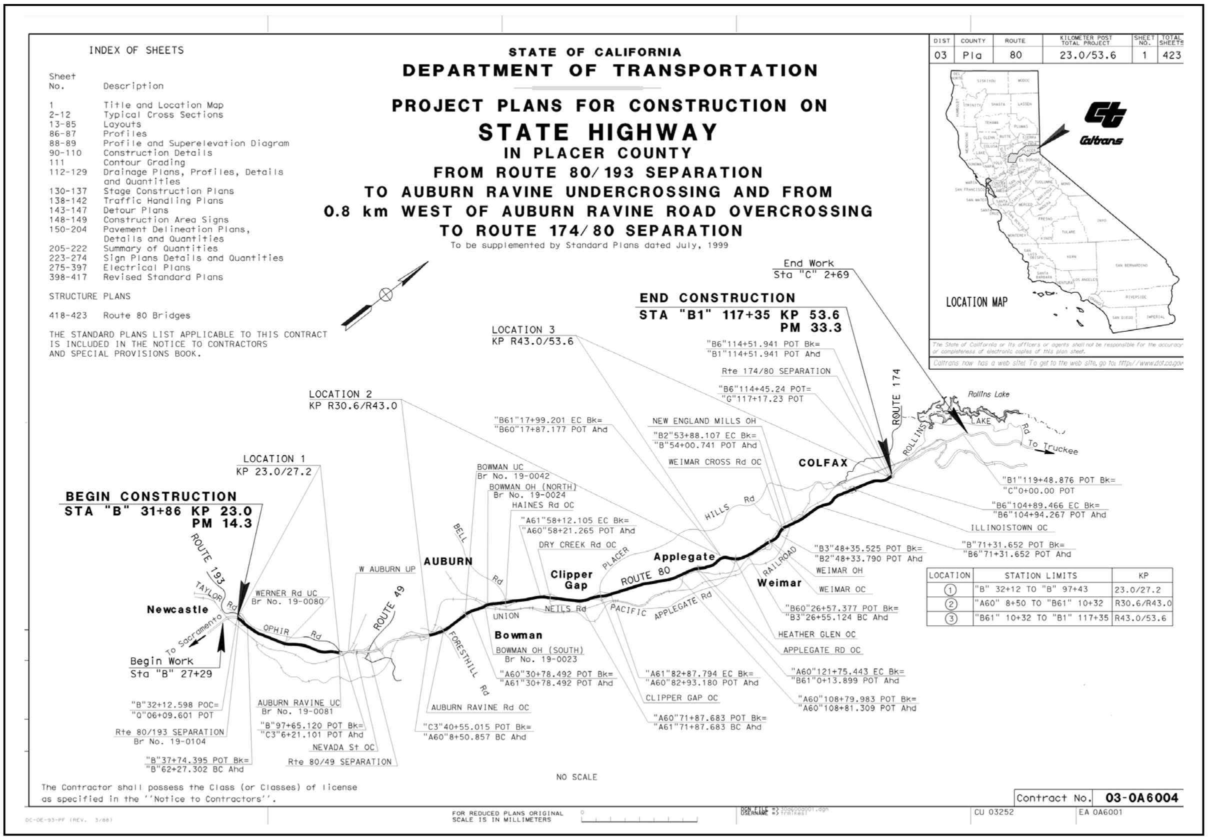
INTERIM REPORT
CONSTRUCTION COMPLETION
FOR

COLD-IN-PLACE RECYCLING
Placer 80 PM 14.3 /33.3



North Region Materials
Marysville, Ca
August 2006

BACKGROUND:

This portion of Interstate 80 was originally constructed between 1957 and 1959. The original configuration was two 12-foot lanes with an unpaved median shoulder and an outside shoulder in each direction of varying width. The original mainline structural section consisted of:

- 0.33’ Plant Mixed Surfacing (PMS)
- 0.67’ Cement Treated Base (Class A) (CTB)
- 0.50’ Imported Sub-base Material (ISM)

In the 1970’s, widening occurred on the outside shoulders of both sides of the original configuration. The added structural section consisted of:

- 0.60’ Hot Mix Asphalt (HMA)
- 0.80’ CTB
- 1.00’ Aggregate Sub-base (AS)

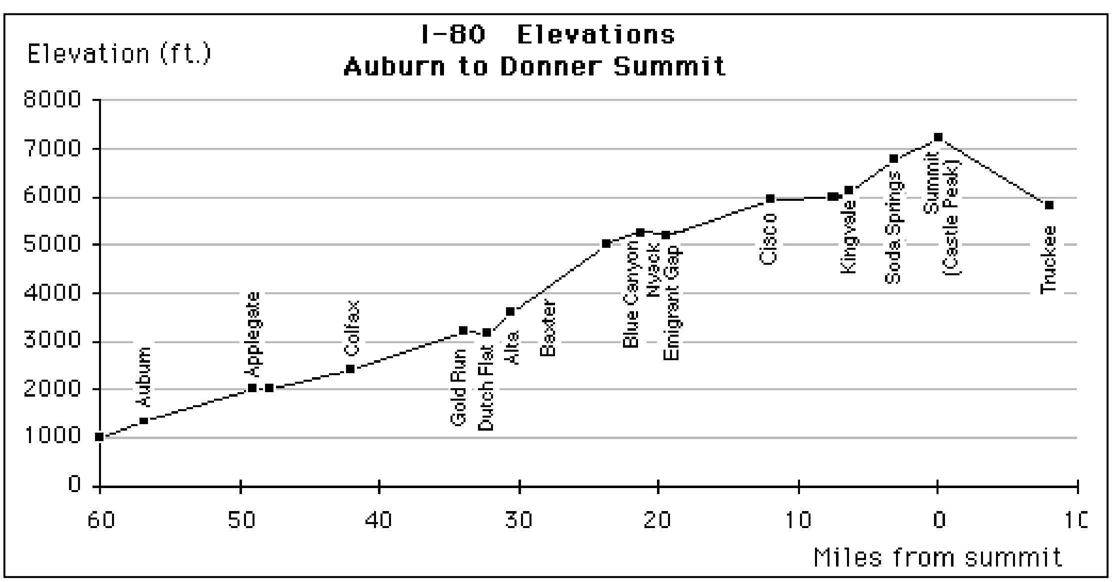
Over the years, the median has been paved with:

- 0.25’ HMA
- 0.50’ Aggregate Base (AB)

In addition, the median has had combinations of metal and concrete barrier rail placed at various locations. Mainline and shoulders have had various surface treatments done.

Traffic on this section of Interstate 80 is moderate to heavy with a large volume of trucks. The 20-year Traffic Index ranges from 14.0 to 14.5 (41 to 55 million ESAL’s). The Average Annual Daily Traffic (AADT) for the project ranged from 100,000 in the Auburn vicinity with approximately 8.5% trucks to 38,500 in the Colfax vicinity with 16% trucks (Attachments A & B).

The geography of the project shows roadway elevations in Auburn of 1234 feet and Colfax of 2420 feet. The roadway profile ranges from rolling undulations to 6.5% grades.



The project area is considered transitional from valley to mountainous. Table 1 shows weather patterns for both ends of the project (Detailed data Attachment C).

Table I				
Location	Rain Days	Avg. Rainfall	Snow Days	Avg. Snowfall
Auburn	67	34.47"	6	1.2"
Colfax	74	47.71"	9	1.7"

ORIGINAL DESIGN:

The project was originally designed as a "Mill and Fill with Overlay". The original plans called for the following structural section[1]:

Mainline: Remove 0.3' existing pavement
0.10' RAC Type O
0.25' HMA ¾" grading
0.30' HMA 1 ½" grading

Shoulder: Remove 0.25'existing pavement
0.25' HMA ¾" grading
0.25' HMA ¾" grading

The project required the contractor to work nights and to back-fill any milled areas in the same shift.

RECYCLED DESIGN:

In April 2004, talks began between Caltrans and the Contractor (Teichert Construction) on alternative methods that could be used to construct the project. The driving force behind exploring a different methodology was public safety and the escalating cost of bitumen, aggregates, and fuel.

In November 2004, Caltrans and Teichert Construction agreed to Contract Change Order (CCO) #21. CCO #21 was a direct result of a Contract Reduction Incentive Proposal, to modify the contract from "Mill and Fill with Overlay" to a "Cold-In-Place Recycle with Overlay" using foamed asphalt as the recycling medium.
Per CCO #21- "A cost reduction incentive to eliminate a portion of the 100 mm cold plane and 37.5 mm asphalt concrete and replace with an equivalent 104 mm depth section of cold-in-place recycled material. "
"The contractor has proposed a Cold-In-Place recycling process. The process will take place from Bell Road (station A61.42+82) to the end location #3 in Colfax (station B1 117+35). The planned work is to cold plane 100 mm of existing pavement and replace with 100 mm of asphalt concrete (37.5mm). The contractor has proposed a recycling system that consists of cold planing the existing pavement to a depth of 104 mm, mixing the grindings with cement slurry and foamed asphalt, running the mixture through a tamping screed and performing final compaction. The grinding, mixing and tamping screed work are performed by a Wirtgen Cold Recycle WR 4200. The WR 4200 is

[1] Materials Report, dated February 26,1999, amended May 10,1999,November 3, 1999 &January 12, 2004

supported by a Wirtgen WM 1000 cement slurry mixer, asphalt truck, and rollers. The change order includes details of the proposed equipment, methods and mix design." CCO#21 called for recycling 3,718,435 ft^2 of existing pavement to a depth of 0.3' with Cold Foam and 1% Type II cement.
"In accordance with the attached specification, in lieu of performing the contract specified 60 mm Cold Planing Asphalt Pavement covered under Contract item #41 COLD PLANE ASPHALT CONCRETE PAVEMENT, and in place performing the 19 mm Asphalt Concrete paving under Contract item #65 ASPHALT CONCRETE (TYPE A), between Bell Rd A61 42+82 and the end of location #3 B1 117+35, perform Cold-In-Place Recycling to a depth of 75 mm…"

Based on CCO #21 in August 2004 North Region Engineering Services, Marysville Materials Branch conducted an extensive field investigation to determine if the project was appropriate for recycling. Eighty-nine cores (Attachment D) were taken in six separate locations, three east bound, three west bound. Cores varied in thickness from a minimum thickness on the A60 line, station 103+50 EB of 0.32' to a maximum thickness on the B-Line station 64+60 WB of 0.95'.

Typically, cores were removed intact and were uniform throughout all sections. Cores consisted of dense graded asphalt concrete (DGAC) in two or more lifts, with some areas showing surface treatments such as open graded asphalt concrete (OGAC). In all areas with surface treatments, the treatments showed signs of extensive wear, as indicated by wear through in one or both wheel paths.

Pavement surface investigation showed transverse cracking at 12 to 15 feet intervals, indicative of CTB as an under laying material. Fatigue cracking was noted throughout the project. Coring showed fatigue cracking as bottom up, indicating that pavement had exceeded its design life. All coring was done to the bottom of the CTB and showed no significant CTB failure. Table 2 shows average asphalt concrete thickness.

Table II

Direction	Location[2]	Avg. Depth (mm)	Avg. Depth (ft)
EB	1	140	0.46
EB	2A	139	0.46
EB	2B	149	0.49
WB	1	194	0.64
WB	2A	140	0.46
WB	2B	156	0.51

Based on the field investigation and a minimum depth of 0.32' a Cold-In-Place Recycle (CIPR) depth of 0.30 feet was recommended. This allowed for an average depth of 0.20 feet to remain undisturbed, minimizing the potential for delamination of existing asphalt concrete from existing CTB.

[2]Attachment D "Coring Locations"

CIPR Mix Design:

A CIPR mix design was conducted in September 2004 by North Region Engineering Services, Marysville Materials Branch[3], to determine existing grading of recycled material, foamed bitumen, water for foam and compaction, mineral admixture content, and tensile strengths (ITS) of foamed material. Cores taken to determine pavement thickness were used for the CIPR mix design. Utilizing a Wirtgen WLB10 foam mix design machine and a CIR (South Africa) Paddle mixer, the mix design based on a 0.3' recycle depth called for:

Recycled Asphalt Pavement (RAP), graded to 100% passing the ¾" sieve
1 to 1.5 % Type II cement (Value to be field adjusted)
2.5% bitumen, AR-4000 grade (by weight of the RAP)
3% water for foaming, (by weight of the bitumen)
1-2% pre-compaction water

CIPR Structural Section Design:

For design purposes, it was assumed that the untreated RAP would be as strong as Class II aggregate base. To determine the Gravel Equivalent (G_E) and Gravel Factor[4] (G_f), a straight-line ratio of tensile strengths was used. Using average worst-case tensile strengths[5], and using the formula G_{fcipr}=(Treated ITS)/(Untreated ITS) + 0.1, resulted in a G_{fcipr} of 1.8. Because this was the first project in the State of California to use this process, a conservative approach was taken and the G_f was maximized at 1.4 which is equivalent to Asphalt treated base material. Based on Caltrans current HDM design guidelines the project required a G_E of 2.54'. This required the following structural section:

Mainline	0.12' RAC	Shoulder	0.25' DGAC
	0.25' DGAC		0.25' CIPR
	0.30' CIPR		0.10' DGAC (E)
	0.20' DGAC (existing)		
	0.80' CTB (existing)		
	1.00' AS (existing)		

Because of the high traffic volume, it was determined that a fog seal of CQS-1 at a 50% dilution and an application rate of 0.008-0.015 gl/ft^2 would be required. Further, the design called for the following:

Minimum cure time prior to overlay would be 3 calendar days.
Maximum cure time prior to overlay would be 7 calendar days.
Temporary paint stripe would be placed at the end of each shift prior to trafficking.
Order of operation required that CIPR begin in the number 1 lane.

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[3]Attachment E, CIPR Mix Design
[4]As defined by Chapter 600 of the Caltran's Highway Design Manual (HDM)
[5] Attachment F, Structural Section Design

Testing Protocol:

For this project, material and density testing requirements were as follows:

A lot was considered 33,000 ft^2

Minimum relative density would be 96% and determined in accordance with California Test 216 to determine the material maximum density and California Test 375, utilizing a nuclear gauge in back scatter mode, to determine relative density.

Grading would be determined in accordance with California Test 202 and would conform to Table III.

Table III	
Sieve	Percent Passing
3"	100%
1 1/2"	100%
1"	90%

CONSTRUCTION:

As part of CCO #21, a Specification for Cold-In-Place Recycling was issued to the contractor[6]. In April 2005, construction began on the recycle portion of the project. The prime contractor was Teichert Construction, the recycling sub-contractor was Valentine Surfacing, with the contractor's materials and quality control testing by Curry Group Inc. Quality Assurance and acceptance testing was performed by Caltrans Auburn Construction Office and North Region Materials, Marysville.
Construction started just west of the Applegate ramp and was recycled in the following order:

Outside shoulder:	Applegate on ramp to Bowman off ramp WB	(5.73 Miles)
Number 3 lane:	Applegate on ramp to Bowman off ramp WB	(5.73 Miles)
Number 2 lane:	Applegate on ramp to Bowman off ramp WB	(5.73 Miles)
Number 1 lane:	Applegate on ramp to Bowman off ramp WB	(5.73 Miles)
Outside shoulder:	Bowman on ramp to Applegate off ramp EB	(5.76 Miles)
Number 2 lane:	Bowman on ramp to Applegate off ramp EB	(5.76 Miles)
Number 1 lane:	Bowman on ramp to Applegate off ramp EB	(5.76 Miles)
Inside shoulder:	Bowman on ramp to Applegate off ramp EB	(5.76 Miles)
Outside shoulder:	Applegate on ramp to Colfax EB	(7.09 Miles)
Number 1 lane:	Applegate on ramp to Colfax EB	(7.09 Miles)
Inside shoulder:	Applegate on ramp to Colfax EB	(7.09 Miles)
Outside shoulder:	Colfax to Applegate on ramp WB	(6.65 Miles)
Number 1 lane:	Colfax to Applegate on ramp WB	(6.65 Miles)
Inside shoulder	Colfax to Applegate on ramp WB	(6.65 Miles)
	Total	87.18 Miles

[6] Attachment G, Specification issued under CCO#21 for CIPR

Construction Process:
Recycling of the shoulders was accomplished utilizing daytime lane closures. Recycling of the mainline was accomplished utilizing nighttime lane closures, due to high traffic volumes. The recycling train was kept compact to minimize impacts on traffic and consisted of:

3000-Gallon Bitumen Truck.
WM 1000 Cement Slurry Mixer.
WR 4200 Recycler with integral paving screed.
Two Tandem Axle Steel Drum Rollers.
One Pneumatic Tired Roller.
One 3000-Gallon Water Truck.

Having the bitumen truck, the WM 1000 and WR4200 travel as a unit meant all milling, slurry mixing, foaming and lay down of material was accomplished in one pass within the equipment train. This minimized disruptions to traffic due to ingress and egress of construction vehicles. Normal mill and fill operations would require a constant stream of trucks hauling out millings and bringing in asphalt. Typical for a 2500 ton paving shift would be 105 trucks in and out for milling and 110 trucks in and out for delivery of asphalt, for a total of 215 trucks. The recycling operation, based on 1.5 lane miles of production, required 6 oil trucks, one bulk cement truck, and 8 water trucks for a total of 15 trucks.

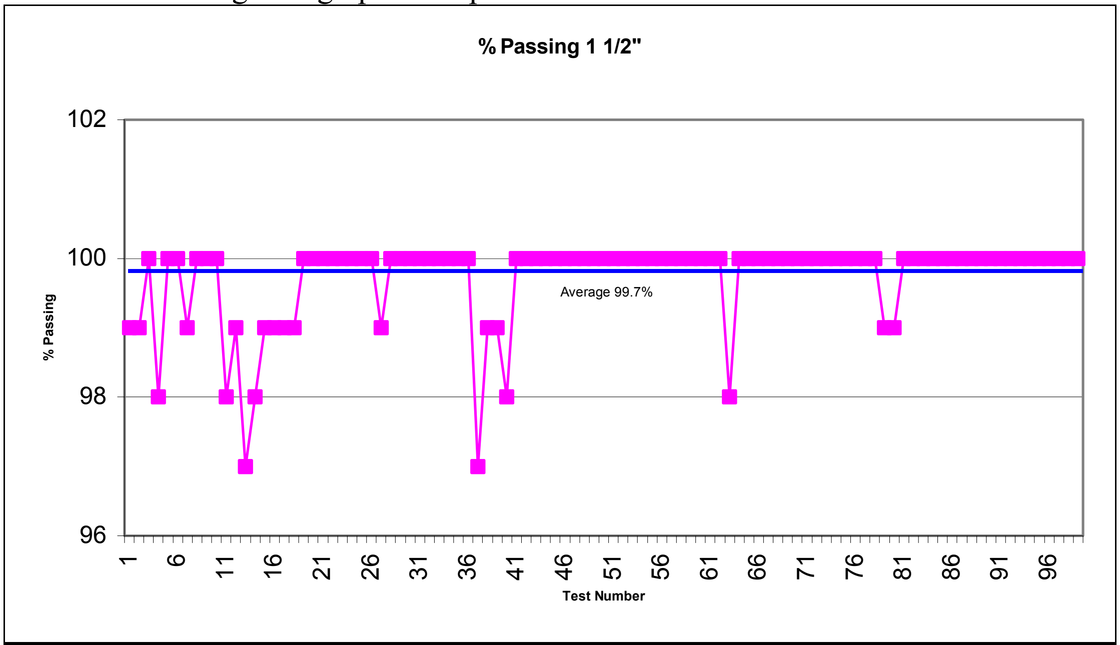
Because the foamed recycled material was laid down to grade, no reworking of material was required and rolling operations begin immediately.

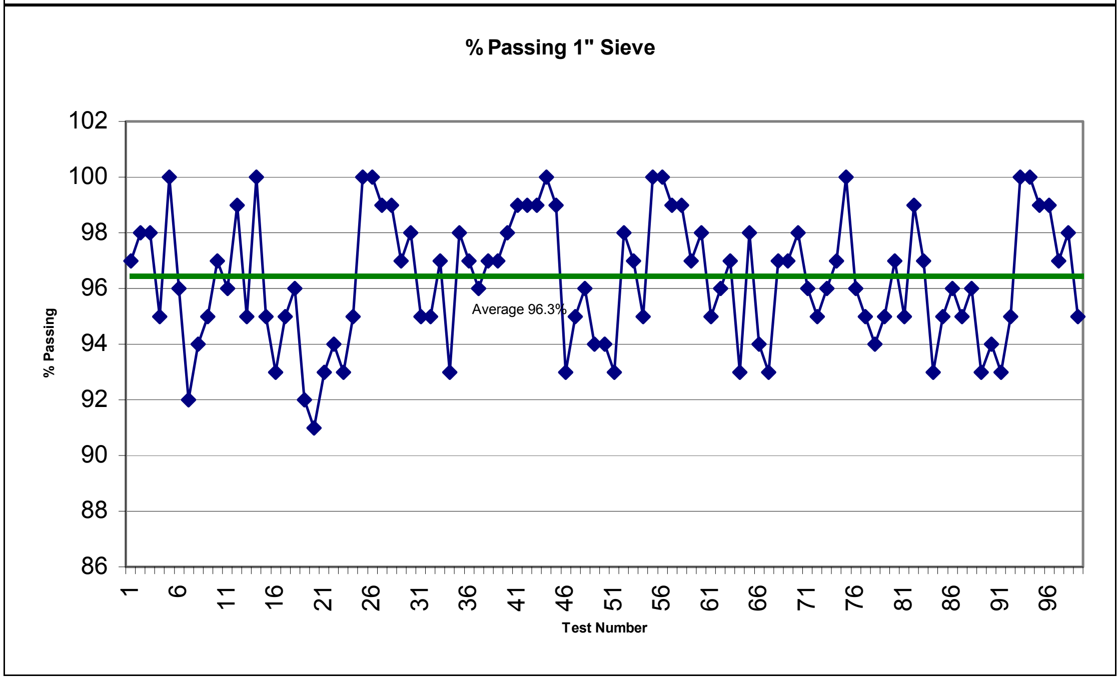
Gradings:
Ninety-nine grading samples were taken for the project. Table IV shows an analysis of the gradings.

Table IV

Analysis of Grading	Sieve	
	1 ½”	1”
Highest Value	100	100
Lowest Value	97	91
Average	99.7	96.3
Standard Deviation	0.7	2.3

The charts below give a graphical representation of the test data:





Gradings in the project were affected by the condition of the existing pavement, and pavement temperature. Existing pavement condition ranged from oxidized with block cracking to entirely alligatored pavement.

Compaction:
A total of 195 relative density tests were taken for the project. Theoretical Maximum Density was determined by California Test 216, and density readings were taken utilizing a nuclear gauge and California Test 375.
For this project, in addition to performance results measured as 96% relative compaction, the specification also required the contractor to have available on the project the following compaction equipment:

One - 10 tonne pneumatic tired roller
Two - 10 tonne double drum vibratory steel wheeled rollers

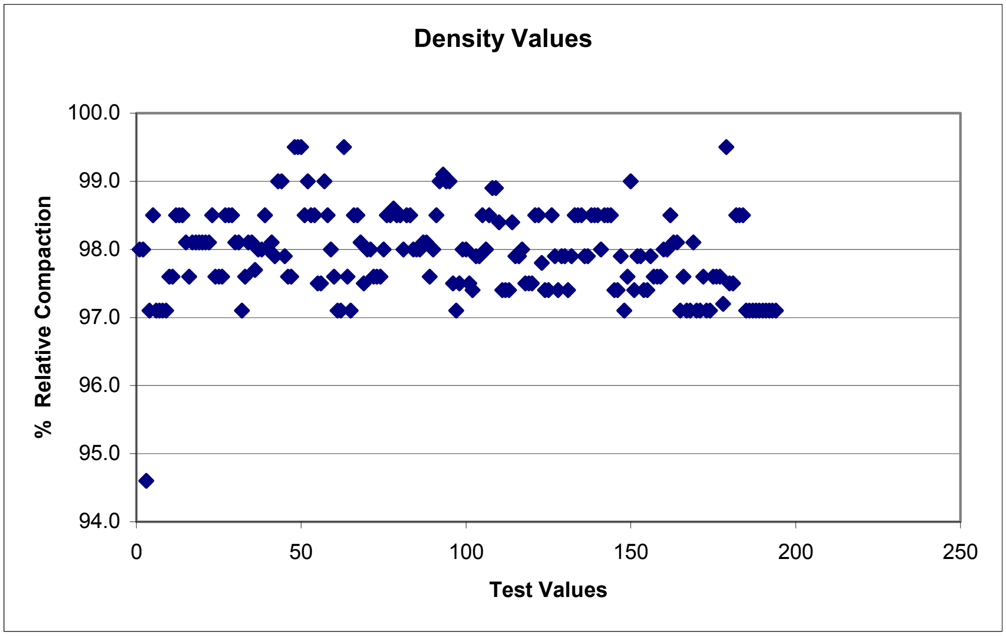
As part of the recycling, the contractor performed a start up test strip to verify materials characteristics and to establish a rolling pattern. This pattern was maintained throughout the project and consisted of a break down roll (steel drum), two coverages as an intermediate roll (steel drum), and three coverages as a final roll (pneumatic). Table V shows an analysis of the test results.

Table V	
Analysis of Density Testing	% Relative Compaction
Highest Value	99.5
Lowest Value	97.1[7]
Average	98.0
Standard Deviation	0.60

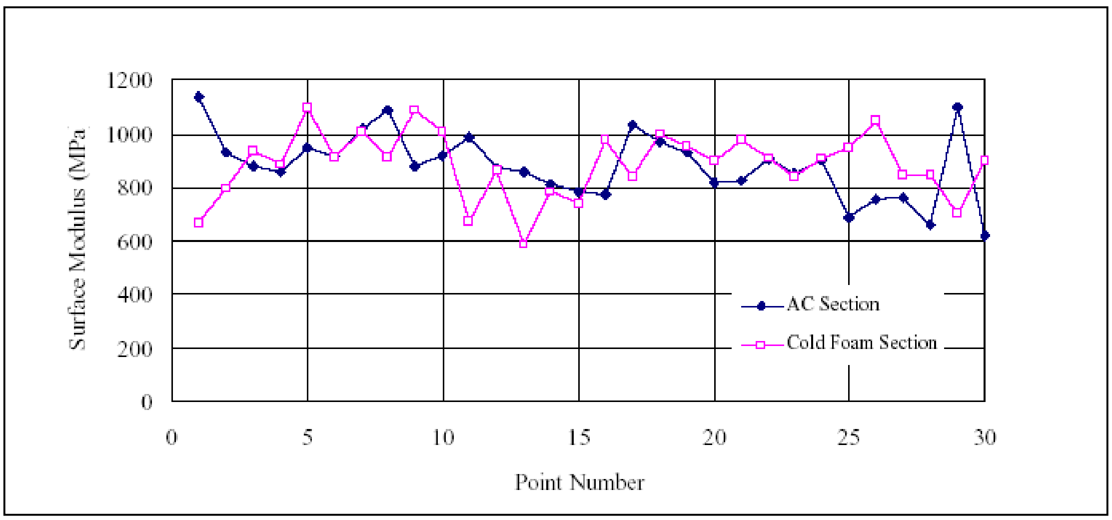
[7] One test showed a value of 94.6 and was considered an outlier, and not used in statistical analysis.

Compaction results are directly related to moisture content in the foamed material. The high compaction numbers show that consistent moisture content was maintained during recycling operations.

A graphical representation is shown below:



Initial Falling Weight Deflectometer Testing:
On July 11, 2005 a Falling Weight Deflectometer analysis was done on two sections within the project limits[8]. One section was recycled (.30'), the other a conventional mill and fill (.30'). Both sections had near identical CTB and AS below. The graph shows the surface modulus of both sections.



[8] Attachment I, "FWD Back-Calculation I-80 Rehabilitation Sections"

As can be seen in the comparison, the difference in overall stiffness of the two structures is insignificant.

Constructibility:
Over all the recycling process went very well. Average production was about 1-½ lane miles per day.
Very early on in the process it was determined that, in sections of the roadway that had multiple lanes and fixed facilities on both sides (HMA dike or guard rail and a median barrier), pre grinding in advance of the recycling operation was necessary in order to maintain existing cross slope. Expansion of the recycled material was caused by the addition of bitumen, cement, moisture, and a difference in relative compaction of the existing pavement prior to recycling and the recycled product. This expansion was calculated to be approximately 10 to 12 percent. In other areas with only one fixed facility, i.e. median barrier, it was only necessary to pre-grind if the adjacent section was not being recycled, or if recycling was to commence on the outside edge and move inward. Grinding depth varied from ½ to 1 inch. This equated to an additional 10 to 20 trucks moving in and out of the lane closure.

Pre-charging the WR4200 recycler with recycled foam material (see photo below) from the prior days operation was done to avoid having to back up the recycle train, or move material around with a loader to evenly distribute start up material.

Because of the heavy truck traffic in the early morning (between 5:00 am and 9:00 am), the changes in grade and the difference in stiffness between the interface of fresh recycled material and prior recycled material or AC, 15 to 20 feet of the foamed material at the beginning and end was removed and replaced with Hot Mix Asphalt (HMA). This acted as a shock absorber to truck loading. This was done to avoid minor irregularities at the interfaces, which might require repair prior to paving operations.

Fog seals were placed after the recycling operation and prior to trafficking. Initial spread rates were too high, and even with sand placed as a blotter, vehicles tracked the fog seal and, in some instances, picked up the surface of the recycle material, thus exposing a fresh face. This would sometimes lead to rapid raveling. The solution was to decrease the application rate by approximately 25% residual, and place sand at about ½ to 1 pound per square foot.

Cure time required prior to trafficking was found to be dependant on the ambient temperature, traffic loading and vehicle speed. The cure time was reduced with higher ambient temperatures. The average cure time required was about 4 hours. After that, traffic was allowed without speed restrictions.

In 2005, the season the recycling took place; California had an unprecedented number of rain days, and volume of rain. When rain was predicted within 24 hours of opening to traffic, operations were suspended. On one occasion rain was predicted to start approximately 6 hours after the scheduled opening to traffic, was to be light in nature and last less than half of the day. Instead, the rain started one hour prior to opening to traffic and continued for about 28 hours. While the section held together under traffic, it started to ravel under the traffic tire loading. As a result, rutting occurred. This required the first two inches of material to be removed and replaced with HMA.
Because of the unprecedented amount of rainfall and consecutive rain days, the sub-grade material below the CTB became super saturated and actually had water flowing through it. This water found cracks in the CTB and worked its way up through some seams between the recycled material and HMA (see photo below). This same type of failure

occurred in the HMA. It is interesting to note that after repairs and the first lift of the overlay was placed, no other failures occurred in the recycle section. However, failures were still noted in the HMA to HMA[9] seams.

The specification called for covering up all recycled material with HMA within seven days of recycling. Because of operational needs recycled material stayed uncovered and

[9] Teichert Letter, Attachment H

bearing traffic for up to 60 days on the shoulder and 30 days on the mainline. This extended period had little to no effect on the surface of the recycled material.

CONCLUSION:
This recycle project, utilizing foamed asphalt as a recycling agent, should be considered a success in that:

- It is the first project for Caltrans in which recycling was done on a high volume Interstate Highway, and immediately trafficked.
- It is the highest volume roadway to be recycled and immediately trafficked to date in the United States.
- Impacts to traffic during recycling operations were minimal and considered less than what would be encountered utilizing a mill and fill operation.
- It proved traffic could be run on foamed recycle material within four hours of placement and for extended periods of time, under weather that ranged from torrential downpours to temperatures of over 100° F for seven days.
- There were no claims for windshield breakage due to recycling operations. In contrast, there were a number of claims due to the mill and fill operation.
- Initial FWD testing showed the foamed recycle section equal to or stronger than an equivalent thickness of HMA.
- The project saved an estimated:
    - 112,100 tons of aggregate
    - 2,800 tons of bitumen
    - 4,700 truck trips @ an estimate 50 miles round trip
    - 235,000 truck traveled miles.
    - 23,000 gallons of diesel fuel @ $2.50/gl=$58,750
- After one year of service, no distress has been noted in the recycled areas.

FUTURE TESTING & REPORTS:
North Region Materials, Marysville will continue to perform FWD testing of the project, once a year for the next 4 years. Comparative results will be available on the North Region Materials, Marysville web site: http://northregion/materials/

A final report will be issued by North Region Materials, Marysville in September 2010.

Attachment A

2005 Annual Average Daily Traffic

District	Route	Rte Suf	County	PM Prefix	Postmile	Description	Back Peak Hour	Back Peak Month	Back AADT	Ahead Peak Hour	Ahead Peak Month	Ahead AADT
3	80		SAC	M	1.36	WEST EL CAMINO AVENUE	7200	86000	81000	6800	88000	84000
3	80		SAC	M	2.55	SACRAMENTO, JCT. RTE. 5	6800	88000	84000	11300	153000	144000
3	80		SAC	M	3.64	TRUXEL ROAD	11300	153000	144000	11500	146000	138000
3	80		SAC	M	4.98	SACRAMENTO, NORTHGATE BOULEVARD	11500	146000	138000	14900	157000	146000
3	80		SAC	M	6.12	SACRAMENTO, NORWOOD AVENUE	14900	157000	146000	11200	146000	144000
3	80		SAC	M	7.63	SACRAMENTO, RALEY BOULEVARD	11200	146000	144000	11200	149000	141000
3	80		SAC	M	8.67	SACRAMENTO, WINTERS STREET	11200	149000	141000	15100	157000	147000
3	80		SAC	M	9.4	SACRAMENTO, LONGVIEW DRIVE	15100	157000	147000	12300	155000	146000
3	80		SAC	M	10.36	WATT AVENUE	12300	155000	146000	15100	149000	136000
3	80		SAC	R	10.99	JCT. RTE. 51	15100	149000	136000	22700	258000	240000
3	80		SAC	R	11.11	JCT. RTE. 244 EAST						
3	80		SAC		12.48	MADISON AVENUE	22600	257000	239000	20900	219000	207000
3	80		SAC		14.45	GREENBACK LANE/ELKHORN BOULEVARD	20900	219000	207000	14000	194000	184000
3	80		SAC		16.69	ANTELOPE ROAD	14000	194000	184000	14100	185000	175000
3	80		SAC		18	SACRAMENTO COUNTY						
3	80		PLA		0	PLACER COUNTY (ROSEVILLE SOUTH CITY LIMITS)						
3	80		PLA		0.27	ROSEVILLE, RIVERSIDE AVENUE/AUBURN BOULEVARD	14100	185000	175000	11400	168000	159000
3	80		PLA		1.98	ROSEVILLE, DOUGLAS BOULEVARD	11400	168000	159000	13100	164000	154000
3	80		PLA		3.07	ROSEVILLE, EAST ROSEVILLE (ATLANTIC STREET)	13100	164000	154000	11900	168000	160000
3	80		PLA		3.66	ROSEVILLE, TAYLOR ROAD	11900	168000	160000	12600	158000	150000
3	80		PLA		4.16	ROSEVILLE, JCT. RTE. 65	12600	158000	150000	10300	120000	117000
3	80		PLA		6.06	ROCKLIN, ROCKLIN ROAD -	10300	120000	117000	8500	100000	97000
3	80		PLA		7.42	ROCKLIN, SIERRA COLLEGE BOULEVARD	8500	100000	97000	8400	104000	97000
3	80		PLA		8.72	LOOMIS, HORSESHOE BAR ROAD	8400	104000	97000	8500	93000	92000
3	80		PLA		10.35	PENRYN ROAD	8500	93000	92000	8200	88000	87000
3	80		PLA		13.81	NEWCASTLE ROAD	8200	88000	87000	7800	86000	82000
3	80		PLA		14.3	NEWCASTLE, JCT. RTE. 193 WEST	7800	86000	82000	7700	92000	85000
3	80		PLA		16.85	AUBURN, OPHIR ROAD	7700	92000	85000	7600	97000	88000
3	80		PLA		17.29	AUBURN, NEVADA STREET	7600	97000	88000	8000	100000	83000
3	80		PLA		17.54	AUBURN, JCT. RTE. 49	8000	100000	83000	6200	72000	65000
3	80		PLA		17.83	AUBURN, ELM AVENUE	6200	72000	65000	6300	73000	64000
3	80		PLA	R	18.94	LINCOLN WAY	6300	73000	64000	6000	68000	61000
3	80		PLA	R	19.47	AUBURN RAVINE/AUBURN- FORESTHILL ROADS	6000	68000	61000	5500	65000	55000
3	80		PLA	R	20.13	BOWMAN	5500	65000	55000	6200	71000	58000
3	80		PLA	R	21.13	HAINES/BELL ROADS	6200	71000	58000	5200	55000	50000
3	80		PLA	R	22.21	DRY CREEK ROAD	5200	55000	50000	5800	60000	51000
3	80		PLA	R	23.43	CLIPPER GAP/PLACER HILLS ROADS	5800	60000	51000	4450	49500	39500
3	80		PLA	R	26.21	APPLEGATE/CROTHER ROADS	4450	49500	39500	4350	41000	40500
3	80		PLA		27.39	HEATHER GLEN	4350	41000	40500	4350	44500	40000
3	80		PLA		28.59	WEIMAR ROAD	4350	44500	40000	4350	44500	39500
3	80		PLA		29.32	WEIMAR CROSSROAD	4350	44500	39500	4000	41000	37000
3	80		PLA		31.79	ILLINOISTOWN	4000	41000	37000	3850	38500	34500

District	Route	Rte Suf	County	PM Prefix	Postmile	Description	Back Peak Hour	Back Peak Month	Back AADT	Ahead Peak Hour	Ahead Peak Month	Ahead AADT
3	80		PLA		33.13	COLFAX, JCT. RTE. 174 NORTH	3850	38500	34500	4350	32000	28500
3	80		PLA		37.78	MAGRA ROAD	4350	32000	28500	4750	32500	28500
3	80		PLA		38.35	ALPINE	4750	32500	28500	4850	34500	28500
3	80		PLA		41.37	GOLD RUN	4850	34500	28500	4700	31000	27500
3	80		PLA		41.75	GOLD RUN SAFETY ROADSIDE REST AREA (ELEV. 3080 FEET						
3	80		PLA		42.19	SAWMILL (TO GOLD RUN)	4700	31000	27500	4050	35000	28000
3	80		PLA		43.17	MONTE VISTA	4050	35000	28000	3750	36000	27500
3	80		PLA		44.75	ALTA ROAD	3750	36000	27500	3500	32500	26500
3	80		PLA		46.31	CRYSTAL SPRINGS ROAD	3500	32500	26500	3650	32500	26000
3	80		PLA		46.94	BAXTER	3650	32500	26000	3800	34000	26000
3	80		PLA		49	DRUM FOREBAY ROAD	3800	34000	26000	3800	33500	26000
3	80		PLA		53.36	BLUE CANYON ROAD	3800	33500	26000	4550	33500	26000
3	80		PLA		54.81	PUTTS LAKE/NYACK	4550	33500	26000	4600	35000	26500
3	80		PLA	R	56.06	CARPENTER FLAT	4600	35000	26500	4500	35000	26500
3	80		PLA	R	58.71	PLACER-NEVADA COUNTY LINE						
3	80		PLA	R	58.84	YUBA GAP	4500	35000	26500	4400	32500	26500
3	80		PLA	R	59.54	JCT. RTE. 20 WEST	4400	32500	26500	5300	36000	29000
3	80		PLA	R	62.03	CARYLE ROAD, INDIAN SPRINGS	5300	36000	29000	5700	36000	29000
3	80		PLA	R	62.75	NEVADA-PLACER COUNTY LINE						
3	80		PLA	R	63.52	CISCO GROVE	5700	36000	29000	4400	36500	28500
3	80		PLA	R	66.2	HAMPSHIRE ROCKS	4400	36500	28500	4050	34500	28000
3	80		PLA		69.23	KINGVALE	4050	34500	28000	4000	34500	28000
3	80		PLA		69.77	PLACER COUNTY	4000	34500	28000			
3	80		NEV		0	NEVADA COUNTY				4000	34500	28000
3	80		NEV	R	2.48	SODA SPRINGS	3750	32500	28000	3650	32500	28500
3	80		NEV	R	5.07	CASTLE PEAK	3650	32500	28500	3850	39500	29500
3	80		NEV	R	5.52	DONNER SUMMIT SAFETY ROADSIDE REST AREAS (SUMMIT, ELEV. 7227 FEET)						
3	80		NEV	R	9.07	DONNER LAKE	4200	39500	29500	3650	36000	28500
3	80		NEV		13.21	TRUCKEE, DONNER PARK	3650	36000	28500	4000	37500	29000
3	80		NEV		14.16	TRUCKEE, JCT. RTE. 89 SOUTH	4000	37500	29000	3900	39500	31500
3	80		NEV		14.97	WEST TRUCKEE	3900	39500	31500	2800	42000	30000
3	80		NEV		16.29	JCT. RTE. 89 NORTH, JCT. RTE. 267 SOUTH; TRUCKEE, EAST	2800	42000	30000	4250	37500	30000
3	80		NEV		18.28	TRUCKEE, POLARIS; TRUCKEE AIRPORT ROAD	4250	37500	30000	3250	35000	29000
3	80		NEV		22.41	HIRSCHDALE ROAD OVERHEAD (BOCA)	3250	35000	29000	3850	42500	30000
3	80		NEV		27.29	TRUCKEE RIVER (FLORISTON)	3850	42500	30000	3550	37000	30000
3	80		NEV		29.49	FARAD	3550	37000	30000	3550	37000	30000
3	80		NEV		31.78	NEVADA COUNTY	3550	37000	30000			
3	80		SIE		0	SIERRA COUNTY				3550	37000	30000
3	80		SIE		1.59	NEVADA STATE LINE	3500	38000	28500			
4	82		SCL			SANTA CLARA COUNTY						
4	82		SCL	R	0	SAN JOSE, JCT. RTE. 101				5000	63000	62000
4	82		SCL	R	0.36	SAN JOSE, BLOSSOM HILL ROAD	5000	63000	62000	2700	33500	33000

Attachment B

2004 Annual Average Daily Truck Traffic

RTE	DIST	CNTY	POST MILE	LEG	DESCRIPTION	VEHICLE AADT TOTAL	TRUCK AADT TOTAL	TRUCK % TOT VEH	TRUCK AADT TOTAL By Axle 2	3	4	5+	% TRUCK AADT By Axle 2	3	4	5+	EAL 1-WAY (1000)	YEAR VER/ EST
080	03	YOL	R9.905	B	WEST SACRAMENTO, JCT. RTE. 50	146000	10760	7.37	3069	815	370	6507	28.52	7.57	3.44	60.47	2482	00E
080	03	YOL	R9.905	A	WEST SACRAMENTO, JCT. RTE. 50	76000	8307	10.93	2348	637	291	5032	28.26	7.67	3.5	60.57	1920	00E
080	03	YOL	R11.228	A	JCT. RTE. 84 EAST	80000	8328	10.41	3150	938	578	3662	37.83	11.26	6.94	43.97	1545	04E
080	03	SAC	M2.554	B	SACRAMENTO, JCT. RTE. 5	80000	8328	10.41	3150	938	578	3662	37.83	11.26	6.94	43.97	1545	04V
080	03	SAC	M2.554	A	SACRAMENTO, JCT. RTE. 5	145000	8309	5.73	2692	1080	415	4121	32.4	13	5	49.6	1676	86V
080	03	SAC	R10.989	B	JCT. RTE. 51	136000	8704	6.4	2646	1044	313	4700	30.4	12	3.6	54	1856	86E
080	03	SAC	R10.989	A	JCT. RTE. 51	240000	9336	3.89	2791	672	289	5583	29.9	7.2	3.1	59.8	2128	02E
080	03	SAC	14.454	A	GREENBACK LANE	186000	9263	4.98	3051	627	270	5315	32.94	6.77	2.91	57.38	2038	04V
080	03	PLA	.268	B	ROSEVILLE, RIVERSIDE DRIVE	179000	9272	5.18	3054	628	270	5320	32.94	6.77	2.91	57.38	2040	04E
080	03	PLA	.268	A	ROSEVILLE, RIVERSIDE DRIVE	163000	8590	5.27	2651	638	393	4908	30.86	7.43	4.57	57.14	1903	03E
080	03	PLA	3.07	A	ROSEVILLE, ATLANTIC STREET	158000	9101	5.76	2562	667	267	5604	28.15	7.33	2.93	61.58	2124	00E
080	03	PLA	4.16	B	JCT. RTE. 65	149000	9208	6.18	2592	675	270	5670	28.15	7.33	2.93	61.58	2149	00E
080	03	PLA	4.16	A	JCT. RTE. 65	116000	6450	5.56	1703	319	170	4258	26.4	4.95	2.64	66.01	1583	00E
080	03	PLA	14.301	B	JCT. RTE. 193 WEST	82000	6216	7.58	1641	308	164	4103	26.4	4.95	2.64	66.01	1525	00E
080	03	PLA	17.541	B	AUBURN, JCT. RTE. 49	83000	5860	7.06	1911	219	90	3641	32.61	3.73	1.53	62.14	1356	04E
080	03	PLA	17.541	A	AUBURN, JCT. RTE. 49	65000	5558	8.55	1812	207	85	3454	32.61	3.73	1.53	62.14	1287	04E
080	03	PLA	R19.465	B	AUBURN RAVINE ROAD	60000	5826	9.71	1900	217	89	3620	32.61	3.73	1.53	62.14	1348	04E
080	03	PLA	R19.465	A	AUBURN RAVINE ROAD	55000	5946	10.81	1939	222	91	3695	32.61	3.73	1.53	62.14	1376	04E
080	03	PLA	R23.429	A	CLIPPER GAP	41500	6030	14.53	1966	225	92	3747	32.61	3.73	1.53	62.14	1396	04E
080	03	PLA	33.131	B	COLFAX, JCT. RTE. 174 NORTH	34500	5510	15.97	1528	207	79	3696	27.73	3.76	1.43	67.08	1359	00E

RTE	DIST	CNTY	POST MILE	LEG	DESCRIPTION	VEHICLE AADT TOTAL	TRUCK AADT TOTAL	TRUCK % TOT VEH	TRUCK AADT TOTAL By Axle 2	3	4	5+	% TRUCK AADT By Axle 2	3	4	5+	EAL 1-WAY (1000)	YEAR VER/ EST
080	03	PLA	33.131	A	COLFAX, JCT. RTE. 174 NORTH	28500	5401	18.95	1498	203	77	3623	27.73	3.76	1.43	67.08	1332	00E
080	03	NEV	R59.54	B	Jct. Rte. 20 West	26500	5698	21.5	1580	214	81	3822	27.73	3.76	1.43	67.08	1405	00E
080	03	NEV	R59.54	A	Jct. Rte. 20 West	29000	5461	18.83	1400	230	80	3751	25.64	4.21	1.47	68.68	1376	00E
080	03	NEV	14.164	B	TRUCKEE, JCT. RTE. 89 SOUTH	29000	5197	17.92	1354	193	73	3578	26.05	3.72	1.4	68.84	1310	00E
080	03	NEV	14.164	A	TRUCKEE, JCT. RTE. 89 SOUTH	31500	5566	17.67	1404	181	74	3907	25.22	3.25	1.33	70.2	1425	04E
080	03	NEV	16.285	A	JCT. RTE. 89 NORTH, JCT. RTE. 267 SOUTH	30000	5568	18.56	1404	181	74	3909	25.22	3.25	1.33	70.2	1425	04E
080	03	SIE	1.593	B	NEVADA STATE LINE	30000	5568	18.56	1404	181	74	3909	25.22	3.25	1.33	70.2	1425	04E

Attachment C

Climate Summary - Precipitation

AUBURN, CALIFORNIA

Period of Record General Climate Summary - Precipitation

Station:(040383) AUBURN														
From Year=1914 To Year=2006														
	Precipitation											Total Snowfall		
	Mean	High	Year	Low	Year	1 Day Max.		>= 0.01 in.	>= 0.10 in.	>= 0.50 in.	>= 1.00 in.	Mean	High	Year
	in.	in.	-	in.	-	in.	dd/yyyy or yyyymmdd	# Days	# Days	# Days	# Days	in.	in.	-
January	6.40	18.42	1995	0.52	1976	4.75	10/1995	11	8	5	2	0.4	6.5	1972
February	6.01	17.61	1986	0.07	1953	3.98	19/1986	10	8	4	2	0.2	4.0	1989
March	5.25	16.77	1991	0.00	1926	3.37	09/1939	10	8	4	2	0.2	4.0	1991
April	2.79	9.95	1942	0.00	1933	3.85	07/1935	7	5	2	1	0.2	4.5	1982
May	1.21	5.58	1998	0.00	1920	2.94	16/1996	4	3	1	0	0.0	0.0	1949
June	0.37	2.64	1929	0.00	1915	1.97	16/1929	2	1	0	0	0.0	0.0	1949
July	0.05	2.97	1974	0.00	1914	2.03	09/1974	0	0	0	0	0.0	0.0	1948
August	0.08	1.59	1976	0.00	1914	1.21	15/1976	1	0	0	0	0.0	0.0	1948
September	0.46	3.99	1918	0.00	1914	2.00	12/1918	2	1	0	0	0.0	0.0	1948
October	1.83	13.86	1962	0.00	1915	5.41	13/1962	4	3	1	1	0.0	0.0	1948
November	4.16	13.92	1950	0.00	1929	3.76	21/1950	8	6	3	1	0.1	5.5	1985
December	5.86	18.78	1955	0.00	1989	4.02	20/1981	10	8	4	2	0.1	4.2	1972
Annual	34.47	64.87	1983	11.76	1976	5.41	19621013	67	50	25	11	1.2	10.7	1972
Winter	18.28	36.52	1956	4.59	1976	4.75	19950110	31	24	13	6	0.7	7.4	1989
Spring	9.25	24.47	1995	2.08	1934	3.85	19350407	20	15	7	3	0.4	4.5	1982
Summer	0.49	3.53	1974	0.00	1915	2.03	19740709	2	1	0	0	0.0	0.0	1949
Fall	6.45	19.09	1982	0.00	1929	5.41	19621013	13	9	5	2	0.1	5.5	1985

Table updated on Jul 28, 2006
For monthly and annual means, thresholds, and sums:
Months with 5 or more missing days are not considered
Years with 1 or more missing months are not considered
Seasons are climatological not calendar seasons
Winter = Dec., Jan., and Feb. Spring = Mar., Apr., and May
Summer = Jun., Jul., and Aug. Fall = Sep., Oct., and Nov.

COLFAX, CALIFORNIA

Period of Record General Climate Summary - Precipitation

Station:(041912) COLFAX														
From Year=1948 To Year=2006														
	Precipitation											Total Snowfall		
	Mean	High	Year	Low	Year	1 Day Max.		>= 0.01 in.	>= 0.10 in.	>= 0.50 in.	>= 1.00 in.	Mean	High	Year
	in.	in.	-	in.	-	in.	dd/yyyy or yyyymmdd	# Days	# Days	# Days	# Days	in.	in.	-
January	8.62	22.50	1995	0.35	1984	5.41	21/1967	11	9	6	3	5.2	39.0	1950
February	7.53	24.76	1986	0.09	1953	5.97	08/1960	10	8	5	3	3.0	38.0	1990
March	7.12	19.98	1989	0.44	1956	3.90	01/1974	11	9	5	2	2.6	24.5	1985
April	3.62	10.07	1963	0.12	1949	3.88	27/1953	8	6	2	1	0.9	10.0	1975
May	1.68	8.84	1957	0.00	1970	4.65	18/1957	5	3	1	0	0.0	0.0	1949
June	0.60	3.49	1967	0.00	1949	1.97	13/1967	2	1	0	0	0.0	0.0	1949
July	0.11	3.55	1974	0.00	1948	2.28	08/1974	0	0	0	0	0.0	0.0	1948
August	0.20	2.16	1976	0.00	1948	1.26	15/1976	1	0	0	0	0.0	0.0	1948
September	0.73	4.00	1986	0.00	1948	2.12	18/1959	2	1	0	0	0.0	0.0	1948
October	2.61	21.36	1962	0.00	1952	10.02	13/1962	4	3	2	1	0.0	0.0	1948
November	6.44	18.40	1950	0.00	1959	5.10	21/1950	9	7	4	2	0.3	8.0	1985
December	8.46	26.42	1996	0.00	1989	6.37	22/1964	11	9	5	3	1.7	18.0	1988
Annual	47.71	86.91	1983	15.38	1976	10.02	19621013	74	56	31	17	13.8	71.5	1952
Winter	24.61	43.86	1952	6.75	1991	6.37	19641222	32	25	16	9	9.9	55.5	1949
Spring	12.41	29.82	1995	2.59	2004	4.65	19570518	24	18	9	4	3.5	24.5	1985
Summer	0.91	4.11	1974	0.00	1951	2.28	19740708	3	2	1	0	0.0	0.0	1949
Fall	9.79	24.84	1950	2.03	1980	10.02	19621013	15	11	6	3	0.3	8.0	1985

Table updated on Jul 28, 2006
For monthly and annual means, thresholds, and sums:
Months with 5 or more missing days are not considered
Years with 1 or more missing months are not considered
Seasons are climatological not calendar seasons
Winter = Dec., Jan., and Feb. Spring = Mar., Apr., and May
Summer = Jun., Jul., and Aug. Fall = Sep., Oct., and Nov.

Attachment D

Log of Cores

PLA-080 03-0A6003 - Coring Data

PLA-080 Location 1 - East Bound

station	depth	core #	layout	direction	lane	base
32+60	4.000	#1	L-2	EB	#1	CTB
34+00	4.000	#2	L-2	EB	#1	CTB
36+50	5.000	#3	L-3	EB	#1	CTB
63+50	6.500	#4	L-4	EB	#1	CTB
66+00	5.750	#5	L-4	EB	#1	CTB
68+50	6.250	#6	L-4	EB	#1	CTB
71+00	5.500	#7	L-5	EB	#1	CTB
73+50	5.500	#8	L-5	EB	#1	CTB
76+00	5.500	#9	L-5	EB	#1	CTB
78+00	9.000	GL-1	L-6	EB	#3	CTB
78+50	5.250	#10	L-6	EB	#1	CTB
81+00	5.250	GL-2	L-6	EB	#3	AB
81+00	5.000	#11	L-6	EB	#1	CTB
83+50	4.750	#12	L-6	EB	#1	CTB
	77.250	**5.518**	average	depth		

PLA-080 Location 1 - Westbound

station	depth	core #	layout	direction	lane	base
62+50	7.000	#6WB	L-4	WB	#1	CTB
64+50	11.500	O-4	L-4	WB	#3	CTB
						CTB
65+00	6.125	#5WB	L-4	WB	#1	CTB
67+00	6.375	#4WB	L-4	WB	#1	CTB
70+00	5.500	#3WB	L-5	WB	#1	CTB
71+00	9.750	O-3	L-5	WB	#3	CTB
72+50	6.000	#2WB	L-5	WB	#1	CTB
75+00	6.250	#1WB	L-5	WB	#1	CTB
						CTB
79+00	9.500	O-2	L-6	WB	#3	CTB
						CTB
						CTB
95+00	8.400	O-1	L-8	WB	#3	CTB
	76.400	**7.640**	average	depth		

PLA-080 Location 2A - East Bound

station	depth	core #	layout	direction	lane	base
25+00	10.750	#1E	L-15	EB	#1	CTB
27+50	4.500	#2E	L-17	EB	#1	CTB
28+00	6.500	B-1	L-17	EB	#3	CTB
30+00	4.500	#3E	L-18	EB	#1	CTB
32+00	6.250	B-2	L-18	EB	#3	CTB
32+50	4.250	#4E	L-19	EB	#1	CTB
35+00	10.000	#5E	L-19	EB	#1	CTB
37+50	5.000	#6E	L-19	EB	#1	CTB
40+00	5.250	#7E	L-21	EB	#1	CTB
42+50	5.500	#8E	L-21	EB	#1	CTB
45+00	5.500	#9E	L-23	EB	#1	CTB
46+00	5.000	B-1	L-23	EB	#1	CTB
48+50	6.000	B-2	L-24	EB	#1	CTB
51+00	4.875	B-3	L-25	EB	#1	CTB
53+50	4.500	B-4	L-25	EB	#1	CTB
56+00	4.500	B-5	L-26	EB	#1	CTB
58+50	5.000	B-6	L-28	EB	#1	CTB
61+00	4.500	B-7	L-28	EB	#1	CTB
63+50	5.250	B-8	L-30	EB	#1	CTB
66+00	5.000	B-9	L-31	EB	#1	CTB
68+50	5.500	B-10	L-31	EB	#1	CTB
71+00	5.000	B-11	L-31	EB	#1	CTB
72+50	5.500	CT-1	L-31	EB	#3	CTB
75+00	5.000	CT-2	L-32	EB	#3	CTB
77+50	5.000	CT-3	L-33	EB	#3	CTB
91+00	5.000	CG-11	L-37	EB	#1	CTB
93+50	5.250	CG-10	L-37	EB	#1	CTB
96+00	5.000	CG-9	L-38	EB	#1	CTB
98+50	4.750	CG-8	L-38	EB	#1	CTB
101+00	5.000	CG-7	L-38	EB	#1	CTB
103+50	3.875	CG-6	L-39	EB	#1	CTB
105+00	6.500	T-1	L-39	EB	#3	CTB
106+00	5.000	CG-5	L-39	EB	#1	CTB
107+50	6.250	T-2	L-39	EB	#3	CTB
108+50	4.750	CG-4	L-39	EB	#1	CTB
110+00	6.500	T-3	L-40	EB	#3	CTB
111+00	4.500	CG-3	L-40	EB	#1	CTB
112+50	5.750	T-4	L-40	EB	#3	CTB
113+50	4.750	CG-2	L-40	EB	#1	CTB
115+00	6.500	T-5	L-40	EB	#3	CTB
116+00	4.750	CG-1	L-40	EB	#1	CTB
117+50	7.000	T-6	L-41	EB	#3	CTB
	229.750	**5.470**	average	depth		

PLA-080 Location 2A - West Bound

station	depth	core #	layout	direction	lane	base
74+00	5.875		L-32	WB	#2	CTB
77+00	5.875		L-33	WB	#2	CTB
93+00	5.375		L-37	WB	#2	CTB
109+00	5.500		L-39	WB	#2	CTB
112+00	5.000		L-40	WB	#2	CTB
118+00	5.370		L-41	WB	#2	
	32.995	**5.499**	average	depth		

PLA-080 Location 2B - East Bound

station	depth	core #	layout	direction	lane	base
8+00	5.000	T-7	L-45	EB	#3	CTB
20+50	6.000	T-8	L-46	EB	#2	CTB
26+00	4.500	T-9	L-47	EB	#2	CTB
32+00	5.500	T-10	L-48	EB	#2	CTB
36+50	5.750	T-11	L-49	EB	#2	CTB
39+00	6.250	T-12	L-50	EB	#2	CTB
41+00	6.750	T-13	L-51	EB	#2	CTB
42+00	6.000	T-14	L-52	EB	#2	CTB
44+50	7.500	T-15	L-53	EB	#2	CTB
47+00	5.250	T-16	L-54	EB	#2	CTB
	58.500	**5.850**	average	depth		

PLA-080 Location 2B- West Bound

station	depth	core #	layout	direction	lane	base
28+50	7.500		L-51	WB	#2	CTB
31+00	5.000		L-51	WB	#2	CTB
33+50	6.500		L-51	WB	#2	CTB
36+00	7.000		L-52	WB	#2	CTB
37+00	5.500		L-52	WB	#2	CTB
40+20	5.000		L-53	WB	#2	CTB
41+10	6.000		L-53	WB	#2	CTB
43+60	6.500		L-54	WB	#2	CTB
	49.000	**6.125**	average	depth		

Attachment E

CIPR Mix Design

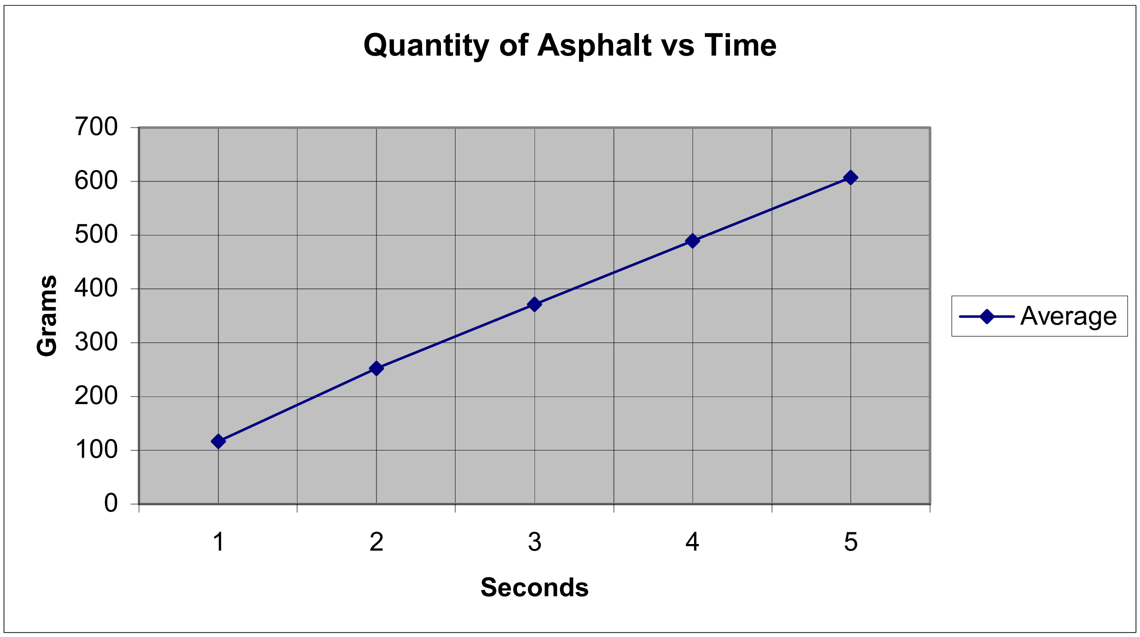
Calibration of WLB-10

Data Table 1

Time (seconds)	Test 1	Test 2	Test 3	Average
1	118	116	-	117
2	~~244~~	251	253	252
3	371	372	-	372
4	489	489	-	489
5	605	~~583~~	608	607

1. Graph weight vs. time.

Illustration 1



2. Calculate the equation of the line.

Equation of the Line:

$$M = \frac{(Y_5 - Y_1)}{(X_5 - X_1)} \qquad M = \frac{607-117}{5-1} = \frac{490}{4} = 122.5$$

Pick a set of values e.g. (5, 607), substitute and solve for B: (Y = MX + B)

1. 607 = (122.5) (5) + B
2. 607 = 612.5 + B
3. (607 – 612.5) = B
4. –5.5 = B

So the equation of the line is: **Y = (122.5) X – 5.5**

Now we will solve for **X** (this is just to make calculations easier later).

<u>X = (0.008163)Y +(0.04)</u> Where X is the time and Y is the number of grams of asphalt.

Check the equation by substituting a pair of X & Y values:

From Test 2 we have X=4 & Y=489

Is 4 = (0.008163)(489) + (0.044898) $\Rightarrow$ 4 = 3.99 + 0.04 $\Rightarrow$ 4 = 4.03 (checks)

3. Back calculate time required to deliver 500 grams of asphalt.

Calculating time required to deliver 500 grams of asphalt:

X = ?, Y = 500g $\Rightarrow$ From line equation: X = (0.008163)(500) + (0.04) = **<u>4.12 s</u>**

4. Set digital timer for this time.

CALCULATE SETTING OF WATER RATE (FLOW METER):

Note: Here we are dropping off the delay factor (0.04) since the delay is only initially and not for the entire time the valve is open.

X = 1 s, Y = ? $\Rightarrow$ X = (0.008163)Y (remember we are ignoring the delay factor here)

1. 1 = (0.008163)Y
2. 1.00 / (0.008163) = (0.008163) / (0.008163) Y
3. 1.00 / (0.008163) = Y
4. 122.5 = Y use Y=123

123 grams of asphalt per 1-second spray.

5. Calculate 2% of the asphalt grams delivered per second. This is the amount of water we will be adding to the asphalt.

(0.02)(123g/s) = 2.46 g/s of water needed

6. Calculate the equivalent in liters/ hour (flow meter readings).

Example: How to convert grams per second (g/s) to liters per hour (l/h):

$$2.5\ \frac{\text{grams}}{\text{second}} \times \frac{1\ \text{liter}}{1000\ \text{g}} \times \frac{60\ \text{seconds}}{1\ \text{minute}} \times \frac{60\ \text{minutes}}{1\ \text{hour}} = 9.0\ \frac{\text{liters}}{\text{hour}}$$

7. Repeat for 3% and 4% water.

For our example: 2 % water the rate is 9.0 l/h.
3 % water, the rate is 13.3 l/h.
4 % water, the rate is 17.7 l/h.

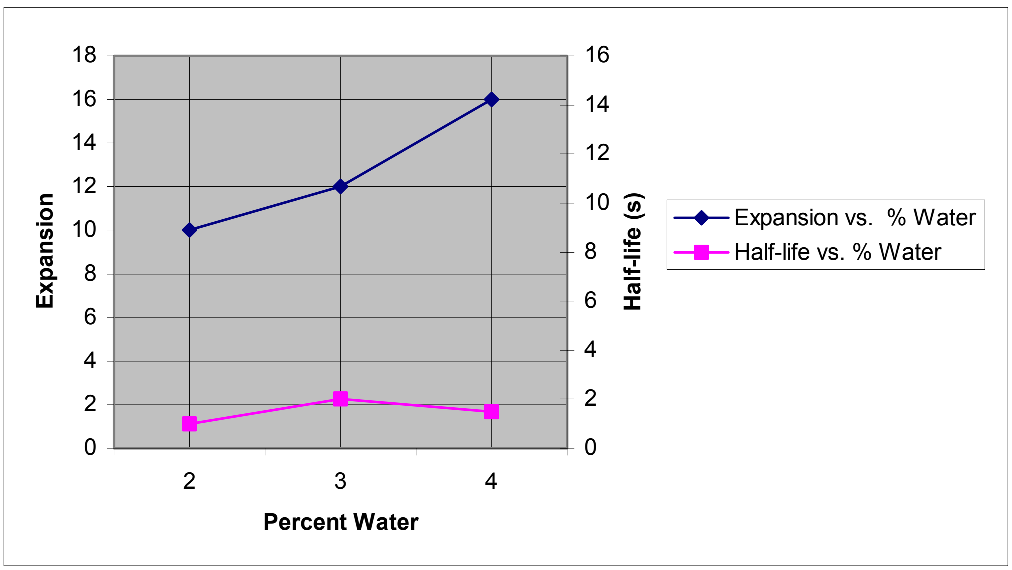
TEST EXPANSION & HALF-LIFE OF VARIOUS WATER PERCENTAGES:

Data Table 2

Water	**Expansion**	**Half-life** (in seconds)
2%	10	1
3%	12	2
4%	15	1.5

8. Plot Expansion vs. Percent Water and Half-Life vs. Percent Water.

Illustration 2



9. Choose optimum moisture from graph. Set flow meter for corresponding rate.

Optimum moisture from graph is approximately 3% water.

SETTING TIMER FOR FOAMING SAMPLE MATERIAL:

10. Choose percent binder to foam.
11. Add 0.5% for waste.

2.0% binder, 2.0 + 0.5 = 2.5%

12. Determine timer setting: Multiply percent by weight of sample to be mixed. We used 8400g sample.

    (.025) x (8400 grams) = 210 grams.

13. Go back to graph (Illustration #1) and equation of line to calculate time required.

    X = ?, Y = 210g
    X = (0.008163)(210) + (0.04) = **1.76s**

14. Set timer to this time. Foam sample and then prepare briquettes for curing.
15. Calculate timer setting for next binder percentage.

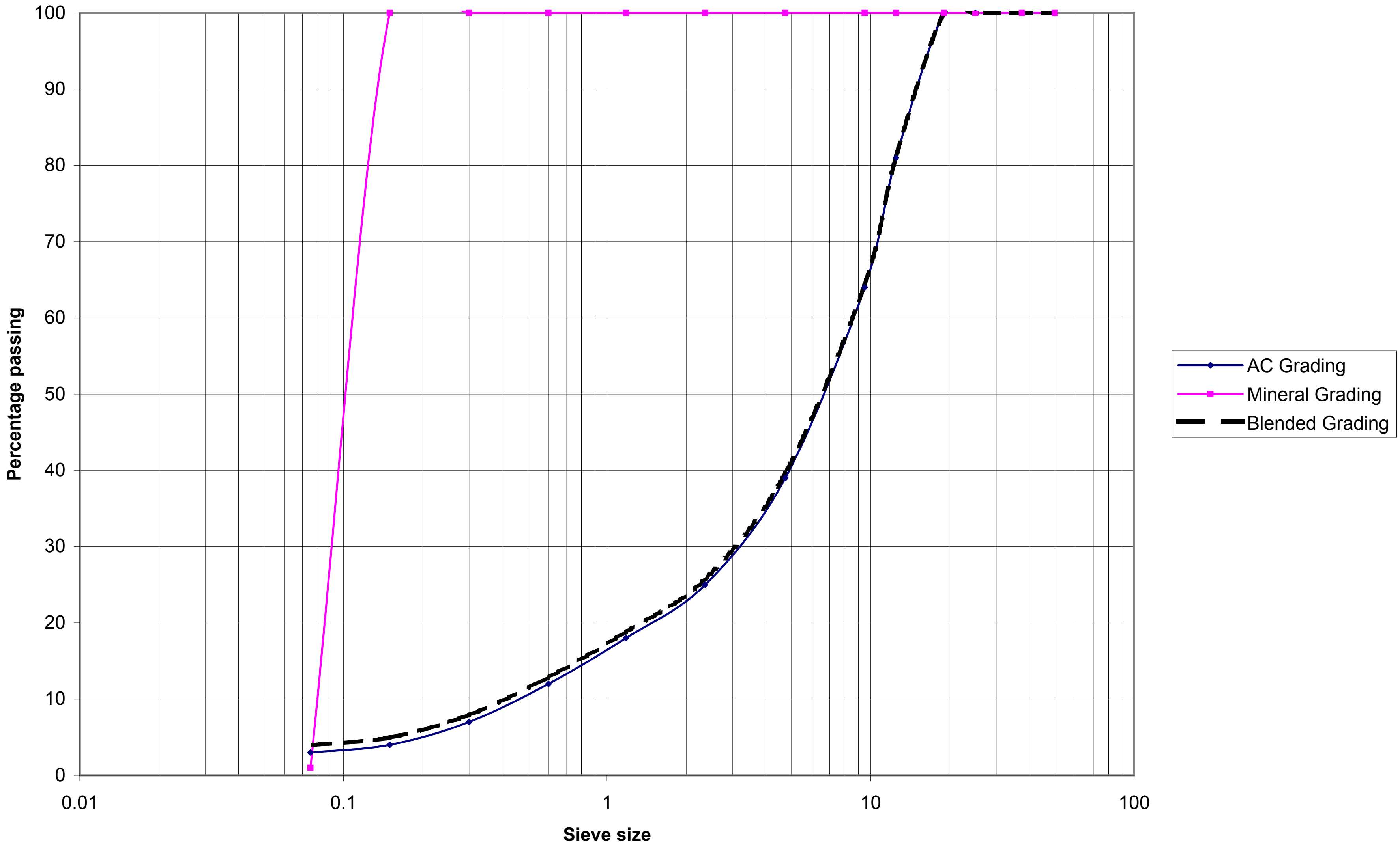
    2.5 % binder, 2.5 + 0.5 = 3.0%

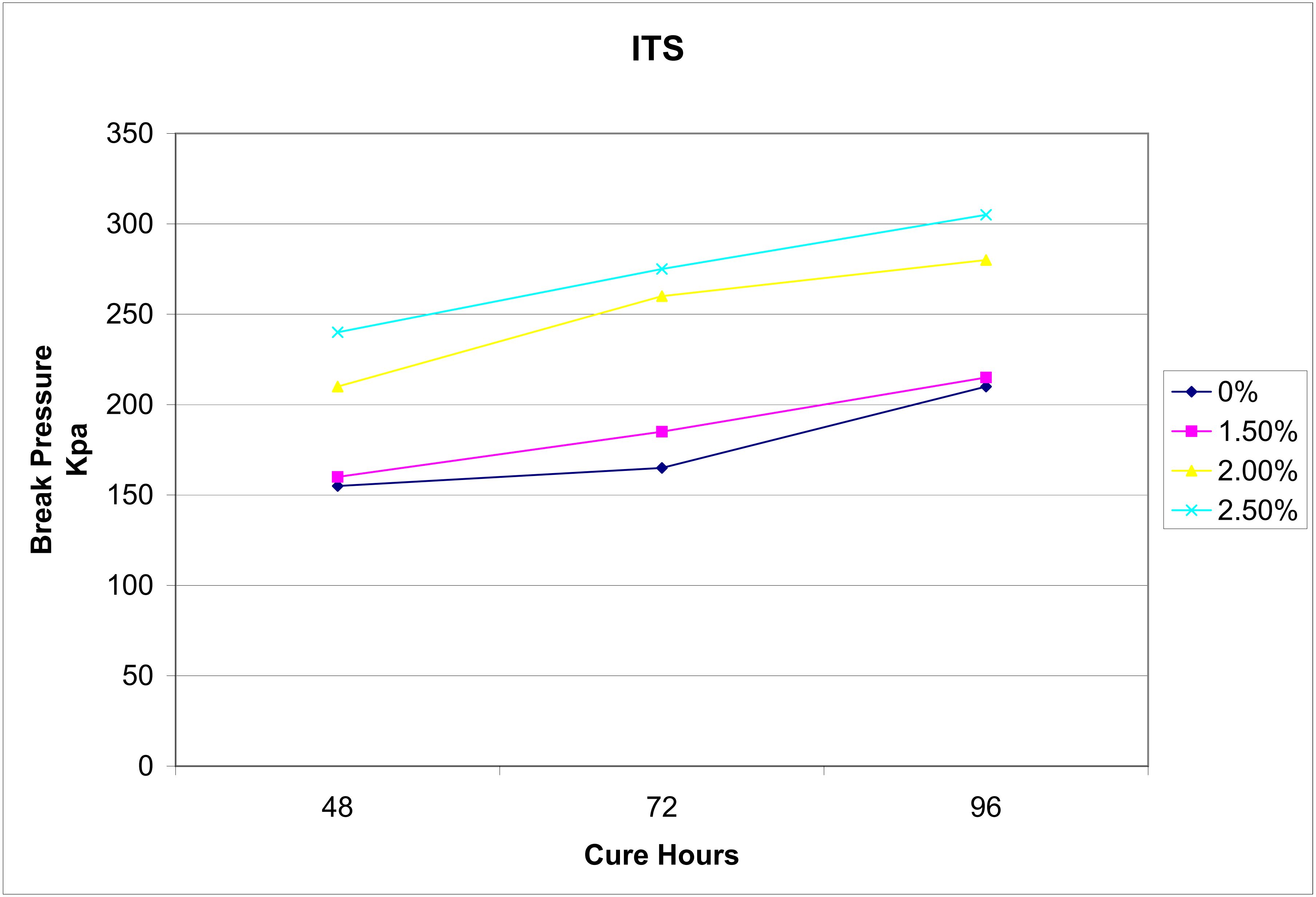
    X = (0.008163)(252) + (0.04) = **2.10s**

Test Sample #1: 3 % Foam water
3 % Compaction water
2.5 % oil
1 % Cement

Test Sample #2: 3 % Foam water
3.5 % Compaction water
2.0 % oil
1 % Cement

CIR Sieve Analysis




ITS
Break Pressure
Kpa
350
300
250
200
150
100
50
0
48
72
96
Cure Hours
0%
1.50%
2.00%
2.50%

Attachment F

Structural Section Design

M e m o r a n d u m

Flex your power!
Be energy efficient!

To: MR. PATRICK BISHOP, PE
Design Branch, S-13

Date: November 3, 2004

File: 03-PLA-80
KP 23.0/27.3; 30.6/55.4
(PM 14.3/16.9; 19.0/33.1)
03-1A6004

Attn: Pete Spector

From: DEPARTMENT OF TRANSPORTATION
North Region – Materials Laboratory

Subject: **Alternate Structural Section Recommendations**

An alternate structural section recommendation has been made for the above referenced project for PM 20.0 to PM 33.1.

A total of 89 full depth cores were taken on Pla-80 in six separate sections, three east bound, three west bound. This was completed to determine the existing pavement thickness profile. Cores varied from a minimum thickness of 98.4-mm (3.87") at station 103+50 EB (A60-line) to a maximum thickness of 292-mm (11.50") at station 64+50, WB (B-line).

Typically cores were removed in-tack, and were very uniform throughout all sections cored. Cores consisted of dense graded asphalt concrete in two or more lifts, with some areas showing surface treatments of open graded asphalt concrete or an old chip seal. In all locations with a prior chip seal, the seal showed signs of excessive wear as indicated by wear through in wheel paths.

Pavement surface investigation showed transverse cracking at 3.6 m (12') to 4.6 m (15') intervals, indicative of CTB as an under laying material. Fatigue cracking was noted throughout the project. Coring showed the fatigue cracking as top down cracking, indicating pavement had exceeded its design life. In areas cored, no significant base failures were noted. CTB appeared to be performing well.

STRUCTURAL SECTION RECOMMENDATIONS

MAINLINE and SHOULDERS – Existing PM 20.0/33.1 **TI_{20}=14.5**

Cold in Place Recycle (CIR) 106-mm of existing pavement utilizing:

- 2.5% Foamed asphalt
- 1% Type II cement

- 3% Foamed water
- 1%-2% Compaction water
- Apply a fog seal of 0.451/m^2 to 0.651/m^2 of CQS-1 prior to trafficking
- Utilize temporary paint striping
- Minimum cure time shall be 3 days, and maximum cure time shall be 7 days
- CIR operations shall start in the shoulder.

Required Gravel Equivalent (GE) per HDM 600 for Mainline 848-mm GE

Original Recommended Section:

30-mm RAC (G_f = 1.4) = 42-mm GE
75-mm DGAC (G_f = 1.46) = 110-mm GE
100-mm DGAC (G_f = 1.46) = 149-mm GE
244-mm CTB (G_f = 1.2) = 293-mm GE (existing)
305-mm AS (G_f = 1.0) = 305-mm GE (existing)
Total 754-mm Total 899-mm GE

Assuming that the untreated material is at a minimum as strong as Class II aggregate base, a simple ratio of tensile strengths (ITS) is used to determine the gravel factor (G_f) of CIR. Using the average values obtained during laboratory testing after 48 hours curing for both untreated and Foamed Bitumen at 2.5% and utilizing the formula: G_{fCIR} = [(Treated ITS)/(Untreated ITS)] + 0.1 results in a G_{fCIR} = 1.8. Utilizing a conservative approach, a gravel factor of G_{fCIR} = 1.4 will be used.

New Proposed Section:

30-mm RAC (G_f = 1.4) = 42-mm GE
75-mm DGAC (G_f = 1.46) = 110-mm GE
106-mm CIR (G_f = 1.4) = 149-mm GE
244-mm CTB (G_f = 1.2) = 293-mm GE (existing)
305-mm AS (G_f = 1.0) = 305-mm GE (existing)
Total 760-mm Total 899-mm GE

MATERIALS SPECIFICATIONS

Dense Grade Asphalt Concrete (DGAC) – Type A, 19-mm Maximum Medium shall conform to Section 39 of the Standard Specifications and the Special Provisions and shall be lime-treated.

Rubberized Asphalt Concrete (RAC) – Type O, shall conform to Section 39 of the Standard Specifications, SSP 39-480 and the Special Provisions.

Asphalt Binder – Asphalt binder used for DGAC shall be grade PBA-6A and shall conform to sections 39 and 92 of the Standard Specifications.

Asphalt Binder – Asphalt binder used for CIR shall be grade AR-4000 and shall conform to sections 39 and 92 of the Standard Specifications.

Paint Binder – Shall conform to sections 39 and 92 of the Standard Specifications.

Shoulder Backing – Shall conform to SSP 19-720_M.

If you have any questions please contact me at (530) 741-5378.

JOSEPH F. PETERSON
District Materials Engineer

c: PSpector
File

Attachment G

CIPR Standard Special Provision

EA. NO. 03-0A6004

The special provisions contained herein have been prepared by or under the direction of the following Registered Persons.

HIGHWAYS

REGISTERED CIVIL ENGINEER

REGISTERED PROFESSIONAL ENGINEER
Joseph F. Peterson
No. C 39841
Exp. 12-31-05
CIVIL
STATE OF CALIFORNIA

10-1.__ COLD-IN-PLACE RECYCLING

This work consists of milling the existing asphalt concrete pavement to the length, depth and width as shown on the plans; mixing the cold milled material with expanded asphalt and other additives where required; then spreading and compacting the recycled pavement mixture to the lines and grades as specified in these special provisions and as shown on the plans.

Attention is directed to "Order of Work" elsewhere in these special provisions.

SURFACE PREPARATION

Before any reclaiming or recycling work begins, the Contractor shall prepare the existing roadway by:

A. Clearing all vegetation and other foreign matter from the entire roadway width;
B. Removing all standing water;
C. Referencing the profile and cross slope of the existing pavement to be used to establish the finished surface of the recycled pavement mixture within ± 15 mm of existing profile and cross slope surface; and
D. Pre-marking the proposed longitudinal cut lines on the existing roadway surface.

MATERIALS

Existing Material

A summary of the existing material investigation is available to the Contractor within the "Materials Information" handout. The handout may be obtained from District 3 Materials Branch at 703 B Street Marysville, CA 95901.

Cold Milled Asphalt Concrete

Existing asphalt concrete pavement shall be cold milled, pulverized and sized to conform to the following gradation before mixing with emulsified recycling agent:

Sieve Sizes	Percentage passing
37.5-mm	100
25 -mm	90

The contractor shall insure, by mechanical or manual means, all millings larger than 37.5-mm are disposed of as provided in Section 7-1.13, "Disposal of Material Outside the Highway Right of Way," of the Standard Specifications.

Recycling Asphalt

Recycling asphalt shall be AR-4000 and conform to the requirements of Section 92, "Asphalts," of the Standard Specifications and these special provisions. Recycling asphalt shall be added to the milling and recycling process at the rate prescribed by the mix design. Recycling asphalt that has been heated above 190°C shall not be used for producing foamed asphalt. A 1-liter sample of asphalt shall be taken for each tanker supplied to the project.

The Contractor shall provide test results for asphalt from an AASHTO certified laboratory. The Contractor shall provide test results and a Certificate of Compliance in conformance with Section 92-1.03, "Test Results," of the Standard Specifications.

Samples of asphalt shall be submitted to the Engineer, not less than two weeks prior to commencing recycling operations.

The contractor shall obtain a 1-liter sample of asphalt from the delivery tank prior to incorporation of asphalt into recycling process. A sample shall be taken from each load delivered to the project. Samples shall be delivered to the Engineer at the end of each working day. Sample containers shall be clean, dry, and sealed.

Water

Water used for cold in-place recycling shall be clean and free of foreign substances and shall not cause an adverse effect on the recycled pavement mixture. Water added by the milling machine for compaction purposes shall be added by weight of the recycled pavement mixture per the approved mix design or as directed by the Engineer. Water added by the milling machine for the purposes of expanded asphalt shall be added by weight of the asphalt per the approved mix design or as directed by the Engineer.

Additives

Cement shall be added to the recycled pavement mixture as determined by the mix design. Cement shall be added to the recycled mixture as a slurry, introduced at the pug mill.

Cement shall conform to the provisions in Section 90-2.01, "Portland Cement," of the Standard Specifications.

A Certificate of Compliance in conformance with the provisions of Section 6-1.07, "Certificates of Compliance," of the Standard Specifications shall be furnished with each delivery of cement. The Certificate of Compliance shall be submitted to the Engineer with a certified copy of the mass for each delivery.

CONTRACTOR QUALITY CONTROL INSPECTION, SAMPLING, AND TESTING

The Contractor shall perform process and quality control sampling and testing, and exercise management control to ensure that cold in-place recycling and placement conforms to these specifications. The Contractor and Engineer shall meet one week prior to the start of the cold in-place recycling operations to review the quality control plan. At a minimum the quality control plan shall include the following

- Outline of process which will insure all materials and work submitted for acceptance will conform with the contract.
- Outline the inspection and tests required to support conformance with contract which will be performed by the Contractor.
- Identify the Quality Control Manager and testing personnel along with qualifications
- Identify laboratories and equipment which will be used by the Contractor to performs inspection, sampling and testing required by the contract.
- Document the Contractors policy for obtaining quality and assignment of QC accountability and responsibility.

Process and quality control, sampling, and testing shall be provided during the cold in-place recycling, placement, compaction and finishing. Sampling and testing shall be performed at a rate sufficient to ensure that cold in-place recycling, placement, compaction and finishing conforms to these specifications.

A testing laboratory and personnel shall be provided for the performance of process and quality control testing. The Engineer shall have unrestricted access to mix design, sampling, and testing.

The proficiency of testing laboratories and sampling and testing personnel shall be reviewed, qualified, and certified by the Department's Independent Assurance Program prior to providing services to the project.

The project shall be divided into 3,000 square meter lots. For each lot the Contractor shall provide the following information:

1. Length, width and depth of cut, and measured weight (tonnes) of material processed.
2. Amount of asphalt added (tonnes), and calculated percentage of asphalt mass compared to the total mass of the material processed in the lot.
3. Amount of any cement mixed in the recycling process.
4. For each lot, the Contractor shall obtain a 10,000 gram sample of the recycled material behind the recycling equipment. This sample shall become the property of the Engineer.
5. For each lot, a minimum 5000 g sample of the recycled material shall be taken and placed in sealed plastic containers so as not to allow loss of moisture. The Contractor shall perform California test 202, sieve analysis and California test 226, moisture content. If the result of the gradation test does not meet the specified maximum particle size requirement, the test results shall be reported immediately to the Engineer. The Contractor shall take corrective action to reprocess the material, until the processed material conforms to the gradation requirements. Moisture and gradation results shall be reported in writing to the Engineer at the end of each work shift.
6. Some sections of the pavement being recycled may require field adjustment for optimum results. For any changes made by the Contractor from one lot to the next, the Contractor shall document the reason for the change and identify each lot where such changes were made.
7. After final compaction of the recycled pavement, the average in-place density, based on CT 216, and average asphalt/moisture content based on CT 231, for each lot shall be determined based upon three individual tests. During density testing of the compacted recycled pavement, the nuclear gauge shall be set to the same recycled section thickness. The average residual moisture content for each lot shall be determined by the following equation:

    Average Residual Moisture Content (%) = Average moisture content (%) after recycling – Average moisture content before recycling (%) – (Residual asphalt of emulsified recycling agent (%) x Emulsified recycling agent (%) added)

    Any subsequent surface treatment or overlay shall not be allowed until the Average Residual Moisture Content (%) is less than 4 percent.

    After compaction, but prior to opening the roadway to traffic, the average in-place density for each lot shall have a relative compaction of not less than 97 percent, as determined by California Test 231.

    If additional rolling does not achieve the minimum relative compaction, a new rolling pattern shall be established, such that a new maximum dry density is determined with the rollers specified. However, care should be taken not to over-roll the mat based on visual observations of cracking or shoving. A new rolling pattern shall be established if the material being recycled changes.

The Contractor shall measure and record the actual depth of cut at both ends of the milling drum, at least once every 100-m along the cut length. Measurements shall be taken in the presence of the Engineer and submitted in writing to the Engineer at the end of each day.

The Contractor shall provide daily reports of asphalt application rate and quantity, water application rate and quantity, average residual moisture content of the recycled pavement at compaction, and average density and relative compaction at placement.

The cold recycled material cross slope shall be checked regularly during spreading using a level. The smoothness shall not vary more than 6 mm from the lower edge of a 3.6-m ± 0.06-m straightedge placed on the surface parallel and transversely to the centerline after rolling of the recycled pavement is completed.

When Portland Cement is used, the contractor shall submit a daily log with the quantity of material incorporated; mass processed and certified weigh tickets to the Engineer.

Compacting Equipment

Compacting equipment shall conform to the requirements of the provisions in Section 39-5.02, "Compacting Equipment," of the Standard Specifications. The contractor shall provide a minimum of one pneumatic-tired roller weighing at least 10-tonnes, and two double drum, vibratory, steel-wheeled rollers weighing at least 10-tonnes. Rollers shall have a width of not less than 1.7-m.

The double drum, vibratory, steel-wheeled roller operating in static or vibratory mode, shall perform final rolling, to eliminate pneumatic tire marks and to achieve density.

COMPACTION

Initial Compaction

Compacting of the recycled mix shall be completed using rollers meeting the requirements of these special provisions. A rolling pattern shall be established to achieve a maximum density determined by California Test 231. The rolling pattern shall be determined in the test strip as required by these special provisions.

The selected rolling pattern shall be followed, unless changes in the recycled mix or placement conditions occur and a new rolling pattern is established at that time. The rolling pattern shall change when major displacement and/or cracking of the recycled material is occurring.

Rolling shall start no more than 30 minutes behind the paver. When possible, rolling shall not be started or stopped on uncompacted material but with rolling patterns established so that they can begin and end on previously compacted material or the adjacent, existing surfacing.

TEST STRIP AND START UP PROCEDURES

As part of the first day of operations, the Contractor shall construct, within the limits to be cold in-place recycled, a test strip of recycled pavement mixture of a single lane width at least 500 meters in length. The test strip section shall:

A. Demonstrate, to the Engineer, that the equipment, materials and processes proposed and furnished by the Contractor can produce a recycled pavement mixture layer that conforms to the requirements of these special provisions;
B. Determine the effect on the grading and the consistency of the milling and mixing of the reclaimed material by varying the forward speed of the reclaiming machine and the rotation rate of the milling drum to produce a homogeneous layer;
C. Determine the optimal spread rates for expanded asphalt, additives and water recommended for the mixture, and
D. Determine the sequence and manner of rolling necessary to obtain the specified compaction.

The Contractor shall test and report to the Engineer the results of moisture content, gradation and relative compaction of the completed test strip of recycled pavement mixture. In addition, the Contractor shall provide records of application rate for water, expanded asphalt, and additives.

Cold in-place recycling operations may continue through the first day, unless the Contractor does not meet the specified grading and relative compaction, or if it has been demonstrated that the Contractor's equipment and process fail to meet the requirements for successful completion of the cold in-place recycling process in conformance with these special provisions.

Cold in-place recycling operations shall not begin until a test strip conforming to the special provisions has been constructed.

Test strips that do not conform to the special provisions shall be reworked, recompacted or removed and replaced at the Contractor's expense. The Contractor shall use the same equipment, materials and construction methods used to construct an acceptable test strip for the remainder of the recycling operations.

The Contractor shall provide a report of expanded asphalt application rate, quantity of additive, application rate and quantity of water, application rate and moisture content of the recycled mixture, or water, and in-place density and relative compaction for the test strip.

The Contractor shall construct additional test strips when the compaction of any lot of completed recycled pavement mixture is below 96 percent relative compaction per California Test 231.

MILLING AND MIXING RECYCLING MATERIALS CONSTRUCTION

No cold in-place recycling work shall be performed during wet conditions, nor started if the National Weather Service for the county where work is to be performed forecast rain within 24 hours. No cold in-place recycling work shall be performed unless the pavement temperature is

16°C and rising.

Unsuitable subgrade material shall be removed as determined by the Contractor and approved by the Engineer. Removal of unsuitable subgrade material will be paid for as extra work as provided in Section 4-1.03D, of the Standard Specifications. Where unsuitable subgrade material is encountered during the recycling process, the subgrade material shall be

A. Excavated and removed to a depth of 300 mm; and
B. Replaced and backfilled to a level even with the existing road with Class 2 Aggregate Base in conformance with Sections 26-1.04, "Spreading" and 26-1.05, "Compacting," of the Standard Specifications, topped with 50-mm of Type A asphalt concrete or premixed bituminous surfacing. If premixed bituminous surfacing is used, it shall be removed and replaced with Type A asphalt concrete prior to placement of the asphalt concrete final surfacing. Backfill shall be placed in layers and compacted until the level of the existing road is reached.

To ensure complete recycling across the full width of the roadway, longitudinal joints between successive cuts shall overlap a minimum of 100-mm. Longitudinal joints shall coincide with changes in the existing cross slope at centerline and edge of the travel way.

The Contractor shall ensure that there are no gap of unrecycled material created between successive cuts (along the same longitudinal cut line), nor any untreated wedges created by the entry of the milling drum into the existing material.

SPREADING AND COMPACTING RECYCLED PAVEMENT MIXTURE MATERIAL

Remove, by hand, and dispose of all visible oversized crack filler in the cold milled material or in the recycled pavement mixture.

The cold in-place recycled pavement mixture shall be shaped and compacted to the depth, lines and grades shown on the plans and as required by these special provisions. The recycled layer shall conform to the required grading, recommended asphalt and moisture content and consistency prior to compacting. The recycled pavement mixture shall exit from the mixing chamber in a manner that prevents particle segregation. Care shall be exercised while spreading to avoid segregation, tearing or scarring of the final compacted surface. The profile and cross slope of the compacted recycled pavement mixture shall match the profile and cross slope of the existing pavement prior to beginning recycling.

Rolling shall commence at a time interval following the milling, mixing and spreading of the recycled pavement mixture, as determined by the Contractor. Time intervals shall be based on ambient temperatures, and weather.

The final surface shall be free of ruts, bumps, indentations and segregation of fine and coarse aggregate, conforming to the profile and cross slope of the existing pavement prior to recycling.

After compaction has been achieved, and prior to opening the cold in-place recycled pavement mixture to traffic, the Contractor shall apply a fog seal to the recycled pavement surface. The fog seal shall be quick set emulsified asphalt that has been diluted 50 percent by volume with water. The fog seal shall be applied to the finished surface at a rate of 0.20 to 0.90 liters per square meter. The rate of application shall be determined by the Contractor and shall be such that a stable and safe roadway surface can be maintained until the surface is overlayed.

Prior to beginning recycling operations each day, the Contractor shall sweep all segments of stabilized base surface constructed the prior day to remove loose material.

Prior to opening the recycled roadway surface to traffic, the Contractor shall sweep all segments of loose materials. The Engineer will determine whether the quality of material and workmanship provided conforms to the requirements of these special provisions and whether or not the recycled material will support public traffic.

The Contractor shall be responsible for protecting and maintaining the recycled pavement mixture layer until the initial layer of asphalt surfacing is placed. Any repairs required shall be at the Contractor's expense. Any damage or defects in the layer shall be repaired immediately. An even and uniform surface shall be maintained.

The recycled pavement layer shall remain in place prior to the initial layer of asphalt surfacing is placed either:

A. A minimum of 3 days and until there is less than 1 percent moisture remaining in the cold in-place recycled pavement mixture, or
B. A maximum of 14 days.

Attachment H

Teichert Letter

8689 Thys Court
Sacramento, CA 95828-1006
P.O. Box 276830
Sacramento, CA 95827-6830
(916) 386-5900 • FAX (916) 386-2940

TEICHERT CONSTRUCTION Established 1887
Heavy & Highway Division

June 2, 2006

Department of Transportation
North Region – Auburn Field Office
14300 Musso Road
Auburn, CA 95603

Attn: Rod Murphy
Resident Engineer

Re: Report on 1st Season's Performance of Recycled AC vs. 1-1/2" virgin AC Substrate
Hwy 80 Auburn to Colfax – Contract No. 03-0A6004
Teichert Job #1400054

Dear Rod,

As you know, at the end of last season the entire project was covered by the first of two layers of ¾" dense AC. Underlaying this layer of ¾" dense AC is a substrate of either Recycled AC or Virgin 1-1/2" AC. This allows us to compare the performance of each substrate over the first season's exposure.

This last winter we encountered severe weather conditions with snowplows clearing snow as far down as Bell Road and record rain being recorded for the month of March. This severe weather in combination with heavy truck and vehicle traffic on Highway 80 resulted in five small areas of distressed asphalt pavement that required repair ahead of placing the second and final layer of ¾" dense AC. **None of the distressed areas occurred where Recycled AC was used as the substrate.**

During its first season of exposure to severe weather, the pavement in which Recycled AC was utilized as the substrate performed superior to the pavement in which 1-1/2" virgin AC was utilized as the substrate.

Sincerely,

TEICHERT CONSTRUCTION

John R. Purvis
Project Manager

FAX: (530) 878-1277
CC: Caltrans: Lynette Spadorcio, Brian Syftestad, Joe Peterson
Teichert: Outgoing, LR, MG, ME, DS, AY, SAC, VSI

Attachment I

FWD Back-Calculation I-80 Rehabilitation Sections

DRAFT

FWD Back-Calculation on

Interstate Highway 80 Rehabilitation Sections

Part of Partnered Pavement Research Program (PPRP)
Strategic Plan Item 4.12

Technical Memorandum prepared for
California Department of Transportation (Caltrans)
Office of Flexible Pavement Materials

Technical Memorandum TM-UCB-PRC-2005-11

Prepared by:
Pengcheng Fu, John T. Harvey, Nicholas F. Coetzee and Per Ullidtz

Pavement Research Center
University of California, Berkeley
University of California, Davis

July 2005

1.0 TESTING AND ANALYSIS PERFORMED

This technical memo presents resilient moduli (also referred to as stiffness) of pavement layers back-calculated using CalBack for two sections on the I-80 rehabilitation projects near Auburn, California. The testing was performed by Caltrans using their Falling Weight Deflectometer (FWD). Several different structures were analyzed. 30 locations were tested for each section, and 3 drops with different loads were applied at each location. The length of each section was approximately 1500 m. The FWD testing was carried out between 1:00 PM and 2:00 PM on July 11, 2005. The structural profiles of the two sections provided by District 3 are shown in Table 1.

Table 1 Structural Profiles Provided by District 3 for the Two FWD Testing Sections

	Section A (Using Cold Foam)		Section B (Using AC)	
Layer #	**Material**	**Thickness (mm)**	**Material**	**Thickness (mm)**
1	19 mm AC AR4000	38	19 mm AC AR4000	37
2	Cold foam mix	100	37.5 mm AC AR4000	100
3	Existing AC	45	Existing AC	42
4	First lift CTB*	122	First lift CTB*	122
5	Second lift CTB*	150	Second lift CTB*	150
6	Subbase & Subgrade		Subbase & Subgrade	

*CTB lifts are separated by asphaltic bond breaker.

The data provided on July 12 have two limitations:

1. Only one cross-section was provided. Back-calculated stiffness is sensitive to layer thickness, and better and more consistent estimates of the stiffness of each layer are obtained from back-calculation with correct cross-sections for each location. This is

particularly true where thin, soft layers are located above thick, stiff layers, which is the case for both structures analyzed. A sensitivity study of the calculated results compared to assumed thickness of the CTB layer is presented in the attached Appendix.

2. The ages of the recycled materials were not stated in the data. The back-calculated stiffness of a pavement layer is representative of the age of the pavement when tested.

2.0 SURFACE MODULUS

The surface modulus calculated at Sensor 1 is a rough indicator of the overall stiffness of the pavement structure. The surface moduli along the two sections calculated by CalBack are shown in Figure 1. Although the surface moduli along the two sections inevitably have some fluctuation, generally speaking the difference of the overall stiffness of the two structures is insignificant.

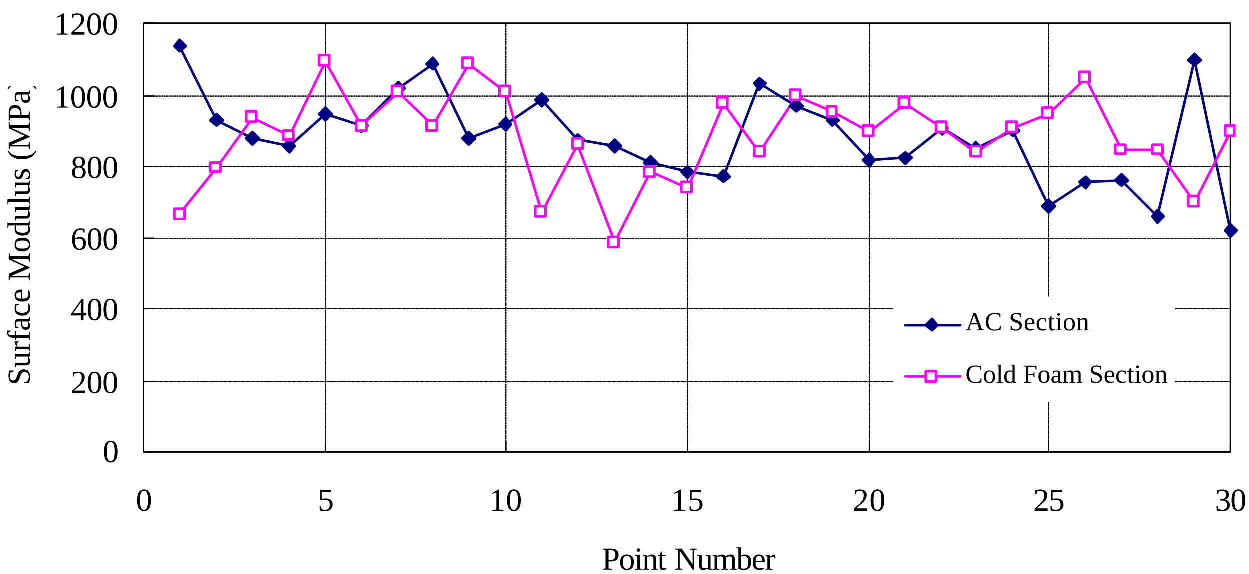


Figure 1. Surface moduli at Sensor 1.

3.0 BACK-CALCULATED MODULI

3.1 Assumptions

The pavement structures analyzed are complex because of the thin softer layers located above the thick stiff CTB layer. This structure makes determining the stiffnesses of the thin softer layer from the FWD data difficult. Therefore, combining some layers with similar stiffness is necessary.

In addition, the back-calculated values are sometimes sensitive to the initial seed values. Therefore, during the entire analysis process, a step-by-step approach was employed to determine the initial seed values, and to guarantee reasonable and reliable results. The details of these preliminary investigations and sensitivity studies that lead to the final cross-sections and seed values used for the analyses are not presented in this memorandum. In the final results given below, the following assumptions were used:

- the cold foam mix or 37.5 mm AC AR4000 is combined with the existing AC, which is only 42 to 45 mm thick
- the CTB layers with two lifts are regarded as a single layer
- all layers beneath the CTB layer, which are not identified by the cores, are regarded as subgrade.

3.2 Results

The mean value of the resilient modulus of each layer, the coefficient of variation, and the 80% confidence intervals of the resilient moduli are listed in Tables 2 and 3. The fluctuation of the resilient modulus values of each layer along the two sections is shown in Fig.2.

Table 2 Back-calculated Results of Section A (Cold Foam)

Layer	**Thickness (mm)**	**Resilient Modulus (MPa) Mean**	**Coeff. of Variation**	**80% Conf. Interval**
AC overlay	38	1500*		
Cold foam mix Existing AC	145	1778	33%	(1210, 2660)
CTB	272	2491	35%	(1260, 3740)
Subgrade	Infinite	229	12%	(200, 260)

Table 3 Back-calculated Results of Section B (Using AC)

Layer	**Thickness (mm)**	**Resilient Modulus (MPa) Mean**	**Coeff. of Variation**	**80% Conf. Interval**
AC overlay	37	1500*		
37.5-mm max size aggregate AC Existing AC	142	2449	36%	(1580, 3580)
CTB	272	2601	38%	(1430, 4260)
Subgrade	Infinite	195	12%	(160, 220)

*According to the FWD data, at the time of testing, the temperature at the surface of the pavements was between 56°C and 61°C. The resilient modulus of an AR4000 mix should be within the range of 1000 to 1500 MPa at this temperature, according to stiffness master curves developed by the PRC. Because the main concern is the stiffness of the second layer, the resilient modulus of the first layer was fixed to 1500 MPa (the upper limit value) in order to 1) reduce the number of unknown variables and to 2) obtain conservative estimates of the stiffness of the underlying layers.

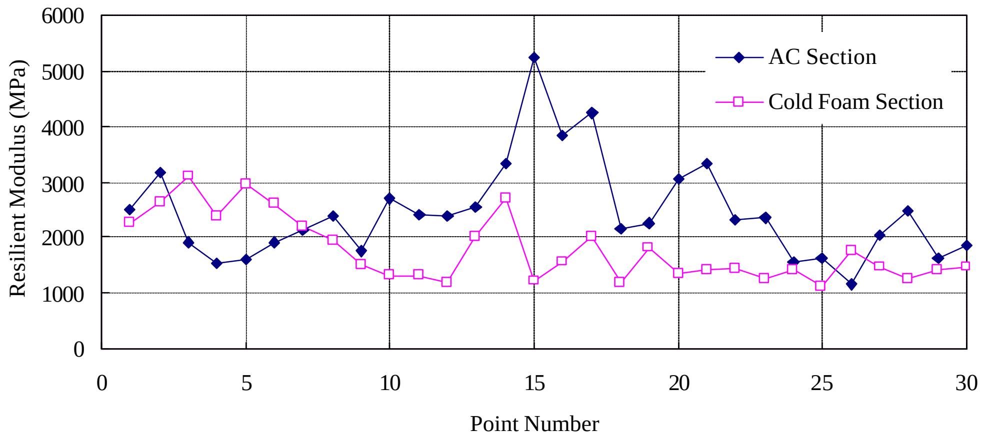


Figure 2a. Resilient modulus of Layer 2 (cold foam layer and existing AC or 37.5-mm maximum size aggregate AC layer with existing AC).

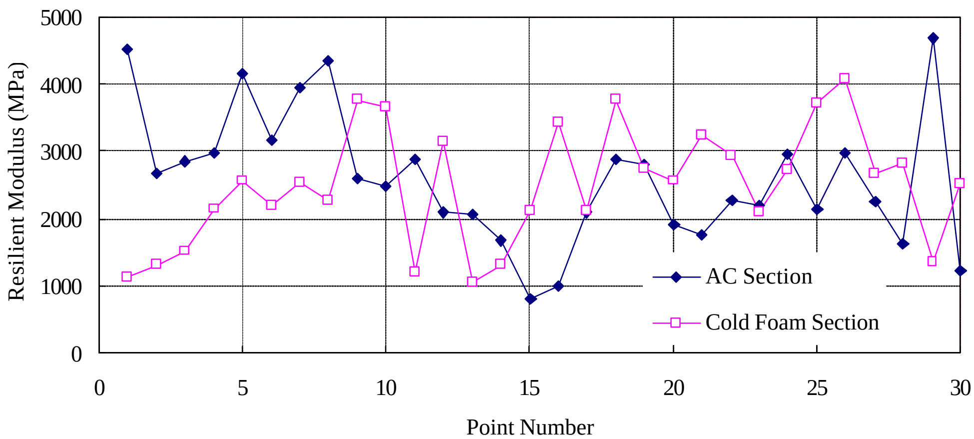


Figure 2b. Resilient modulus of Layer 3 (CTB).

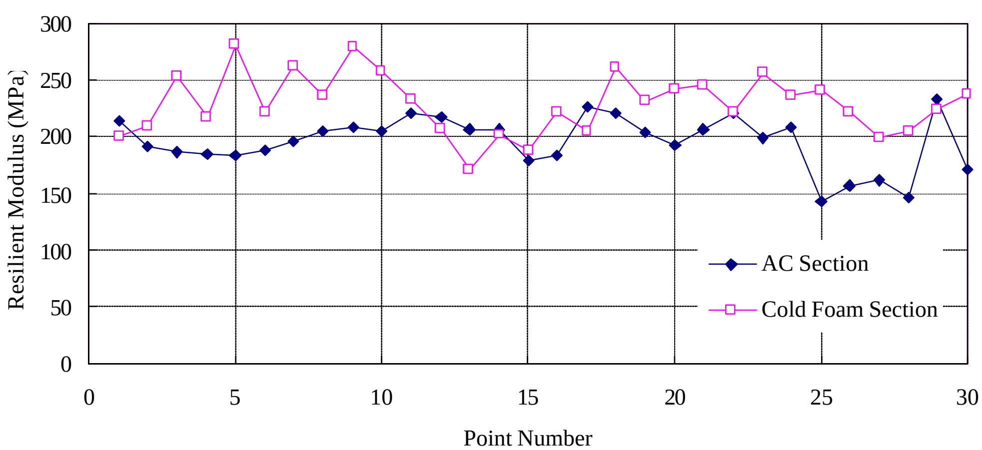


Figure 2c. Resilient modulus of Layer 4 (subgrade).

4.0 CONCLUSIONS

The main difference between the two pavement sections investigated is the materials used for the second layer. The objective of this study is to provide back-calculated stiffnesses for the layers in the pavement structures, and in particular to estimate the stiffness of the cold foam mix in one structure and of the 37.5-mm AC in the other structure. The conclusions from the back-calculations are as follows:

- The overall stiffness values of the two pavement structures indicated by the surface moduli are similar. The variation along the section is typical of that of other projects in which the pavement structure is relatively homogenous.
- The average back-calculated stiffness of the cold foam material combined with the existing AC layer below it is 1778 MPa, with an 80% confidence range of 1210 to 2660 MPa along the section tested.
- The back-calculated stiffness of the cold foam mix is roughly 25% lower than that of the 37.5-mm AC layer in the other structure. In both structures the layer in question was combined with the thin existing AC layer below it for back-calculation.
- The back-calculated CTB stiffness values of the two sections are very similar. The subgrade stiffness of the section using cold foam is slightly higher than the other section.
- The coefficient of variation of the resilient moduli of Layer 2 (cold foam combined with existing AC or 37.5-mm maximum size aggregate AC) and Layer 3 (CTB) along the sections is relatively high (>30%) for both structures. This is likely due in part to

variations in actual thickness compared to the assumed thickness, and in the case of the CTB, may indicate more damaged areas as well as variations in thickness. However, in both cases the variability is typical of structures with relatively homogenous structures. The coefficient of variation of the stiffness of the subgrade along the sections is very low (12%).

APPENDIX A: ANALYSIS APPROACH

A step-by-step approach was employed in the analysis process. The differences among the steps include:

1. How the layers were combined for analysis;
2. Initial seed values of the stiffness;
3. Stiffnesses for different layers set to fixed values or back-calculated.

The 10 steps can be divided into 3 stages according to their objectives:

Stage 1, Step 1–3. A three-layer structure is used in this stage. The objective is to find reasonable initial seed values of stiffness by combining the layers to only 3 equivalent layers.

Stage 2, Step 4–7. Use a four-layer structure to back-calculate the stiffness of each layer. The results from Step6 were selected as the ultimate results.

Stage 3, Step 8–10. The sensitivity of the results to SG stiffness and CTB thickness were investigated.

The configurations of the steps are listed in Table A-1. The results of each step are listed in Tables A-2 and A-3.

Table A-1 Configurations of Each Step

	Seed Value (MPa)									
	Step 1 3 Layers	Step2 3 Layers	Step3 3 Layers	Step4 4 Layers	Step5 4 Layers	Step6 4 Layers	Step7 4 Layers	Step8 3 Layers	Step9 3 Layers	Step10 3 Layers
37-38 mm AC overlay	1000	2000	1500	1000	1000	1500	1500	1000	1000	1000
100 mm FB or AC 42-45 mm old AC				2000	2000	2000	2000	2000	2000	2000
272 mm CTB	2000	2000	2000	2600	2600		2600	2600	2600 (218 mm thickness assumed)	2600 (218 mm thickness assumed
Granular subbase and SG	200	200	200	200	200	200	200	210	200	200

Shaded cell means fixed value

Table A-2 Back-calculation Results of Each Step for Section A (using cold foam).

Step	Mean Stiffness (MPa)					Coefficient of Variation				
	37-38 mm AC overlay	100 mm FB or AC	42-45 mm old AC	272 mm CTB	Granular subbase and SG	37-38 mm AC overlay	100 mm FB or AC	42-45 mm old AC	272 mm CTB	Granular subbase and SG
Step 1	1000			3541	215	0%			34%	11%
Step 2	2000			2105	237	0%			28%	13%
Step 3	1460			2600	228	18%			31%	12%
Step 4	1000	1816		2600	226	0%	41%		0%	18%
Step 5	1000	2123		2405	230	0%	36%		36%	11%
Step 6	1500	1778		2491	229	0%	33%		35%	12%
Step 7	1500	1584		2600	226	0%	35%		0%	18%
Step 8	1000	1909		2594	210	0%	35%		59%	0%
Step 9	1000	1653		3102	231	0%	27%		34%	12%
Step 10	1000	2204		2008	225	0%	33%		31%	12%

Shaded cell means fixed value

Table A-3 Back-calculation results of each step for Section B (using AC).

Step	Mean Stiffness (MPa)					Coefficient of Variation				
	37-38 mm AC overlay	100 mm FB or AC	42-45 mm old AC	272 mm CTB	Granular subbase and SG	37-38 mm AC overlay	100 mm FB or AC	42-45 mm old AC	272 mm CTB	Granular subbase and SG
Step 1	1000			4092	181	0%			41%	11%
Step 2	2000			2540	198	0%			33%	11%
Step 3	2014			2576	197	30%			39%	12%
Step 4	1000	3253		2600	193	0%	52%		0%	16%
Step 5	1000	3056		2497	196	0%	41%		39%	12%
Step 6	1500	2449		2601	195	0%	36%		38%	12%
Step 7	1500	2406		2600	194	0%	51%		0%	16%
Step 8	1000	3521		2016	210	0%	26%		37%	0%
Step 9	1000	2641		3273	198	0%	42%		40%	12%
Step 10	1000	3185		2144	190	0%	25%		28%	12%

Shaded cell means fixed value