Business, Transportation and Housing Agency

Analysis of Cost Differential Between Asphalt Containing Crumb Rubber and Conventional Asphalt for 2007

Public Resources Code Section 42703

Prepared by:

Caltrans

This is to certify that this analysis meets the requirements of Public Resources Code section 42703.

Recommend approval by

WILL KEMPTON, Director
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11/19/08
Date

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12/9/08
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Executive Summary

Public Resources Code (PRC) section 42703 requires the Secretary of the Business, Transportation and Housing Agency to prepare annually by January 1, an "analysis comparing the cost differential between asphalt containing crumb rubber and conventional asphalt." PRC 42703 also requires the California Department of Transportation (Caltrans) to meet specified crumb rubber (CRM) usage targets and to increase CRM usage by specified dates unless "the cost of asphalt containing crumb rubber exceeds the cost of conventional asphalt." This analysis addresses both requirements.

A thorough analysis of the relative costs of asphalt containing CRM compared to conventional asphalt is hindered by the lack of a robust pavement management system to collect data for a number of factors. Since actual asphalt materials lifespan and maintenance costs for both rubberized hot mix asphalt (RHMA) and hot mix asphalt (HMA) are not currently available, they were assumed to be the same in order to perform the required analysis. The cost comparison analysis was performed based on the four major program types used to fund projects. For Capital Preventative Maintenance (CAPM) projects the cost of RHMA does not exceed that of conventional asphalt. This is due to RHMA's pavement design, which allows it to be placed at a reduced thickness to that of conventional HMA. For rehabilitation and pavement preservation projects, the cost of RHMA is 4 to 10 percent higher than conventional asphalt. For new construction projects, there is insufficient data to establish a cost comparison, because RHMA is primarily used as thin overlays and rarely used in new pavement designs.

In 2007, Caltrans' CRM use ranged from at least 9.70 pounds to as much as 15.44 pounds of CRM per metric ton of total asphalt paving materials. This exceeds the specified 2007 average amount of not less than 6.62 pounds of CRM per metric ton.

The Secretary of the Business, Housing and Transportation Agency finds that Caltrans should continue to use CRM in highway paving projects. Since in some applications the cost of RHMA can exceed the cost of HMA, Caltrans must continue to use sound engineering judgment to determine when and where RHMA should be used. With the continued commitment to use CRM, Caltrans anticipates meeting the calendar year 2010 annual average amount of not less than 8.27 pounds of CRM per metric ton of total asphalt paving materials used.

Background

In 1980 Caltrans started experimenting with the use of crumb rubber generated from waste tires as a modifier for asphalt. In March 1992, Caltrans published a "Design Guide for Asphalt Rubber Hot Mix-Gap Grade[1]" (ARHM-GG), and by the mid 1990s Caltrans had constructed over 100 projects using RHMA.

Senate Bill 876 (SB 876) was approved by the Legislature and signed by the Governor in 2000. SB 876 added Section 42889.3 to the PRC that requires Caltrans on or before January 1 of each year to report to the Legislature and California Integrated Waste Management Board on the use of waste tires in transportation and civil engineering projects during the previous five years.

Since the implementation of PRC section 42889.3, Caltrans has reported a steady increase in the use of asphalt containing CRM specifically in the form of "rubberized hot mix asphalt" (RHMA)[2]. Caltrans published the Asphalt Rubber Usage Guide[3] (2003) and issued policies regarding crumb rubber usage.

Assembly Bill 338 (AB 338) was chaptered in 2005, adding Section 42703 to the PRC relating to recycling. The intent of this legislation was to require Caltrans to use more asphalt containing CRM when it was cost-effective, compared to conventional asphalt. The ultimate goal of this legislation was to increase the recycling of the 43,000,000 scrap tires generated each year in California and, therefore, reduce the amount of tires placed in landfills and scrap tire piles.

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[1] Asphalt Rubber Hot Mix –Gap Grade (ARHM-GG) was later designated as Rubberized Asphalt Concrete –Gap Grade (RAC-G) and is now designated as Rubberized Hot Mix Asphalt – Gap Grade (RHMA–G).

[2] Rubberized Hot Mix Asphalt formerly referred to as Rubberized Asphalt Concrete (RAC).

[3] Asphalt Rubber Usage Guide contains RAC history and state-of-practice information regarding RAC product selection and use, engineering design criteria, production, construction, and quality control and quality assurance for asphalt rubber binder and RAC.

PRC Section 42703 (Appendix 1) requires Caltrans to meet increasing specified amounts of CRM usage by January 1 of the years 2007, 2010, and 2013. The Secretary of Business, Transportation, and Housing must prepare an annual cost differential analysis based on the PRC section 42703 requirement.

> (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.

Caltrans has a history of being proactive in promoting CRM usage. Caltrans' Chief Engineer issued a policy memorandum, emphasizing the use of rubberized asphalt concrete as the strategy of choice for flexible pavement alternatives when it meets Caltrans' engineering criteria and is cost-effective. In early 2007, Caltrans revised the standard specifications to only allow the usage of CRM manufactured in the United States and derived from waste tires taken from vehicles owned and operated in the United States. Also, Caltrans recently modified its standard specifications to encourage usage of RHMA by consolidating and including it into Section 39 "Hot Mix Asphalt."

The addition of RHMA to the Caltrans standard specifications shows that RHMA use has matured and is now accepted as a routine application.

Cost Comparison Analysis and Results

The cost comparison analysis was segregated by the four major program types used by Caltrans to fund projects: New construction, rehabilitation, CAPM, and preservation. To allow relative comparisons between HMA and RHMA, the materials were broken into two categories:

- Gap Grade: comparing Rubberized Hot Mix Asphalt – Gap Grade (RHMA –G) versus dense grade conventional asphalt material.
- Open Grade: comparing Rubberized Hot Mix Asphalt - Open Grade (RHMA-O and RHMA-O-HB) versus conventional open grade asphalt material.

The Caltrans Division of Construction Contract Administration System (CAS) was used to obtain the costs of various work items. Maintenance costs for pavements were obtained from the Caltrans Division of Maintenance Integrated Maintenance Management System (IMMS). Five major assumptions were necessary before any cost comparisons could be made (see Table 1 for summary):

1. Per-lane mile cost for material is a theoretical calculation based on the following:
   - Both RHMA material and conventional asphalt material weigh 150 lbs/cubic foot.
   - Standard lane width is 12 feet.
2. Pavement thicknesses placed for CRM asphalt material versus conventional asphalt material are:

- New construction – same thickness, no reduction for asphalt containing CRM because of pavement structure load capacity design requirements.
- Rehabilitation – asphalt containing CRM gap grade is placed at an approximate half the thickness of conventional asphalt dense grade when existing pavement structure is adequate.
- CAPM – asphalt containing CRM gap grade is placed at a reduced thickness compared to conventional asphalt dense grade.
- Preservation (maintenance) – asphalt containing CRM and HMA thicknesses are the same (maintenance overlays are placed at minimum one-inch thickness).

3. Asphalt containing CRM and HMA lifespans are the same.
4. Maintenance costs for asphalt containing CRM and HMA are the same.
5. No reduction of cost can be taken for asphalt containing CRM pavement when used for noise reduction in lieu of soundwalls.

Assumption 1 was necessary since Caltrans does not have a database that contains the required information. The theoretical calculation of lane miles used in the cost analysis somewhat overstates the number of lane miles, due to shoulder, median, and turn lane material quantities is included as lanes.

Assumption 2 was necessary since Caltrans does not have a pavement management system (PMS) that contains the necessary information on existing pavement thickness. Authorized by a 2007/08 budget change proposal, Caltrans will be establishing a pavement structure database over the next three fiscal years.

Assumption 3 was necessary since Caltrans does not have a PMS that contains pavement lifespan data or that can be used to predict pavement lifecycles. Although a PMS is currently under development, such a system

does not exist today to facilitate the determination of actual lifespan durations of highway pavements.

Assumption 4 was necessary since the Caltrans IMMS does not segregate pavement maintenance costs from other work. The IMMS asset category for "ROADWAY" includes work activity charges not only for the roadbed, but for vegetation and slopes, drainage, railings and barriers, signs and sign structures, delineation, walls and fences, and landscape. The "ROADWAY" category of the IMMS also includes work activity charges for sweeping, graffiti removal, snow removal and ice control, and both minor and major damage due to storms or extraordinary events such as earthquakes and slides. To accurately calculate the cost-effectiveness of asphalt containing CRM and HMA, only roadbed maintenance costs should be included. Consequently, maintenance costs are not included in the analysis, and are assumed to be the same for asphalt containing CRM and HMA.

Assumption 5 was made since there is no reduction in soundwall costs based on use of asphalt containing CRM versus conventional asphalt. At this time, the Federal Highway Administration (FHWA) will not provide federal funds for projects to place "quiet pavement" in lieu of soundwalls. Research indicates that open graded asphalt pavement, with or without CRM, provides the same amount of tire noise reduction. Until ongoing research is completed and FHWA approves the use of "quiet pavement" in lieu of soundwalls, no reduction of cost can be used for asphalt containing CRM pavement.

Table 1 Assumptions Used in Cost Comparison Analysis of Asphalt Containing CRM to Conventional Asphalt[4]					
Assumptions		**New Construction**	**Rehabilitation**	**CAPM**	**Preservation (Maintenance)**
Unit Weight lbs/ ft³ *(metric ton/m³)*	**CRM**	**150** *(2.4)*	**150** *(2.4)*	**150** *(2.4)*	**150** *(2.4)*
	Conventional Asphalt	**150** *(2.4)*	**150** *(2.4)*	**150** *(2.4)*	**150** *(2.4)*
Uniform Lane Width (ft)		**12**	**12**	**12**	**12**
Paving Thickness, inch[5] *(mm)*					
CRM Asphalt Open Grade		**1.2** *(30)*	**1.2** *(30)*	**1.2** *(30)*	**1.2** *(30)*
CRM Asphalt Gap Grade		**5[6]** *(127)*	**2.4** *(60)*	**1.8** *(45)*	**1.2** *(30)*
Conventional Asphalt Open Grade		**1.2** *(30)*	**1.2** *(30)*	**1.2** *(30)*	**1.2** *(30)*
Conventional Asphalt Dense Grade		**5** *(127)*	**4.2** *(106)*	**2.4** *(60)*	**1.2** *(30)*
Expected Lifespan (years)[7]					
CRM Asphalt		**20**	**10**	**4**	**5**
Conventional Asphalt		**20**	**10**	**4**	**5**
Maintenance Costs (per lane mile)[8]					
CRM Asphalt		$ N/A	$ N/A	$ N/A	$ N/A
Conventional Asphalt		$ N/A	$ N/A	$ N/A	$ N/A

Using the above assumptions and progress payment data from the CAS, the results of the cost comparison analysis are shown in Table 2. The results are segregated by the four major program types: new construction, rehabilitation, CAPM, and preservation. To prevent any outlying data from influencing the final results, any data beyond one standard deviation was removed and then the cost comparison analysis was recalculated.

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[4] Analysis based on metric data, however, information in Table 1 has been converted to US Customary units.
[5] Paving thickness is based on pavement design guidelines not actual thickness on projects.
[6] Of this amount, 2 ½ inches are RHMA and 2 ½ inches HMA.
[7] Expected lifespan assumed to be the same for asphalt containing CRM and conventional asphalt.
[8] Maintenance costs segregated for CRM asphalt material and conventional asphalt material are not available in IMMS.

Table 2 2007 Data[9] Analysis Results Cost Comparison by Program Type per Lane Mile for Asphalt Containing CRM versus Conventional Asphalt				
All Payment Data Evaluated				
	New Construction	**Rehabilitation**	**CAPM**	**Preservation (Maintenance)**
CRM Asphalt	N/A	$90,040	$63,770	$49,070
Conventional Asphalt	N/A	$89,290	$83,810	$42,140
Excluding Payment Data Greater or Less Than One Standard Deviation (σ) from the Weighted Mean for the Paving Material Contract Price				
	New Construction	**Rehabilitation**	**CAPM**	**Preservation (Maintenance)**
CRM Asphalt	N/A	$91,820	$61,190	$45,390
Conventional Asphalt	N/A	$88,490	$83,720	$41,350

For new construction projects the amount of data on RHMA was insufficient to establish a cost comparison. For rehabilitation program type projects the cost of RHMA is 4 percent higher than HMA. For CAPM program type projects the cost comparison data analysis shows that asphalt containing CRM is cost-effective when compared to conventional asphalt. For preservation program-type projects, the cost of asphalt containing CRM is 10 percent higher than conventional asphalt. On a unit cost basis, RHMA costs on average $108.57 per metric ton versus $86.12 per metric ton for conventional HMA (26 percent more).

Even though RHMA appears to be more costly overall, Caltrans should continue to use RHMA on rehabilitation and preservation program type projects until a robust PMS can be implemented and more complete and accurate data used.

[9] Data compiled for this analysis was based on 485 projects under construction in 2007.

Crumb Rubber Usage Analysis and Results

The data collection process for this analysis captured the available project quantities for RHMA and HMA placed during 2007 from the CAS progress payment database. The method used to determine the amount of CRM per metric ton of asphalt placed required the assumption that the material placed met the project's design as follows:

1. CRM asphalt binder contains between 18 percent and 22 percent CRM.
2. RHMA has the following asphalt binder content ranges:
   - Gap Grade (RHMA –G) contains between 5 percent and 7 percent CRM asphalt binder.
   - Open Grade (RHMA-0 and RHMA -O-HB) contain between 7 percent and 9 percent CRM asphalt binder.

The results of the crumb rubber usage analysis are shown in Table 3.

Table 3
2007 Data[10] Analysis Results
Crumb Rubber Usage

Quantity of Asphalt Placed (Metric Tons)			Range of Pounds of Crumb Rubber Placed		Pounds of CRM per Metric Ton of total Asphalt Placed	
All Paving Material	Conventional Asphalt Material	Asphalt Containing CRM Material	Maximum	Minimum	Max. Level	Min. Level
3,641,889	**2,288,785**	**1,353,104**	**56,235,297**	**35,294,108**	**15.44**	**9.70**

[10] Data compiled for this analysis was based on 485 projects in construction in 2007.

Variations in the exact percentage of CRM used in asphalt rubber binder and the percentage of asphalt rubber binder used per metric ton of paving materials only allow for the calculation of a CRM usage range. Caltrans used at least 9.70 pounds of CRM per metric ton of total asphalt paving materials and as much as 15.44 pounds of CRM per metric ton of total asphalt paving materials for calendar year 2007.

Public Resources Code section 42703 mandates that Caltrans use not less than 6.62 pounds of CRM per metric ton of total asphalt paving materials placed throughout the State for 2007. Even using the lower range of 9.70 pounds of CRM per metric ton of total asphalt paving materials, Caltrans has exceeded the minimum CRM usage of 6.62 pounds of CRM per metric ton of total asphalt paving for 2007.

Based on the minimum calculation of 35,294,108 pounds of CRM used in RHMA, Caltrans has diverted over 3 million[11] waste tires from landfills and tire stock piles for the 2007 calendar year. Information on additional waste tire applications used by Caltrans is available at:
http://www.dot.ca.gov/hq/oppd/rescons/sb876.htm

Recommendations and Findings

It is recommended that Caltrans:

1. In support of the legislative intent, continue to develop good engineering applications of CRM usage to meet project delivery needs.

2. Continue pursuing development and implementation of a robust PMS and collect the data necessary to provide actual pavement data, such as amount of lane miles, pavement structure, type and precise location, and pavement lifespan.

[11] Passenger tire equivalents (PTE) is based on 12 pounds of CRM per recycled tire used.

3. Continue to replace the CAS with a construction management system that is capable of generating needed CRM usage analysis for future crumb rubber annual analyses.

4. Upgrade the IMMS to segregate roadbed cost information and provide the necessary maintenance information used in a PMS. It is recognized that this would cost in excess of $2 million to modify the IMMS and train users, and that there is an increased person year cost to develop and input the additional information.

The Secretary of Business, Housing and Transportation Agency understands the budgetary and resource constraints Caltrans has towards implementing these proposed recommendations for improvements to the future CRM annual analyses. It is also recognizes that budgetary actions will be required to implement some of the above recommendations.

The Secretary of Business, Housing and Transportation Agency finds that:

1. Caltrans used at least 6.62 pounds of CRM per metric ton of total asphalt paving materials, meeting the 2007 PRC section 42703 legislative requirement.

2. Caltrans projects using CRM asphalt paving materials diverted over 3 million waste tires from landfills and tire stock piles during the 2007 calendar year.

3. Although RHMA is more costly than conventional HMA, the cost of RHMA does not exceed the cost of conventional HMA in limited applications where thicknesses of pavement using RHMA can be reduced from that of conventional asphalt.

Appendix I – Public Resources Code Section 42703

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.