CALIFORNIA STATE TRANSPORTATION AGENCY

Analysis of Cost Differential Between Asphalt Containing Crumb Rubber and Conventional Asphalt for 2014 ("2014 Crumb Rubber Report")

Public Resources Code Section 42703

Prepared by

CALIFORNIA DEPARTMENT OF TRANSPORTATION

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Contents

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Executive Summary

Assembly Bill 338, relating to recycling, was chaptered in 2005 and added section 42703 to the Public Resources Code. The intent of this legislation was to require the California Department of Transportation (Caltrans) to use more asphalt containing crumb rubber when it is cost-effective compared with conventional asphalt. The ultimate goal of this legislation is to increase the recycling of the more than 40 million reusable and waste tires generated each year in California and thereby reduce the amount of tires placed in landfills and scrap tire piles. In calendar year 2014, Caltrans projects using asphalt containing crumb rubber diverted more than 2.7 million waste tires from landfills and tire stockpiles.

Public Resources Code section 42703 requires Caltrans to meet specified usage amounts of crumb rubber modifier (CRM) in asphalt pavement and requires the Secretary of the California State Transportation Agency to prepare an annual analysis comparing the cost differential between asphalt containing crumb rubber and conventional asphalt paving material. This report addresses Public Resources Code sections 42703(a)(3), 42703(b)(2), 42703(c)(1)(A), (B), and (C), and 42703(c)(2). (See appendix for the full text of section 42703.) For this analysis, the four major pavement project categories were used: pavement preservation (maintenance), rehabilitation, Capital Preventive Maintenance (CAPM), and "New Capacity/Safety/Temp. Detours."

Public Resource Code section 42703(a)(3) requires that on and after January 1, 2013, Caltrans shall use, on an annual average, not less than 11.58 pounds of CRM per metric ton of the total asphalt paving materials used, which is a calculated target percentage of 35 percent. Of the 3.7 million metric tons of paving asphalt Caltrans used in calendar year 2014, a million metric tons contained crumb rubber, which is an average of 26.7 percent. Caltrans used an average of 35.2 million pounds of CRM in rubberized asphalt concrete, which equates to 9.42 pounds of CRM per metric ton. (See table 1 and the chart on page 2.)

Caltrans failed to meet the mandated CRM usage requirement because of constructability issues in the "New Capacity/Safety/Temp. Detours" category, which includes locally funded bond projects and State Transportation Improvement Program projects. On these projects, conventional asphalt is the only option for the base layers under the concrete pavement. Rubberized asphalt concrete can be used only on the top two inches of the structural section (Section 631.3, Caltrans Highway Design Manual). Requiring CRM usage in the base layers of asphalt pavement is currently being explored as another opportunity to meet the requirements of the law. If only the top two inches of the structural section are eligible to determine CRM usage, the percentage of asphalt containing crumb rubber would be 15.96 pounds of CRM per metric ton, or 45.3 percent, rather than the 26.7 percent calculated using the total amount of all asphalt paving materials.

Over six times more metric tons of conventional asphalt than asphalt containing crumb rubber were used in the "New Capacity/Safety/Temp. Detours" category and about eight times more for rehabilitation projects. For pavement preservation, the amount of asphalt containing crumb rubber was 60.9 percent of the total asphalt used, and for CAPM projects, it was 37.4 percent.

However, because of the higher tonnage of conventional asphalt used in the "New Capacity/Safety/Temp. Detours" category and for rehabilitation projects, the total metric tons of conventional asphalt used was about 2.7 times the total metric tons of asphalt containing crumb rubber. (See table 2 on page 3.)

Public Resources Code section 42703(b)(2) mandates that 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 section 42703(a) shall be rubberized asphalt concrete. (That is, half of asphalt used to meet the specified pounds per metric ton, or the targeted percentage, must be rubberized asphalt concrete.) In calendar year 2014, Caltrans used 100 percent rubberized asphalt concrete to comply with the requirements of Public Resources Code section 42703(b)(2).

At this time, the material life span and maintenance costs for asphalt materials cannot be analyzed as required by Public Resources Code sections 42703(c)(1)(A) and 42703(c)(1)(B). However, by the end of calendar year 2016, after the Caltrans pavement management system completes three annual pavement condition surveys, the life span and duration of asphalt materials can be calculated and will be provided as required.

In order to perform the analysis required by Public Resources Code section 42703(c)(1)(C), the material life span and maintenance costs for both asphalt containing crumb rubber and conventional asphalt were assumed equal. The initial cost per metric ton of asphalt containing crumb rubber varies depending on the project category. For pavement preservation (maintenance) projects, the initial cost of asphalt containing crumb rubber was 3.1 percent less than conventional asphalt. For all other project categories, the initial cost of asphalt containing crumb rubber was more than the cost of conventional asphalt: for rehabilitation projects, about 35.4 percent more; for CAPM projects, 15.6 percent more; and for "New Capacity/Safety/Temp. Detours" projects, 9.1 percent more. (See table 3 on page 6.)

Caltrans made and is making various efforts to increase and estimate crumb rubber usage in future projects. These efforts include:

(1) A memo was issued on February 10, 2015, requiring all asphalt pavement projects to be reviewed for use of asphalt containing crumb rubber. Exceptions require approval by the respective District Director.
(2) A memo was issued on September 25, 2015, requiring consideration of rubberized hot mix asphalt (RHMA) as the first choice for flexible pavement strategies in projects. The memo also requires Districts to provide proposed RHMA and hot mix asphalt (HMA) usage for the current year and two years in the future with a list of projects.
(3) A Construction Policy Bulletin (CPB) is being developed that will require all contractors to submit quantities of crumb rubber usage to Caltrans on a monthly basis for tracking purposes. The bulletin is expected to be published by the end of June 2016.
(4) The Asphalt Task Group of the Rock Products Committee (joint venture by Caltrans and Industry) is working on a project to increase crumb rubber usage by using CRM and Caltrans PG+5 asphalt binder in HMA. The scheduled completion date is June 30, 2018 for issuing a Construction Policy Bulletin (CPB) or Construction Manual Update.

Caltrans' research has shown that asphalt pavement containing crumb rubber overlays are cost-effective when used to resist reflective cracking. Caltrans will continue to use sound engineering judgment to determine when and where asphalt containing crumb rubber shall be placed, implement projects and strategies to increase crumb rubber use, and implement ways to improve tracking of current usage and predict future usage.

Crumb Rubber Usage Analysis and Results

Public Resource Code section 42703(a)(3) requires that on and after January 1, 2013, Caltrans shall use, on an annual average, not less than 11.58 pounds of CRM per metric ton of total asphalt paving materials used.

Caltrans' Division of Construction's Contract Administration System progress payment database provided the pavement project costs and the total tonnage of asphalt containing crumb rubber and conventional asphalt placed during calendar year 2014. The method used to determine the amount of CRM per metric ton of asphalt placed required the following assumptions:

1. CRM asphalt binder contains between 18 to 22 percent CRM for rubberized hot-mix asphalt; calculations were based on a value of 20 percent.

2. CRM asphalt binder contains between 8 to 12 percent CRM for hot-mix asphalt with terminal blend binder; calculations were based on a value of 10 percent.

3. Asphalt containing crumb rubber has the following CRM asphalt binder content ranges:

    - Gap-graded rubberized hot-mix asphalt contains between 7.5 to 9 percent CRM asphalt binder, based on average field mix designs; a value of 8 percent was used for calculations.

    - Open-graded rubberized hot-mix asphalt contains between 7.5 to 10 percent CRM asphalt binder, based on average field mix designs; a value of 8 percent was used for calculations.

    - Hot-mix asphalt terminal blend contains between 5.2 to 6 percent CRM asphalt binder, based on average field mix designs; a value of 5.2 percent was used for calculations.

To comply with Public Resources Code section 42703(a), subparagraphs (1) through (3), target percentages were calculated as follows, based on Caltrans' use of CRM per metric ton of the total amount of asphalt paving materials used:

1. For 2007 through 2009, the annual average mandate of 6.62 pounds equals 20 percent.
2. For 2010 through 2012, the annual average mandate of 8.27 pounds equals 25 percent.
3. For 2013 and beyond, the annual average mandate of 11.58 pounds equals 35 percent.

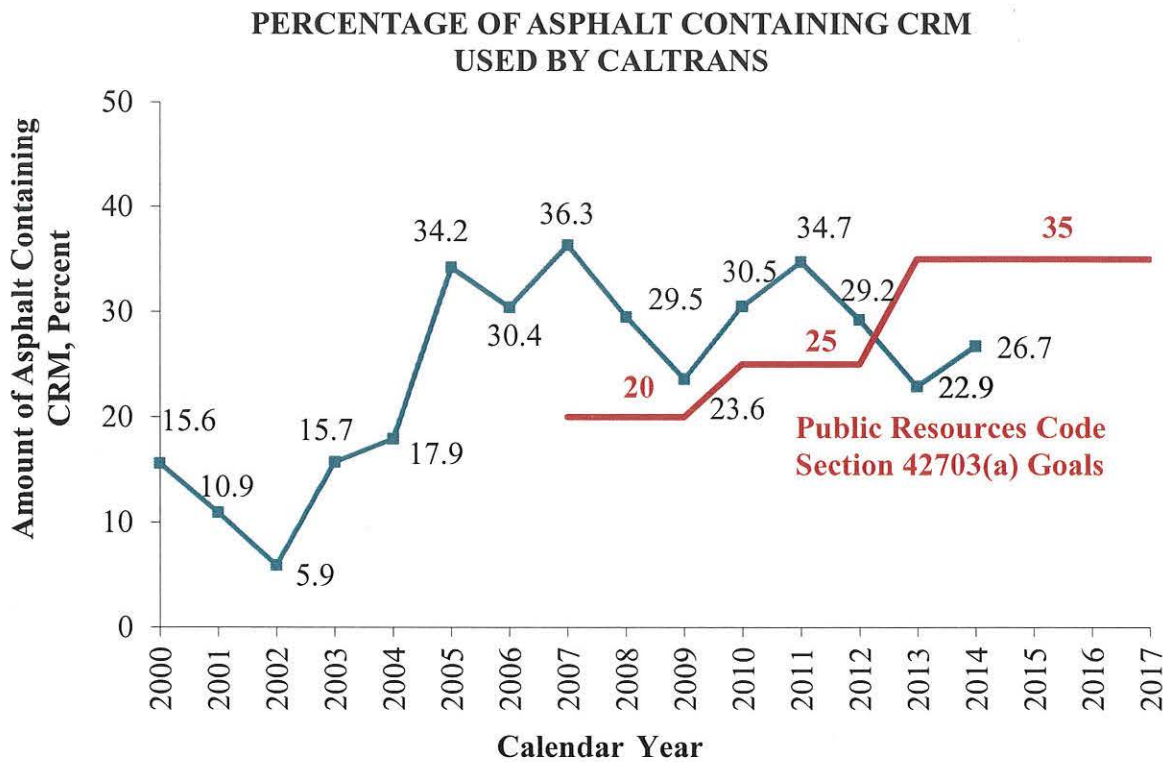
The results of the crumb rubber usage analysis are shown in table 1 and the chart on the next page.

Table 1

2014 DATA ANALYSIS RESULTS
CRUMB RUBBER USAGE*

Quantity of Asphalt Placed (Metric Tons)			Asphalt Containing Crumb Rubber to Total Asphalt Paving (Percent)	Crumb Rubber Placed (Average Pounds)	Pounds of CRM per Metric Ton of Total Asphalt Placed (Calculated)
Total Asphalt	Conventional Asphalt	Asphalt Containing Crumb Rubber			
3,738,054	2,739,547	998,507	26.7	35,220,943	9.42

*Data compiled for this analysis was based on 377 projects in construction paving in calendar year 2014.



In calendar year 2014, Caltrans projects using asphalt containing crumb rubber diverted more than 2.7 million waste tires from landfills and tire stockpiles. Of the 3.7 million metric tons of paving asphalt Caltrans used, 1.0 million metric tons contained crumb rubber, which is an average of 26.7 percent of the total paving asphalt. Caltrans used an average of 35.2 million pounds of CRM in rubberized asphalt concrete, which equates to 9.42 pounds of CRM per metric ton.

Caltrans failed to meet the 2013 mandate of 11.58 pounds of CRM per metric ton, or 35 percent, of the total asphalt paving used because of constructability issues in the "New Capacity/ Safety/Temp. Detours" category, which includes locally funded bond projects and State Transportation Improvement Program projects. On these projects, conventional asphalt is the only option for the base layers under the concrete pavement. Rubberized asphalt concrete can be used only on the top two inches of the structural section (per Section 631.3, Caltrans Highway Design Manual) . Requiring CRM usage in the base layers of asphalt pavement is currently being explored as another opportunity to meet the requirements of the law. If only the top two inches of the structural section are eligible to determine CRM usage, the percentage of asphalt containing crumb rubber would be 15.96 pounds of CRM per metric ton, or 45.3 percent, rather than the 26.7 percent calculated using the total amount of all asphalt paving materials.

As shown in table 2, approximately six times more metric tons of conventional asphalt than asphalt containing crumb rubber were used in the "New Capacity/Safety/Temp. Detours" category and about eight times more for rehabilitation projects. For pavement preservation, the amount of asphalt containing crumb rubber was 60.9 percent of the total asphalt used, and for CAPM, it was 37.4 percent. However, because of the higher tonnage of conventional asphalt used in the "New Capacity/Safety/Temp. Detours" category and for rehabilitation projects,

the total metric tons of conventional asphalt used was about 2.7 times the total metric tons of asphalt containing crumb rubber.

Table 2

2014 DATA ANALYSIS RESULTS
CRM USAGE PER METRIC TON BY PAVEMENT PROJECT TYPE
FOR ASPHALT CONTAINING CRM VERSUS CONVENTIONAL ASPHALT

Pavement Category	Total Asphalt Used	Conventional Asphalt	Asphalt Containing CRM	Percent of Asphalt Containing CRM
Pavement preservation (maintenance)	734,315	289,817	447,497	60.9
CAPM	655,178	410,179	244,999	37.4
Rehabilitation	374,261	331,875	42,386	11.3
New Capacity/Safety/Temp. Detours	1,974,300	1,710,676	263,625	13.4
Total	3,738,054	2,739,547	998,507	26.7

Public Resources Code section 42703(b)(2) mandates that 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 section 42703(a) shall be rubberized asphalt concrete. (That is, half of the asphalt used to meet the mandated pounds per metric ton, or the percentages shown in the chart on page 2, must be rubberized asphalt concrete.) In calendar year 2014, Caltrans used 100 percent rubberized asphalt concrete to comply with the requirements of Public Resources Code section 42703(b)(2).

In the future, in order to meet mandated usage amounts of asphalt containing crumb rubber, all asphalt pavement projects will be required to report the amount of asphalt containing crumb rubber used. In addition, the Division of Maintenance and the Division of Design will review all asphalt pavement projects for use of asphalt containing crumb rubber during a three-year period so that such usage can be predicted prior to project construction. During construction, exceptions to using asphalt containing crumb rubber may be considered because of such things as the availability of asphalt concrete, constructability, environmental factors, and cost. Exceptions may cover the following situations:

- When CRM project quantities are less than 1,000 metric tons or stage construction operations require less than 1,000 metric tons per stage.
- When the temperature is below 45 degrees Fahrenheit.
- Where the roadway is above 3,000 feet in elevation.

- When placed as a concrete pavement asphalt base.
- When placed as a bond breaker between the asphalt and concrete pavement layers.

Asphalt pavement guidelines, such as the *Highway Design Manual*, will be updated to allow use of conventional asphalt by exception only. Caltrans will also explore the opportunity to require a small amount of CRM be incorporated into asphalt binders used in all highway asphalt paving materials.

Cost Comparison Analysis and Results

Public Resources Code section 42703(c)(1) requires the Secretary of the California State Transportation Agency to prepare annually by January 1 an analysis comparing the cost differential between asphalt containing crumb rubber and conventional asphalt. The cost comparison analysis for calendar year 2014 was segregated by the four major pavement project categories: pavement preservation (maintenance), rehabilitation, CAPM, and "New Capacity/Safety/Temp. Detours" projects (such as lane additions, new road alignments, and safety and landscape projects).

Caltrans' Division of Construction's Contract Administration System progress payment database was used to obtain the costs of various pavement projects and total tonnage of materials.

Four major assumptions were necessary before any cost comparisons could be made.

1. Cost per metric ton for asphalt material was calculated based on the tonnage and bid item cost of the asphalt material.

2. Cost comparisons were completed for the following categories of projects:

   - Pavement Preservation (Maintenance). Overlay strategies, compared and placed at the same one-inch minimum thickness under the maintenance preservation program.

   - Rehabilitation. Pavement rehabilitation projects funded in the State Highway Operation and Protection Program (SHOPP).

   - CAPM. CAPM strategies are thinner than rehabilitation strategies and are usually double the thickness of pavement preservation (maintenance) treatments funded from the SHOPP.

   - New Capacity/Safety/Temp. Detours. All other program projects not listed in the above categories (such as safety, landscape, State Transportation Improvement Program, and protective betterment projects).

   These assumptions were necessary because Caltrans has many different types of projects, such as roadway rehabilitation, roadside, safety, and drainage, that contain small amounts of asphalt that would make a cost-per-metric-ton analysis meaningless. Similar types of strategies need to be compared for an accurate cost comparison between asphalt containing crumb rubber and conventional asphalt.

3. Rehabilitation strategies with asphalt containing crumb rubber and conventional asphalt life spans were considered the same.

   This assumption was necessary because pavement life span data that can be used to predict pavement life cycles is under development in PaveM. For this report, expected life spans were assumed the same for asphalt containing crumb rubber and conventional asphalt. The asphalt life span was assumed to be three to five years for pavement preservation

(maintenance) projects, ten years for rehabilitation projects, five to seven years for CAPM projects, and twenty years for new construction projects. However, by the end of calendar year 2016, after the Caltrans pavement management system completes three annual pavement condition surveys, the life span and duration of asphalt materials can be calculated and will be provided, as required by Public Resources Code section 42073(c)(1)(A).

4. Maintenance costs for asphalt containing crumb rubber and conventional asphalt were considered the same and did not affect the cost comparison.

   This assumption was necessary because Caltrans' Integrated Maintenance Management System does not segregate pavement maintenance costs for asphalt containing crumb rubber and conventional asphalt material from other pavement work. Caltrans' ability to segregate and calculate maintenance costs for asphalt containing crumb rubber or conventional asphalt locations is difficult to quantify accurately. Consequently, maintenance costs were not included in the analysis and were assumed the same for asphalt containing crumb rubber and conventional asphalt.

These four listed assumptions and the progress payment data from the Division of Construction's Contract Administration System were used for the cost comparison analysis. The results shown in table 3 are segregated by the four major pavement project categories.

Table 3

2014 DATA ANALYSIS RESULTS
INITIAL COST COMPARISON PER METRIC TON BY PAVEMENT PROJECT TYPE FOR ASPHALT CONTAINING CRUMB RUBBER VERSUS CONVENTIONAL ASPHALT

Type of Asphalt	Pavement Preservation (Maintenance)	Rehabilitation	CAPM	New Capacity/ Safety/Temp. Detours
Asphalt containing crumb rubber	$ 98.90	$98.50	$89.81	$86.76
Conventional asphalt	$102.02	$72.73	$77.69	$79.56

For pavement preservation (maintenance) projects, the initial cost of asphalt containing crumb rubber was 3.1 percent less than conventional asphalt. For all other project categories, the initial cost of asphalt containing crumb rubber was more than the cost of conventional asphalt: for rehabilitation projects, about 35.4 percent more; for CAPM projects, 15.6 percent more; and for "New Capacity/Safety/Temp. Detours" projects, 9.1 percent more.

While asphalt pavement containing crumb rubber does initially cost more per metric ton than conventional asphalt pavement for most project categories, Caltrans' research has shown that asphalt containing crumb rubber resists reflective cracking better than conventional asphalt pavement. Caltrans will continue to use sound engineering judgment to determine when and where asphalt containing crumb rubber shall be placed.

Findings and Recommendations

For calendar year 2014, the Secretary of the California State Transportation Agency finds that:

1. Caltrans used an average of 9.42 pounds of CRM per metric ton of total asphalt paving materials, failing to meet the Public Resources Code section 42703(a)(3) requirement of 11.58 pounds of CRM per metric ton of total asphalt paving material used. Caltrans' usage of asphalt containing crumb rubber was 26.7 percent of the total paving asphalt used.

2. Caltrans used 100 percent rubberized asphalt concrete to comply with the requirements of Public Resources Code section 42703(b)(2). This amount exceeds the Public Resources Code section 42703(b)(2) requirement that 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 section 42703(a) shall be rubberized asphalt concrete.

3. The initial cost per metric ton of asphalt containing crumb rubber varies between 3.1 percent less to 35.4 percent more than the cost of conventional asphalt, depending on the project category. Caltrans' research has shown that asphalt pavement containing crumb rubber overlays are cost-effective when used to resist reflective cracking. Caltrans will continue to use sound engineering judgment to determine when and where asphalt containing crumb rubber shall be placed.

4. Caltrans projects using asphalt containing crumb rubber diverted more than 2.7 million waste tires from landfills and tire stockpiles during calendar year 2014. Information about additional waste tire applications used by Caltrans is available on the Internet at <http://www.dot.ca.gov/hq/oppd/rescons/sb876.htm>.

5. Caltrans' Division of Maintenance and Division of Design will review all asphalt pavement projects for use of asphalt containing crumb rubber during a three-year period so that such usage can be predicted prior to project construction. During construction, exceptions to using asphalt containing crumb rubber may be considered because of such things as the availability of asphalt concrete, constructability, environmental factors, and cost. Asphalt pavement guidelines, such as the *Highway Design Manual*, will be updated to allow the use of conventional asphalt by exception only. Caltrans will also explore the opportunity to require a small amount of CRM be incorporated into asphalt binders used in all highway asphalt paving materials.

6. Caltrans failed to meet the mandated usage requirement because of constructability issues in the "New Capacity/Safety/Temp. Detours" and "Rehabilitation" categories. On these projects, conventional asphalt is the only option for the base layers under the concrete pavement. Rubberized asphalt concrete can be used only on the top two inches of the structural section (Section 631.3, Caltrans Highway Design Manual). Requiring CRM usage in the base layers of asphalt pavement is currently being explored as another opportunity to meet the requirements of the law. If only the top two inches of the structural section are eligible to determine CRM usage, the percentage of asphalt containing crumb rubber would

be 15.96 pounds of CRM per metric ton, or 45.3 percent, rather than the 26.7 percent calculated using the total amount of all asphalt paving materials.

Appendix: Public Resources Code Section 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 Transportation shall, on or before January 1 of each year, 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 [*sic*] 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.