

PG 64-28TR

Testing the equivalency of PG 64-28TR and PG 64-28PM binders

[Study conducted from 10/1/08 through 3/15/09]
(Final corrected version)

Cooperative effort of:

- Caltrans
- Granite Construction
- Federal Lands in Denver
- Nevada DOT
- Paramount Petroleum Corp.
- Asphalt Institute

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Testing the equivalency of PG 64-28TR and PG 64-28PM binders

Introduction

This binder comparison study was conducted to determine if the “terminal blend” of waste tire rubber with asphalt (PG 64-28TR) can be considered equal to the same grade of polymer modified asphalt (PG 64-28PM).

These two binders (TR and PM) comply with the same Caltrans specification, except that for the PG 64-28TR binder the solubility requirement is 1% lower at 97.5%.

In concept Caltrans has approved the specifications for two terminal blend grades; PG 64-28TR and PG 76-22TR, pending one or two demonstration projects.

To comply with this requirement for a demo project, a change order was arranged for a major paving project by Granite Construction, in District 8, on I-40 near Essex.

This demo project was constructed in October 2008.

The demo project made it possible to observe and evaluate field construction, and obtain materials samples for laboratory testing.

This report presents the binder test data from four laboratories; FHWA Federal Lands, Nevada DOT, Paramount Petroleum Corporation, and Asphalt Institute, which all participated in this study at no charge.

The significance of officially approving these two “terminal blend” binder grades relates to Assembly Bill 338 (AB 338). This Bill mandates Caltrans to use increasing tonnages of asphalt-rubber on its projects, with a minimum of 50% for all asphalt paving by 2013. Because asphalt-rubber (“wet process”) can not be used in dense-graded mixes, Caltrans will be forced to reduce its use of asphalt dense graded hot-mix for its structural pavement sections in order to remain in compliance with the AB 338 requirement. It could result in Caltrans designing a larger number of new pavements in pcc concrete. (See Appendix 1).

The approval of the terminal blend specification would provide the State of California with a solution; an asphalt-tire rubber binder that can be used in dense graded hot-mix, and facilitate the compliance with AB 338.

The location of the demo project is in the truck (#2) lane on Westbound I-40, between the McGinley Wash bridge (PM 104.25) and the Black Canyon Wash bridge (PM 102.21). On 10/16/08, deflection testing, coring, and condition surveys were done by Caltrans, while the Asphalt Institute assisted where possible.

Two 500 foot sections with “comparable” levels of distress were marked off for materials sampling and future condition surveys.

For location details and the condition survey results (see Appendix 2).

The added pictures show distress types and distress levels typical for both test sections. Both Caltrans and the Asphalt Institute (AI) obtained a significant amount of materials samples. For the AI materials sample log (see Appendix 3).

Paving operations were observed on 10/16; 10/21 & 22; and 10/28.

Equal to the rest of the paving project, these two test sections are constructed by successively;

- 135mm surface milling,
- applying ss-1h tack coat (at 0.07 gallon/sqyd undiluted),
- placing a bottom lift of 75mm Type C mix,
- ss-1h tack coat (0.03 gallons/sqyd undiluted),
- placing a top lift of 60mm Type C mix,
- followed later by ss-1h tack coat,
- and 20mm of open-grade mix.

Handling of the mixes at the hot-mix plant and during construction were observed and discussed with contractor's personnel involved. The plant operator and the paving crew commented that both Type C mixes with PG 64-28PM and with PG 64-28TR behaved the same. No differences were observed during the paving operations.

Binder testing was conducted by four (4) labs other than Caltrans. For a more accurate evaluation of the PG 64-28PM and PG 64-28TR binders, the four labs were asked to each perform the same set of tests on split samples.

The results of this binder testing are tabulated in Appendix 4.

A review of the test results shows that both the PM and TR materials are graded as a PG 64-28 by all four labs, with test results close together. Only the Absolute Viscosities (AASHTO T202) show significant differences from lab to lab. It is well known that this is to be expected for polymer modified asphalts.

The consistency of the produced binders was evaluated by comparing samples taken from different days of production for both the PM and the TR materials. (See Appendix 5). The PG 64-28PM material samples were taken 12 days apart, and show good consistency. The PG 64-28TR material samples were taken from two consecutive days of production. The test results for the TR material show a similar level of variability as the PM material. However for the second day (10/23/08) the TR material tests closer to the grade limits. The fact that the TR material was only produced for the two days of the demo, may be the reason for this.

Discussion and conclusions;

To facilitate later comparison with Caltrans' binder test results, the test data from the four labs has been averaged and the standard deviation determined. (See Appendix 6).

Assuming that the PG grading system defines the behavior of binders correctly, one must conclude that binders of the same grade will perform similarly. Therefore these two binders; PG 64-28PM and PG 64-28TR should be considered equal.

Appendix 1

Assembly Bill AB 338 and its significance
for the future use of asphalt on Caltrans projects.

Relevance to AB 338

The State Legislature in California has mandated Caltrans to use increasing amounts of waste tire rubber in the Asphalt materials used for its paving projects.

This was put into law in 2005 by means of Assembly Bill 338 (AB 338), which added Section 42703 (see Appendix 1A) to the Public Resources Code (PRC).

PRC Section 42703 refers to; crumb rubber (CRM), asphalt containing crumb rubber, rubberized asphalt concrete, RAC, asphalt rubber, and Asphalt-Rubber Binder, all within the same text. ASTM has a standard definition for Asphalt-Rubber Binder.

By January 2013 the CRM usage requirement will peak. By then Caltrans must use, on an annual average, not less than 11.58 pounds of CRM per metric ton of the total amount of (all) asphalt paving materials used.

More specific is the requirement that from 2007 until January 2015, not less than 50 percent of the asphalt pavement used shall be “rubberized asphalt concrete”.

At present three methods of combining waste tire rubber with Asphalt exist;

1. the “wet” process,
2. the “dry” process, and
3. the “terminal blend” process.

The wet process requires the crumb rubber to react with the Asphalt at elevated temperatures for approximately 45 minutes in a separate reaction tank, before combining with aggregate in the hot-mix plant.

The dry process adds the crumb rubber with the aggregate into the hot-mix plant.

The terminal blend process homogenizes the crumb rubber into the Asphalt at the refinery or terminal, before shipment to the hot-mix plant.

The wet process binder and the dry process result in hot-mix that visibly contains pieces of tire rubber, excluding them for use in dense graded hot-mix. The wet process and dry process binders are typically used for Gap-graded (HMA-GG) and Open-graded (HMA-O) mixes.

Because the terminal blend process completely digests the crumb rubber into the Asphalt binder, this binder can be used in dense graded hot-mix.

Typically the structural section (load bearing component) of asphalt pavements is constructed with dense grade hot-mix. Statewide this represents the majority of asphalt paving tonnage.

The AB 338 requirement that by 2013, at least 50% of all Caltrans asphalt paving materials must contain crumb rubber, will limit Caltrans’ use of dense graded hot-mix to less than 50%. Without a solution such as the terminal blend of waste tire rubber and asphalt, Caltrans will be forced to reduce its use of Asphalt dense graded hot-mix for its structural pavement sections in order to comply with the AB 338 requirement. It would result in Caltrans designing a larger number of its new pavements in pcc concrete.

Appendix 1A

BILL NUMBER: AB 338 CHAPTERED 10/07/05

CHAPTER 709

FILED WITH SECRETARY OF STATE OCTOBER 7, 2005

APPROVED BY GOVERNOR OCTOBER 7, 2005

PASSED THE ASSEMBLY SEPTEMBER 8, 2005

PASSED THE SENATE SEPTEMBER 6, 2005

AMENDED IN SENATE SEPTEMBER 2, 2005

AMENDED IN SENATE AUGUST 16, 2005

AMENDED IN SENATE JUNE 30, 2005

AMENDED IN ASSEMBLY APRIL 19, 2005

INTRODUCED BY Assembly Member Levine

(Principal coauthor: Assembly Member Maze)

(Coauthors: Assembly Members Cohn, DeVore, Shirley Horton, Karnette, Koretz, Ruskin, and Yee)

(Coauthors: Senators Alquist, Chesbro, Denham, Ducheny, and Figueroa)

FEBRUARY 10, 2005

An act to add Section 42703 to the Public Resources Code, relating to recycling.

LEGISLATIVE COUNSEL'S DIGEST

AB 338, Levine Recycling: crumb rubber.

Existing law requires the State Procurement Officer, in purchasing any materials to be used in paving or paving subbase for use by the Department of Transportation and any other state agency that provides road construction and repair services, to make contracts available that utilize recycled materials, including crumb rubber, unless the Director of Transportation determines that the use of the materials is not cost effective based on specified factors.

This bill would define the terms "asphalt containing crumb rubber" and "rubberized asphalt concrete" and would require the department to require the use of crumb rubber (CRM) at a specified percentage, per metric ton, of the total amount of asphalt paving materials used for state highway construction or repair projects that use asphalt as a construction material. The bill would require the amount of asphalt paving materials containing crumb rubber, on and after January 1, 2007, to be not less than 6.62 pounds of CRM per metric ton of the total amount of asphalt paving materials used. The bill would require the Secretary of Business, Transportation and Housing, on or before January 1, 2009, and on or before January 1 annually thereafter, to prepare a specified analysis comparing the cost differential between asphalt containing crumb rubber and conventional asphalt, including specified information.

The bill would require the department, on and after January 1, 2010, to use not less than 8.27 pounds of CRM per metric ton of the total asphalt paving materials used, and on and after January 1, 2013, not less than 11.58 pounds of CRM per metric ton, unless the

department delays the implementation of these requirements, pursuant to a specified procedure.

The bill would specify that, for purposes of complying with those requirements regarding the use of specified percentages of asphalt containing crumb rubber, only crumb rubber manufactured in the United States that is derived from waste tires taken from vehicles owned and operated in the United States may be used.

The bill would require the department and the California Integrated Waste Management Board to develop procedures for using crumb rubber and other tire-derived products in other projects and would require the department to notify and confer with the East Bay Municipal Utility District before using asphalt containing crumb rubber on a state highway construction or repair project that overlays district infrastructure.

THE PEOPLE OF THE STATE OF CALIFORNIA DO ENACT AS FOLLOWS:

SECTION 1. The Legislature finds and declares all of the following:

(a) Thirty-two million scrap tires are currently generated in California each year.

(b) By the year 2020, more than 43,000,000 scrap tires will be generated each year in California.

(c) There are currently up to 6,000,000 tires in legal and illegal scrap tire piles.

(d) Twenty-five percent of California scrap tires, more than 8,000,000 tires, are disposed of in landfills or stockpiled in legal or illegal dumps.

(e) Crumb rubber from recycled scrap tires can be used as an additive for making asphalt for highway construction and repair.

(f) It is state policy to not discard scrap tires in landfills or legal or illegal stockpiles, and to find alternative uses for recycling tires that have been generated in California.

SEC. 2. It is the intent of the Legislature that the Department of Transportation explore all feasible means to stimulate increased usage of crumb rubber throughout the 12 regional districts to help expand the marketplace for crumb rubber in the state.

SEC. 3. Section 42703 is added to the Public Resources Code, to read:

42703. (a) Except as provided in subdivision (d), the Department of Transportation shall require the use of crumb rubber in lieu of other materials at the following levels for state highway construction or repair projects that use asphalt as a construction material:

(1) On and after January 1, 2007, the Department of Transportation shall use, on an annual average, not less than 6.62 pounds of CRM per metric ton of the total amount of asphalt paving materials used.

(2) On and after January 1, 2010, the Department of Transportation shall use, on an annual average, not less than 8.27 pounds of CRM per metric ton of the total amount of asphalt paving materials used.

(3) On and after January 1, 2013, the Department of Transportation

shall use, on an annual average, not less than 11.58 pounds of CRM per metric ton of the total amount of asphalt paving materials used.

(b) (1) The annual average use of crumb rubber required in subdivision (a) shall be achieved on a statewide basis and shall not require the use of asphalt containing crumb rubber in each individual project or in a place where it is not feasible to use that material.

(2) On and after January 1, 2007, and before January 1, 2015, not less than 50 percent of the asphalt pavement used to comply with the requirements of subdivision (a) shall be rubberized asphalt concrete.

(3) On and after January 1, 2015, the Department of Transportation may use any material meeting the definition of asphalt containing crumb rubber, with respect to product type or specification, to comply with the requirements of subdivision (a).

(c) (1) The Secretary of Business, Transportation and Housing shall, on or before January 1, 2009, and on or before January 1 annually thereafter, prepare an analysis comparing the cost differential between asphalt containing crumb rubber and conventional asphalt. The analysis shall include the cost of the quantity of asphalt product needed per lane mile paved and, at a minimum, shall include all of the following:

(A) The lifespan and duration of the asphalt materials.

(B) The maintenance cost of the asphalt materials and other potential cost savings to the department, including, but not limited to, reduced soundwall construction costs resulting from noise reduction qualities of rubberized asphalt concrete.

(C) The difference between each type or specification of asphalt containing crumb rubber, considering the cost-effectiveness of each type or specification separately in comparison to the cost-effectiveness of conventional asphalt paving materials.

(2) Notwithstanding subdivision (a), if, after completing the analysis required by paragraph (1), the secretary determines that the cost of asphalt containing crumb rubber exceeds the cost of conventional asphalt, the Department of Transportation shall continue to meet the requirement specified in paragraph (1) of subdivision (a), and shall not implement the requirement specified in paragraph (2) of subdivision (a). If the secretary determines, pursuant to an analysis prepared pursuant to paragraph (1), that the cost of asphalt containing crumb rubber does not exceed the cost of conventional asphalt, the Department of Transportation shall implement paragraph (2) of subdivision (a) within one year of that determination, but not before January 1, 2010.

(3) Notwithstanding subdivision (a), if the Department of Transportation delays the implementation of paragraph (2) of subdivision (a), the Department of Transportation shall not implement the requirement of paragraph (3) of subdivision (a) until three years after the date the department implements paragraph (2) of subdivision (a).

(d) For the purposes of complying with the requirements of subdivision (a), only crumb rubber manufactured in the United States that is derived from waste tires taken from vehicles owned and operated in the United States may be used.

(e) The Department of Transportation and the board shall develop procedures for using crumb rubber and other derived tire products in other projects.

(f) The Department of Transportation shall notify and confer with the East Bay Municipal Utility District before using asphalt containing crumb rubber on a state highway construction or repair project that overlays district infrastructure.

(g) For purposes of this section the following definitions shall apply:

(1) "Asphalt containing crumb rubber" means any asphalt pavement construction, rehabilitation, or maintenance material that contains reclaimed tire rubber and that is specified for use by the Department of Transportation.

(2) "Crumb rubber" or "CRM" has the same meaning as defined in Section 42801.7.

(3) "Rubberized asphalt concrete" or "RAC" means a paving material that uses an asphalt rubber binder containing an amount of reclaimed tire rubber that is 15 percent or more by weight of the total blend, and that meets other specifications for both the physical properties of asphalt rubber and the application of asphalt rubber, as defined in the American Society for Testing and Materials (ASTM) Standard Specification for Asphalt-Rubber Binder.

Appendix 2

Demo location details and the condition survey results,
with some example pictures.

DATE	REVISION	BY	NO.
08	Sbd	40	1
PROJECT		R143.2/R191.5	
SHEET NO.		1	
SHEET TOTAL		22	



STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION
PROJECT PLANS FOR CONSTRUCTION ON
STATE HIGHWAY
IN SAN BERNARDINO COUNTY NEAR ESSEX
FROM 2.4 KM WEST OF FORTRESS WASH BRIDGE
TO 0.5 KM EAST OF ARDIS DITCH BRIDGE

To be supplemented by Standard Plans dated July, 2004.

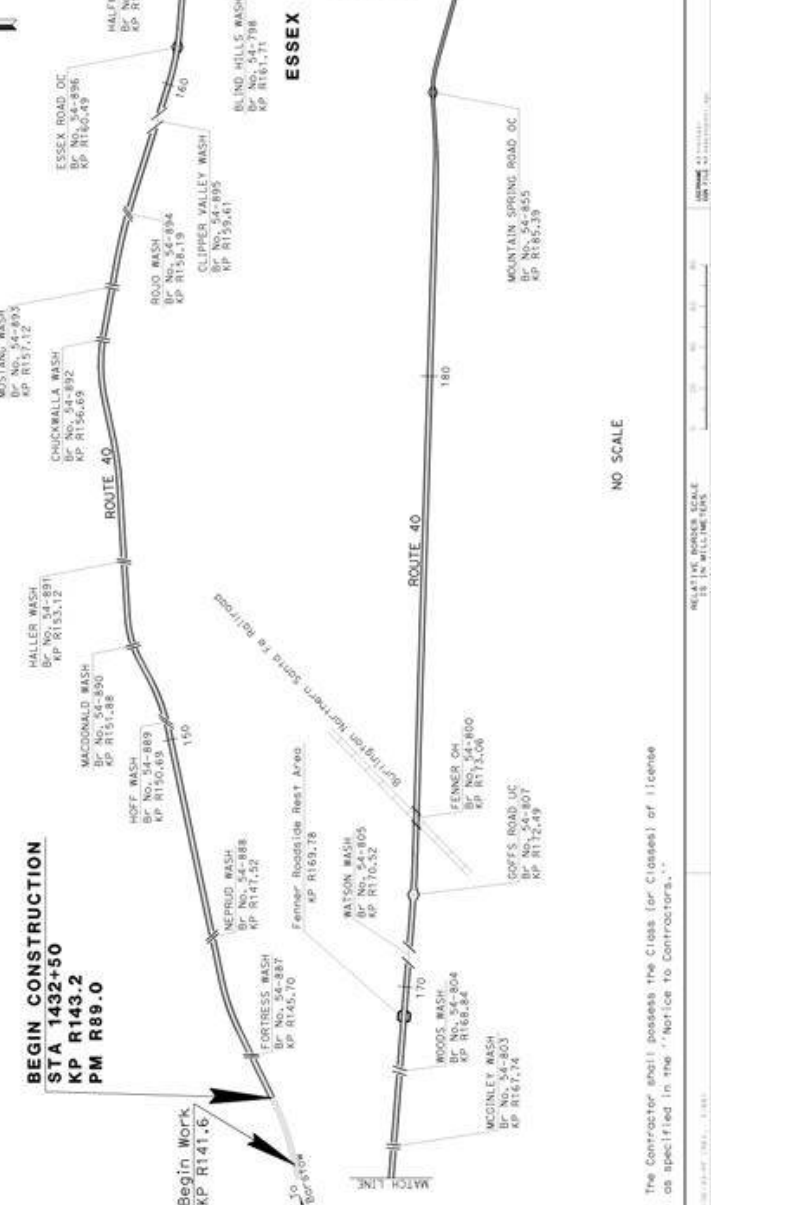
THE STANDARD PLANS LIST APPLICABLE TO THIS CONTRACT IS INCLUDED IN THE NOTICE TO CONTRACTORS AND SPECIAL PROVISIONS BOOK.



BEGIN CONSTRUCTION STA 1432+50
 KP R143.2
 PM R89.0

END CONSTRUCTION STA 1915+50
 KP 191.5
 PM R119.0

BEGIN WORK KP R141.6
 END WORK KP R193.4



NO SCALE

RELATIVE BORDER SCALE IS IN MILLIMETERS

CONTRACT NO. 08-486304

EA 486301

I-40 PG 64-28TR Demo (October 2008)

On 10/16/2008; deflection testing, coring, and condition surveys were done for a comparison of PG 64-28TR Type C mix and PG 64-28PM Type C mix. The areas to be studied are on I-40 (near Essex, CA) in the westbound #2 (truck) lane.

Locations:

There are PostMile (PM) markers at the following bridges;

- McGinley Wash bridge; PM 104.25
- Newton Wash bridge; PM 103.43
- Black Canyon Wash bridge; PM 102.21

The PG 64-28PM mix research sections are between McGinley Wash and Newton Wash.

The PG 64-28TR mix research sections are between Newton Wash and Black Canyon Wash.

From East to West, the following locations (Points) are of significance for the research sections:

- 1) East edge of McGinley Wash bridge; PM 104.25
- 2) Start of PG 64-28PM coring and deflection (0.75 mile) section; PM 104.18
- 3) Start of PG 64-28PM condition survey (500 feet) section; PM 104.0947
- 4) End of PG 64-28PM condition survey section; PM 104.00
- 5) End of PG 64-28PM coring and deflection section, and East edge of Newton Wash bridge; PM 103.43

- 6) Start of PG 64-28TR coring and deflection (1.0 mile) section (536' West of PM 103.43); PM 103.3285
- 7) Start of PG 64-28TR condition survey (500 feet) section : PM 102.7190
- 8) End of PG 64-28TR condition survey section; PM 102.6243
- 9) End of PG 64-28TR coring and deflection section (693' East of Black Canyon Wash bridge's East edge); PM 102.3285
- 10) East edge of Black Canyon Wash bridge; PM 102.21

GPS readings for these locations are as follows;

Point	North (latitude) (degrees – minutes)	West (longitude) (degrees-minutes)	Elevation (feet)	Post Mile (PM)
1)	34 – 48.470	115 – 14.493	1942	104.25
2)	34 – 48.465	115 – 14.553	1938	104.18
3)	34 – 48.455	115 – 14.667	1939	104.0947
4)	34 – 48.447	115 – 14.764	1944	104.0000
5)	34 – 48.399	115 – 15.338	1942	103.43
6)	34 – 48.390	115 – 15.446	1939	103.3285
7)	34 – 48.335	115 – 16.091	1944	102.7190
8)	34 – 48.327	115 – 16.191	1947	102.6243
9)	34 – 48.302	115 – 16.494	1952	102.3285
10)	34 – 48.290	115 – 16.631	1962	102.21

The PG 64-28PM coring and deflection research section runs (0.75 mile) from point 2) to point 5).

The PG 64-28PM condition survey research section runs (500 feet) from point 3) to point 4).

The PG 64-28TR coring and deflection research section runs (1.0 mile) from point 6) to point 9).

The PG 64-28TR condition survey research section runs (500 feet) from point 7) to point 8).

Condition survey results:

The beginning and end of the two condition survey sections are marked with five foot tall orange posts about ten feet from the right side shoulder. Each condition survey section is 500 feet (=150 meters) long.

For equal comparison of the PG 64-28PM and the PG 64-28TR condition survey, the two sections were selected with (as much as possible) a uniform and equal level of distress.

For a more detailed pavement inspection, the pavement was marked in five 30 meter (99 foot) intervals.

The condition survey was performed in the westbound 12 foot wide #2 lane (truck lane) only.

For the PG 64-28PM section (from point 3) to point 4)),

Uniformly the pavement shows extensive, medium severity fatigue cracking, with occurrence a little bit more in the right wheel path. In addition there are approximately 4 light severity transvers cracks, uniformly spaced for each 30 meter interval. No rutting was noticeable.

From 15 meters to 30 meters from point 3), there are three areas with more severe fatigue cracking.

For the PG 64-28TR section (from point 7) to point 8)),

Uniformly the pavement shows extensive, light to medium severity fatigue cracking, with equal occurrence in both wheel paths. In addition there are approximately 2 light severity transvers cracks, uniformly spaced for each 30 meter interval. No rutting was noticeable.

From 24 meters to 48 meters from point 7), there are few areas with more severe fatigue cracking in the right wheel path and 3 areas where chunks (approximately 3 by 5 inches, and 2 inches deep) of pavement have popped out.

As part of the construction, these research sections will be milled down before placing the two lifts of overlay (later to be followed by an open graded wearing surface).

Milled section is 135mm total, ss1-h (0.07 gallon/sqyd undiluted), bottom lift is 75mm, ss1-h (0.03 gallon/sqyd undiluted), top lift is 60mm, ss1-h, open-grade is 20mm.

PG 64-28PM and PG 64-28TR; typical condition



I-40, looking West, PG 64-28PM Test Section



I-40, Pavement condition in PG 64-28PM Test Section (at 60 meters)



I-40, looking East, PG 64-28TR Test Section



I-40, Pavement condition in PG 64-28TR Test Section (at 120 meters)



I-40, Granite Construction windrow paving, PG 64-28PM



I-40, Paving of Test Section, PG 64-28TR

Appendix 3

Asphalt Institute's materials sample log.

I-40 PG 64-28TR Demo (October 2008)

On 10/16; 10/21 & 22; and 10/28 material samples (binder and mix) were collected on I-40 (near Essex, CA) for a comparison of PG 64-28TR Type C mix and PG 64-28PM Type C mix.

General reference locations:

There are PostMile (PM) markers at the following bridges;

- McGinley Wash bridge; PM 104.25
- Newton Wash bridge; PM 103.43
- Black Canyon Wash bridge; PM 102.21

The PG 64-28PM test section is between McGinley Wash and Newton Wash, in the #2 West bound lane. The PG 64-28TR test section is between Newton Wash and Black Canyon Wash, in the #2 West bound lane.

Just as the rest of the paving project, these test sections will be constructed as follows:

Milled section is 135mm total, ss1-h (0.07 gallon/sqyd undiluted), bottom lift is 75mm, ss1-h (0.03 gallon/sqyd undiluted), top lift is 60mm, ss1-h, open-grade is 20mm.

Sample locations and what was obtained:

Asphalt Institute (R. Humer) took the following samples:

- On 10/16/08; 5 one-gallon cans of PG 64-28PM binder

- On 10/22/08; 5 one-gallon cans of PG 64-28TR binder
+ 10 boxes of PG 64-28TR mix (marked A), 1st lift, at PM 102.7190 (point 7), in lane #2.

- On 10/23/08; 2 one-gallon (ribbed) cans of PG 64-28TR binder (to compare with the 10/22/08 sample)
+ 5 boxes of PG 64-28TR mix (marked B), 2nd lift, at PM 102.7190 (point 7), in lane #2.

- On 10/28/08; 2 one-gallon cans of PG 64-28PM binder (to compare with the 10/16/08 sample)
+ 10 boxes of PG 64-28PM mix, 2nd lift, at PM 104.7518 (station 1686+50), in lane #1.

AI Headquarters lab receives:

- all 25 boxes of mix;
- 2 one-gallon cans of PG 64-28PM binder, dated 10/16/08, (one can for testing and one for safe keeping);
- 2 one-gallon cans of PG 64-28TR binder, dated 10/22/08, (one can for testing and one for safe keeping);
- 2 one-gallon ribbed cans of PG 64-28TR binder dated 10/23/08, to compare with the 10/22/08 binder sample, (again one can for testing and one can for safe keeping);
- 2 one-gallon cans of PG 64-28PM binder, dated 10/28/08, to compare with the 10/16/08 binder sample, (again one can for testing and one can for safe keeping);

Appendix 4

Binder test results from four labs.



Sample No: 10-16-2008 ; PG 64-28PM

Lab 1

Lab 2

ASPHALT INSTITUTE
Lab 3

Lab 4

ORIGINAL ASPHALT

Test, Method	Specification	Test Results	Test Results	Test Results	Test Results	
Flash Point, AASHTO T 48	230°C min	298		320	327	
Penetration @ 25°C 100g/5sec, AASHTO T49	n/a	97	95	101	101	
Rotational Viscosity @ 135°C, AASHTO T316	3.0	0.750	0.825	0.802	0.770	
Absolute Viscosity @ 60°C, AASHTO T202		3,850	3,180	16,520	4,232	
Kinematic Viscosity @ 135°C, AASHTO T201		772	830		811	
Solubility in Trichloroethylene (%), AASHTO T44	98.5% Min	99.89		100.00	99.55	
DSR (Dynamic Shear Rheometer), AASHTO T 315						
	Test Temperature, °C	1.00 kPa min at 64 C	delta / G*/sinδ, kPa	delta / G*/sinδ, kPa	delta / G*/sinδ, kPa	delta / G*/sinδ, kPa
	64		70.1 / 1.67	71.3 / 1.63	73.2 / 1.60	72.5 / 1.49
	70		69.6 / 0.93			71.6 / 0.86

RTFO (ROLLING THIN FILM OVEN, AASHTO T240) AGED ASPHALT

Mass Change, AASHTO T 240	1.0% max	0.191	0.156	0.144	0.120	
Penetration @ 25°C 100g/5sec, AASHTO T49		67	66	64	62	
Absolute Viscosity @ 60°C, AASHTO T202		6,660	6,920	10,800	9,005	
Kinematic Viscosity @ 135°C, AASHTO T201		984	953		994	
Ductility @ 25°C, 5cm/min, AASHTO T51		125+	124	130	131	
Elastic Recovery @ 25°C, (%), AASHTO T301	75%	75%	83%	80%	81%	
Absolute Viscosity Ratio (60°C); RTFO Visc/Orig Visc		1.73	2.20	0.65	2.13	
% of Original Penetration at 25°C, 100g/5sec		69.0%	69.5%	63.4%	61.4%	
DSR (Dynamic Shear Rheometer), AASHTO T 315						
	Test Temperature, °C	at 64 C 2.20 kPa min d, max 80 degrees	delta / G*/sinδ, kPa	delta / G*/sinδ, kPa	delta / G*/sinδ, kPa	delta / G*/sinδ, kPa
	64		71.8 / 2.63	71.6 / 2.54	71.4 / 2.79	71.3 / 2.38
	70		73.7 / 1.39	74 / 1.40		71.6 / 1.32
	65.0 Interpolate					71.4 / 2.20

PAV (Pressure Aging Vessel, AASHTO R 28, @ 100°C)

Penetration @ 25°C 100g/5sec, AASHTO T49			34	33	37	
DSR (Dynamic Shear Rheometer), AASHTO T 315						
	Test Temperature, °C	5000 kPa max at 22 C	delta / G*/sinδ, kPa	delta / G*/sinδ, kPa	delta / G*/sinδ, kPa	delta / G*/sinδ, kPa
	22		52.9 / 2657	53.5 / 2620	53.5 / 2500	51.4 / 2840
	19		49.4 / 4126			46.3 / 4130
	16		45.8 / 6222			40.7 / 5530
BBR (Bending Beam Rheometer), AASHTO T 313						
Test Temperature, °C		300 MPa max 0.300 min at -18 C				
	Stiffness, MPa					
	m-value					
- 18 C	Stiffness, MPa		247	243	232	250
	m-value		0.317	0.315	0.311	0.307
- 24 C	Stiffness, MPa					554
	m-value				0.183	
DTT (Direct Tension Tester), AASHTO T 314						
Test Temperature, °C		no requirement (1% min) at -18 C				
	Failure Strain					
- 18 C	Failure Strain			1.64		1.215
	Failure Strain					

Binder Grade Based on Test Results:	AR-grade				
	PBA-grade				
	PG-grade	64 - 28	64 - 28	64 - 28	64 - 28
	Continuous PG grade				65.0 - 28.3



PG--TR Terminal Blend (I-40 Demo), Binder Evaluation

Sample No: 10-22-2008 ; PG 64-28TR

Lab 1

Lab 2

Lab 3

Lab 4

ORIGINAL ASPHALT

Test, Method	Specification	Test Results	Test Results	Test Results	Test Results
Flash Point, AASHTO T 48	230°C min	290		290	304
Penetration @ 25°C 100g/5sec, AASHTO T49		106	114	114	110
Rotational Viscosity @ 135°C, AASHTO T316	3.0	0.71	0.763	0.722	0.735
Absolute Viscosity @ 60°C, AASHTO T202		11,860	9,850	11,341	14,140
Kinematic Viscosity @ 135°C, AASHTO T201		785	795		736
Solubility in Trichloroethylene (%), AASHTO T44	98.5% Min	99.28		98.90	98.81

DSR (Dynamic Shear Rheometer), AASHTO T 315

Test Temperature, °C	1.00 kPa min at 64 C	delta /	delta /	delta /	delta /
		G*/sinδ, kPa	G*/sinδ, kPa	G*/sinδ, kPa	G*/sinδ, kPa
64		71.6 / 1.35	80.6 / 1.11	81.9 / 1.29	71.7 / 1.35
70		68.3 / 0.84			69.4 / 0.83

RTFO (ROLLING THIN FILM OVEN, AASHTO T240) AGED ASPHALT

Test, Method	Specification	Test Results	Test Results	Test Results	Test Results
Mass Change, AASHTO T 240	1.0% max	0.616	0.488	0.512	0.490
Penetration @ 25°C 100g/5sec, AASHTO T49		70	71	69	72
Absolute Viscosity @ 60°C, AASHTO T202		5,800	6,710	9,221	6,775
Kinematic Viscosity @ 135°C, AASHTO T201		996	975		937
Ductility @ 25°C, 5cm/min, AASHTO T51		103	98	96	132
Elastic Recovery @ 25°C, (%), AASHTO T301	75%	80%	90%	83%	81%
Absolute Viscosity Ratio (60°C): RTFO Visc/Orig Visc		0.49	0.70	0.81	0.40
% of Original Penetration at 25°C, 100g/5sec		66.0%	62.3%	60.5%	65.5%

DSR (Dynamic Shear Rheometer), AASHTO T 315

Test Temperature, °C	2.20 kPa min d, max 80 degrees	delta /	delta /	delta /	delta /
		G*/sinδ, kPa	G*/sinδ, kPa	G*/sinδ, kPa	G*/sinδ, kPa
64		74.3 / 2.60	74.2 / 2.41	74.2 / 2.76	71.7 / 2.80
70		77.0 / 1.35	78.2 / 1.27		73.3 / 1.49
66.6 Interpolate					72.4 / 2.20

PAV (Pressure Aging Vessel, AASHTO R 28, @ 100°C

Penetration @ 25°C 100g/5sec, AASHTO T49		36	36	34
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DSR (Dynamic Shear Rheometer), AASHTO T 315

Test Temperature, °C	5000 kPa max at 22 C	delta /	delta /	delta /	delta /
		G* sinδ, kPa	G* sinδ, kPa	G* sinδ, kPa	G* sinδ, kPa
22		48.4 / 2395	47.7 / 2250	47.7 / 2877	46.0 / 2620
19		45.4 / 3569			41.9 / 3650
16		42.4 / 5195			37.6 / 4810

BBR (Bending Beam Rheometer), AASHTO T 313

Test Temperature, °C	Stiffness, MPa	300 MPa max				
- 18 C	m-value	0.300 min				
	Stiffness, MPa	at -18 C	167	169	178	110
- 24 C	m-value		0.313	0.323	0.307	0.324
	Stiffness, MPa					247
	m-value					0.240

DTT (Direct Tension Tester), AASHTO T314

Test Temperature, °C	Failure Strain	no requirement				
- 18 C	Failure Strain	(1% min)		1.99		1.506
	Failure Strain	at -18 C				

Binder Grade Based on Test Results:	AR-grade				
	PBA-grade				
	PG-grade	64 - 28	64 - 28	64 - 28	64 - 28
Continuous PG grade					66.6 - 29.7

CALIFORNIA:

PERFORMANCE GRADED POLYMER MODIFIED ASPHALT BINDER

PROPERTY	Test Method AASHTO or Other	Performance Grade (PG)		
		PG 58-34 PM	PG 64-28 PM	PG 76-22 PM
Original Binder:				
Flash Point, Minimum °C	T48	230	230	230
Solubility, Minimum % ^b	T44	99	99	99
Viscosity at 135°C ^d Maximum, Pa.s	T316	3.0	3.0	3.0
Dynamic Shear, Test Temp. at 10 rad/s, °C Minimum G* / sin(delta), kPa	T315	58 1.00	64 1.00	76 1.00
RTFO Test ^e , Mass Loss, Maximum, %	T240	1.00	1.00	1.00
RTFO Test Aged Binder:				
Dynamic Shear, Test Temp. at 10 rad/s, °C Minimum G* / sin(delta), kPa	T315	58 2.20	64 2.20	76 2.20
Dynamic Shear, Test Temp. at 10 rad/s, °C Maximum (delta), kPa	T315	Note e 80	Note e 80	Note e 80
Elastic Recovery ^f , Test Temp., °C Minimum recovery, %	T301	25 75	25 75	25 65
PAV ^g Aging, Temperature, °C	R28	100	100	110
RTFO Test and PAV Aged Binder:				
Dynamic Shear by DSR, Test Temp. at 10 rad/s, °C Max. G* x sin(delta), kPa	T315	16 5000	22 5000	31 5000
Creep Stiffness by BBR, Test Temperature, °C Maximum S-value, MPa Minimum M-value	T313	-24 300 0.300	-18 300 0.300	-12 300 0.300
NOTES:				
a. Performance Graded Polymer Modified Asphalt Binder (PG Polymer Modified) will not be modified using acid modification.				
b. The Engineer will waive this specification if the supplier is a Quality Supplier as defined by the Department's "Certification Program for Suppliers of Asphalt".				
c. ASTM D5546 is allowed in lieu of AASHTO T44				
d. The engineer will waive this specification if the supplier certifies the asphalt binder can be adequately pumped and mixed at temperatures meeting applicable safety standards.				
e. Test temperature is the "temperature at which G*/sin(delta) equals 2.2 kPa". A graph of log G*/sin(delta) plotted against temperature can be used to determine the test "temperature at which G*/sin(delta) is 2.2kPa". A graph of (delta) versus temperature can also be used to determine delta at "temperature where G*/sin(delta) is 2.2". Direct measurement of (delta) at the "temperature at which G*/sin(delta) is 2.2kPa" is also acceptable.				
f. Test can be performed without force ductility clamp.				
g. "PAV" means Pressurized Aging Vessel.				

Appendix 5

Consistency of production;
comparing samples from different production days.



Original Asphalt

Test, Method	
Flash Point, AASHTO T 48	
Penetration @ 25°C 100g/5sec, AASHTO T49	
Rotational Viscosity @ 135°C, AASHTO T316	
Absolute Viscosity @ 60°C, AASHTO T202	
Kinematic Viscosity @ 135°C, AASHTO T201	
Solubility in Trichloroethylene (%), AASHTO T44	
DSR	
1.00 kPa min, at 64 C	Test Temperature, °C
	64
	70

PM 10/28/2008	PM 10/16/2008
Test Results	Test Results
270	320
107	101
0.737	0.802
8,200	16,520
99.90	100.00
delta / G*/sinδ, kPa	delta / G*/sinδ, kPa
75.7 / 1.28	73.2 / 1.60

TR 10/22/2008	TR 10/23/2008
Test Results	Test Results
290	298
114	121
0.722	0.600
11,341	3,681
98.90	99.10
delta / G*/sinδ, kPa	delta / G*/sinδ, kPa
81.9 / 1.29	82.1 / 0.98 (!)

RTFO Asphalt

Mass Change, AASHTO T 240	
Penetration @ 25°C 100g/5sec, AASHTO T49	
Absolute Viscosity @ 60°C, AASHTO T202	
Kinematic Viscosity @ 135°C, AASHTO T201	
Ductility @ 25°C, 5cm/min, AASHTO T51	
Elastic Recovery @ 25°C, (%), AASHTO T301	
Absolute Viscosity Ratio (60°C); RTFO Visc/Orig Visc	
% of Original Penetration at 25°C, 100g/5sec	
DSR	
at 64 C 2.20 kPa min d, max 80 degrees	Test Temperature, °C
	64
	70

0.415	0.144
65	64
7,981	10,800
125	130
81%	80%
0.97	0.65
60.7%	63.4%
delta / G*/sinδ, kPa	delta / G*/sinδ, kPa
72.1 / 2.46	71.4 / 2.79

0.512	0.47
69	69
9,221	5,520
96	86
83%	73% (!)
0.81	1.50
60.5%	57.0%
delta / G*/sinδ, kPa	delta / G*/sinδ, kPa
74.2 / 2.76	76.1 / 2.48

PAV @ 100 C

Penetration @ 25°C 100g/5sec, AASHTO T49	
DSR	
5000 kPa max at 22 C	Test Temperature, °C
	22
	19
	16

31	33
delta / G* sinδ, kPa	delta / G* sinδ, kPa
52.2 / 2789	53.5 / 2500

36	31
delta / G* sinδ, kPa	delta / G* sinδ, kPa
47.7 / 2877	47.3 / 2506

BBR

Test Temperature, °C	
	Stiffness, MPa
	m-value
- 18 C	Stiffness, MPa
	m-value
- 24 C	Stiffness, MPa
	m-value

243	232
0.311	0.311

178	167
0.307	0.308

DTT

Test Temperature, °C	
- 18 C	Failure Strain
	Failure Strain
	Failure Strain

Binder Grade Based on Test Results:	AR-grade
	PBA-grade
	PG-grade
	Continuous PG grade

64 - 28	64 - 28

64 - 28	63.5 - 28

Appendix 6

Averages and standard deviations
for all test results from the four labs.



Averages and Standard Deviations of four labs

Original Asphalt

PG 64-28PM

PG 64-28TR

Averages Standard Dev.

Averages Standard Dev.

Test, Method	
Flash Point, AASHTO T 48	
Penetration @ 25°C 100g/5sec, AASHTO T49	
Rotational Viscosity @ 135°C, AASHTO T 316	
Absolute Viscosity @ 60°C, AASHTO T202	
Kinematic Viscosity @ 135°C, AASHTO T201	
Solubility in Trichloroethylene (%), AASHTO T44	
DSR	
1.00 kPa min, at 64 C	Test Temperature, °C
	64
	70

Test Results	Standard Dev.
315	15
99	3
0.787	0.033
6946	6398
804	30
99.81	0.23
G*/sinδ, kPa	G*/sinδ, kPa
1.60	0.08

Test Results	Standard Dev.
295	8.1
111	3
0.733	0.023
11,798	1,779
772	32
99.00	0.25
G*/sinδ, kPa	G*/sinδ, kPa
1.28	0.11

RTFO Asphalt

Mass Change, AASHTO T 240	
Penetration @ 25°C 100g/5sec, AASHTO T49	
Absolute Viscosity @ 60°C, AASHTO T202	
Kinematic Viscosity @ 135°C, AASHTO T201	
Ductility @ 25°C, 5cm/min, AASHTO T51	
Elastic Recovery @ 25°C, (%), AASHTO T301	
Absolute Viscosity Ratio (60°C); RTFO Visc/Orig Visc	
% of Original Penetration at 25°C, 100g/5sec	
DSR	
at 64 C 2.20 kPa min d, max 80 degrees	Test Temperature, °C
	64
	70

0.153	0.030
65	2
8346	1944
977	21
128	4
80%	3%
1.68	0.71
66%	4%
G*/sinδ, kPa	G*/sinδ, kPa
2.59	0.17

0.527	0.061
71	1
7,127	1,466
969	30
107	17
84%	5%
0.60	0.19
63%	3%
G*/sinδ, kPa	G*/sinδ, kPa
2.64	0.18

PAV @ 100 C

Penetration @ 25°C 100g/5sec, AASHTO T49	
DSR	
5000 kPa max at 22 C	Test Temperature, °C
	22
	19
	16

35	2
G* sinδ, kPa	G* sinδ, kPa
2654	141

35	1
G* sinδ, kPa	G* sinδ, kPa
2,536	274

BBR

Test Temperature, °C	
	Stiffness, MPa
	m-value
- 18 C	Stiffness, MPa
	m-value
- 24 C	Stiffness, MPa
	m-value

243	8
0.313	0.004

156	31
0.317	0.008

DTT

Test Temperature, °C	
	Failure Strain
- 18 C	Failure Strain
	Failure Strain

1.43	0.30
------	------

1.75	0.34
------	------