



2018 CRUMB RUBBER REPORT

Cost Differential Analysis Between Asphalt Containing Crumb Rubber and Conventional Asphalt

Public Resources Code Section 42703

Prepared by



2020

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SUMMARY

Public Resources Code section 42703 requires the California Department of Transportation (Caltrans) to meet specified usage amounts of crumb rubber modifier 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 these two statutory requirements.

Caltrans met the required crumb rubber modifier usage amounts in calendar year 2018, and Caltrans' estimates that used asphalt containing crumb rubber diverted more than 5.5 million waste tires from landfills and tire stockpiles. The crumb rubber modifier usage requirements affected four major pavement project categories: Pavement preservation (maintenance), rehabilitation, capital preventive maintenance (CAPM), and new capacity/safety/ temporary detours.

Caltrans used an average of 16.38 pounds of crumb rubber modifier per metric ton of all asphalt pavement, exceeding the requirement to use at least 11.58 pounds of crumb rubber modifier per metric ton of asphalt beginning January 1, 2013, per Public Resources Code section 42703(a)(3). (See Table 2 and chart, page 3.)

To perform the cost/benefit analysis required by Public Resources Code section 42703(c)(1)(C), Caltrans has initiated studies to evaluate the life span and maintenance costs of rubberized hot mix asphalt versus regular hot mix asphalt. A 2007 report by the University of California Pavement Research Center indicated that asphalt pavement containing crumb rubber overlays is 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 is placed. Caltrans has a process for life-cycle cost analysis for various pavement treatments and uses the annual pavement condition survey to update and refine this process. Caltrans has completed data collection from three annual pavement condition surveys for analyzing the life span and duration of asphalt materials, as required by Public Resources Code section 42703(c)(1)(A). Caltrans anticipates having the results by calendar year 2021.

The initial cost per metric ton of asphalt containing crumb rubber varied for specific project categories. For pavement preservation (maintenance) projects, the initial cost of asphalt containing crumb rubber was 7.8 percent more than the cost of conventional asphalt; for rehabilitation projects, 8.3 percent more; for capital preventive maintenance, 7.2 percent more; and for new capacity/safety/temporary detour projects, 4.2 percent less. (See Table 4, page 10.)

Caltrans' 2018 Standard Specifications include requirements for contractors to report crumb rubber usage on state highway projects. These requirements are consistent with Caltrans procedures in the *Caltrans Construction Manual*.

CRUMB RUBBER USAGE ANALYSIS

Public Resource Code section 42703(a)(3) requires Caltrans, beginning January 1, 2013, to use an annual average of not less than 11.58 pounds of crumb rubber modifier per metric ton of the total amount of asphalt paving materials Caltrans places.

For the purposes of this report, and as per the definition in Public Resources Code Sections 42703 and 42801.7, the terms “crumb rubber” and “crumb rubber modifier” have the same meaning. These terms are defined as rubber granules derived from a waste tire that are less than or equal to one-quarter inch or six millimeters in size.

Caltrans' Division of Construction's Contract Administration System's Progress Payment Database provided the pavement project costs and the total tonnage of rubberized hot mix asphalt placed and conventional hot mix asphalt placed in calendar year 2018. The method to determine the amount of crumb rubber modifier per metric ton of rubberized hot mix asphalt placed used the following assumptions:

1. Rubberized hot-mix asphalt binder consists of 18 to 22 percent crumb rubber modifier; calculations in this report use the middle of that range (20 percent) as an estimate.
2. The amount of binder in asphalt depends on the application, as follows:
 - a. Gap-graded rubberized hot-mix asphalt contains 7.5 to 9 percent asphalt binder with crumb rubber modifier, based on average field mix designs; calculations in this report use 8 percent as an estimate.
 - b. Open-graded rubberized hot-mix asphalt contains 7.5 to 10 percent asphalt binder with crumb rubber modifier, based on average field mix designs; calculations in this report use 8 percent as an estimate.
 - c. Hot-mix asphalt terminal blend contains 5.2 to 6 percent asphalt binder with crumb rubber modifier, based on average field mix designs; calculations in this report use 5.2 percent as an estimate.

Based on the asphalt binder requirements above, 35 percent of the total asphalt paving materials Caltrans placed needed to be rubberized hot mix asphalt in calendar year 2018. Caltrans uses the target of 35 percent

(see Table 1, Page 2) as an internal factor for ease of calculating, reporting, and monitoring crumb rubber modifier usage.

TABLE 1 CALCULATION FOR 35 PERCENT CRUMB RUBBER MODIFIER TARGET		
Step	Description of Calculation Step	Calculation/Result
1	Percentage of crumb rubber modifier in asphalt binder for rubberized hot mix asphalt (see <i>Crumb Rubber Usage Analysis Assumption #1</i>)	20%
2	Percentage of crumb rubber modifier asphalt binder in rubberized hot mix asphalt (see <i>Crumb Rubber Usage Analysis Assumptions #2a & #2b</i>)	8%
3	Number of Pounds in 1 Metric Ton (<i>Equation</i>)	2205 lbs
4	Pounds of crumb rubber modifier in 1 Metric Ton of rubberized hot mix asphalt (<i>Step 1 x Step 2 x Step 3</i>)	35.28 lbs
5	Pounds of CRM in 1 Metric Ton of total paving asphalt used, statutorily required (<i>PRC §42703(a)(3)</i>)	11.58 lbs
6	Percentage of rubberized hot mix asphalt Caltrans needs to use, of the total paving asphalt used statewide, to meet the statutory requirement of 11.58 lbs Pounds of crumb rubber modifier in 1 Metric Ton (<i>Step 5 ÷ Step 4 x 100%</i>)	32.8%
7	Target percentage of rubberized hot mix asphalt chosen by Caltrans, of the total paving asphalt used statewide, to ensure the statutory requirement of 11.58 lbs pounds of crumb rubber modifier per metric ton is met (<i>Rounded 32.8% up to 35%</i>)	35%

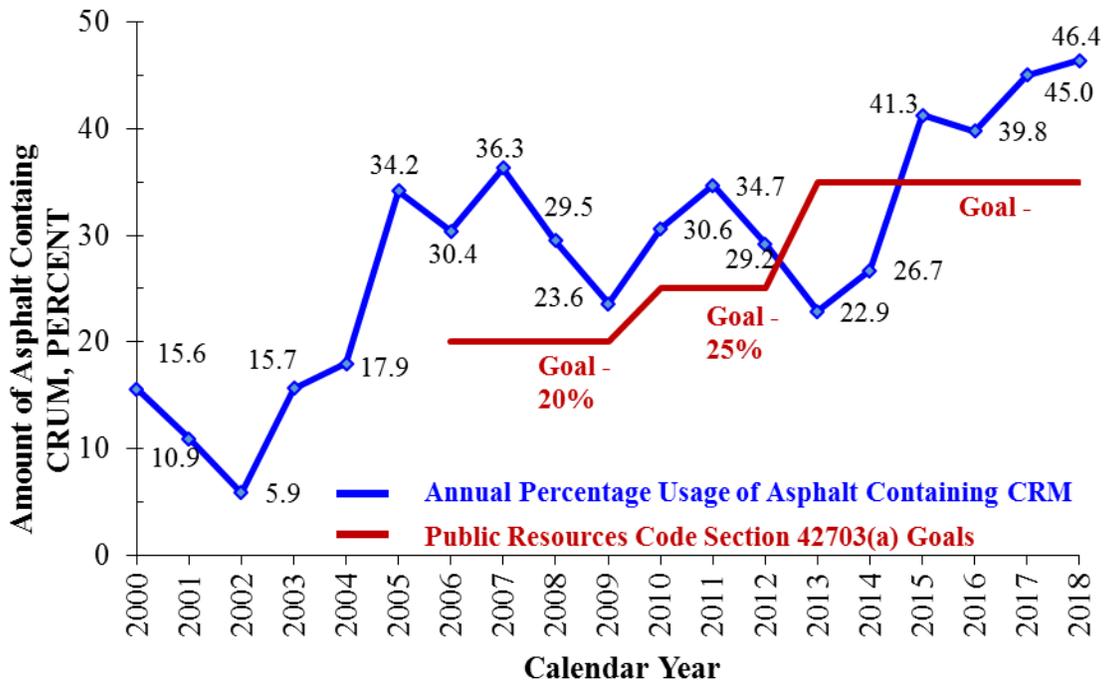
Results of the crumb rubber usage analysis are shown in Table 2 (Page 3) and in the chart (Page 3). Data compiled for this analysis was based on 413 construction projects with paving in calendar year 2018.

Table 2 2018 CRUMB RUBBER USAGE

Quantity of Asphalt Placed

Total Asphalt	4,325,457 metric tons
Conventional Asphalt	2,317,168 metric tons
Asphalt Containing Crumb Rubber	2,008,289 metric tons
Percent of Asphalt Containing Crumb Rubber to Total Asphalt Paving	46.43%
Crumb Rubber Placed (Average Pounds)	70,839,587
Pounds of crumb rubber modifier Per Metric Ton of Total Asphalt Placed (Calculated)	16.38 pounds

CHART: PERCENT OF ASPHALT CONTAINING CRUMB RUBBER MODIFIER USED BY CALTRANS



This chart shows the percent of asphalt containing crumb rubber modifier Caltrans used each calendar year from 2000 to 2018 and the goals used to track compliance with Public Resources Code section 42703(a). The mandated goal beginning in 2007 was 20 percent; in 2010, 25 percent; and since 2013, the goal has been 35 percent.

The percent of asphalt containing crumb rubber modifier Caltrans used each calendar year is as follows:

2000: 15.6 percent	2007: 36.3 percent	2014: 26.7 percent
2001: 10.9 percent	2008: 29.5 percent	2015: 41.3 percent
2002: 5.9 percent	2009: 23.6 percent	2016: 39.8 percent
2003: 15.7 percent	2010: 30.6 percent	2017: 45.0 percent
2004: 17.9 percent	2011: 34.7 percent	2018: 46.4 percent
2005: 34.2 percent	2012: 29.2 percent	
2006: 30.4 percent	2013: 22.9 percent	

Caltrans estimates asphalt containing crumb rubber diverted more than 5.5 million waste tires from landfills and tire stockpiles in 2018, 1 million more tires than in 2017. Of the approximate 4.33 million metric tons of paving asphalt Caltrans used in 2018, about 2.01 million metric tons contained crumb rubber, more than 46 percent of the total. All the asphalt containing crumb rubber was rubberized hot mix asphalt. Caltrans used an average of 70.84 million pounds of crumb rubber modifier in rubberized hot mix asphalt, or 16.38 pounds per metric ton.

Table 3 (Page 5) lists crumb rubber modifier usage per metric ton for asphalt containing crumb rubber modifier versus conventional asphalt. The data are for the four major pavement project categories used in the analysis for this report: pavement preservation (maintenance), rehabilitation, capital preventive maintenance, and new capacity/safety/temporary detours. Descriptions of these categories can be found in this report under Cost Comparison Analysis.

TABLE 3 AMOUNT OF ASPHALT PLACED IN 2018 BY PAVEMENT PROJECT TYPE				
Pavement Category	Total Asphalt Used (metric tons)	Conventional Asphalt (metric tons)	Asphalt Containing crumb rubber modifier (metric tons)	Percent of Asphalt Containing crumb rubber modifier
Pavement preservation (maintenance)	1,926,895	876,789	1,050,106	54.50
Rehabilitation	973,792	741,981	231,810	23.80
CAPM	1,023,961	374,161	649,800	63.46
New capacity/safety/temporary detours	400,809	324,236	76,572	19.10
TOTAL	4,325,457	2,317,168	2,008,289	46.43

The total usage of asphalt containing crumb rubber modifier increased from 1.66 million metric tons in 2017 to 2.01 million metric tons in 2018, an increase of more than 21 percent. This increase was primarily due to increased usage of asphalt containing crumb rubber modifier in two pavement project categories. In the pavement preservation (maintenance) category, Caltrans increased the usage of asphalt containing crumb rubber modifier by more than 0.53 million metric ton. In the rehabilitation category, Caltrans increased the usage of asphalt containing crumb rubber modifier by more than 0.16 million metric ton.

Public Resources Code section 42703(b)(3) allows Caltrans, beginning January 1, 2015, to use any material meeting the product type or specification definition of asphalt containing crumb rubber to comply with the law. In calendar year 2018, Caltrans used only rubberized hot mix asphalt to comply with this policy.

POLICIES AND GUIDELINES

The goal of using rubber in hot-mix asphalt is to slow and minimize the development of cracks, thereby extending the service life of asphalt pavements, and to divert waste tires to reduce tire fires. This policy is described in Caltrans' Highway Design Manual, Chapter 630, specifically in the following excerpts:

- Index 631.3: “Gap graded RHMA is used to meet Public Resources Code section 42703 that specifies specific amounts of crumb rubber modifier (CRM) usage in HMA. To meet the Public Resources Code, regular asphalt binder is substituted with the asphalt rubber binder (that contains CRM) in pavement products to create rubberized HMA (RHMA) product.”
- Index 631.3: “RHMA is commonly specified to retard reflection cracking, resist thermal stresses created by wide temperature fluctuations and add elasticity to a structural overlay.”
- Index 633.1(3)(d):
 - titled “Pavement Design for Design Life Greater than 20 Years.”
 - “The following enhancements shall be incorporated into all flexible pavements designed using the empirical method with a design life greater than twenty years:”
 - “Use RHMA-G (0.15 to 0.20 foot) or a PG-PM binder (minimum 0.20 foot) at the top of the surface layer. The rubberized or polymer modified HMA must be substituted on an equal thickness basis.”

In 2017, Caltrans updated the 2015 *Revised Standard Specifications* and in 2018 incorporated the updates into Caltrans' 2018 *Standard Specifications*, including crumb rubber modifier reporting requirements where contractors work with resident engineers to document, report, and verify the weight, in pounds, of crumb rubber modifier used in contracted projects each month. Caltrans updated the *Caltrans Construction Manual* in 2018 to reflect crumb rubber modifier reporting requirement changes.

Caltrans' Division of Design is reviewing all asphalt pavement projects to determine the amount of asphalt containing crumb rubber used during a 3-year period to enable prediction of future use before project construction.

Asphalt pavement guidelines, such as the *Highway Design Manual*, were updated in 2017 to allow use of conventional asphalt by exception only. During construction, exceptions to using asphalt containing crumb rubber may be considered to accommodate factors such as the availability of asphalt concrete, constructability, environmental factors, and cost. Exceptions to allow for use of conventional hot mix asphalt are allowed in the following situations:

- When crumb rubber modifier project quantities are below 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.

In addition, Caltrans is exploring requiring the incorporation of small amounts of crumb rubber modifier in asphalt binders to be used in all highway asphalt paving materials.

COST COMPARISON ANALYSIS

The cost comparison analysis in calendar year 2018 was segregated by the four major pavement project categories: pavement preservation(maintenance), rehabilitation, capital preventive maintenance, and new capacity/safety/temporary detours (such as lane additions; new road alignments; and safety and landscape projects).

Caltrans' Division of Construction's Contract Administration System's Progress Payment Database was used to obtain the costs of various pavement projects and the total tonnage of materials.

The cost comparisons in this report were made based on the following factors:

1. Cost per metric ton for asphalt material was calculated based on the tonnage and bid item cost.
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 from the State Highway Operation and Protection Program (SHOPP).
 - Capital Preventive Maintenance strategies are thinner than rehabilitation strategies and are usually double the thickness of pavement preservation (maintenance) treatments funded from the SHOPP.
 - New Capacity/Safety/Temporary Detours. All other program projects not listed in the above categories (such as safety, landscape, the State Transportation Improvement Program, and protective betterment projects).

These first two methods were necessary because Caltrans has many different types of projects, such as roadway rehabilitation, roadside, safety, and drainage, which contain small amounts of asphalt that would make a cost-per-metric-ton analysis meaningless. For an accurate cost comparison between asphalt containing crumb rubber and conventional asphalt, we need to compare similar project categories.

3. The life spans of rehabilitation strategies with asphalt containing crumb rubber and of conventional asphalt were considered the same, for this analysis. Caltrans has initiated studies to evaluate the life span and maintenance costs of rubberized hot mix asphalt versus regular hot mix asphalt.

Caltrans has completed data collection from three annual pavement condition surveys of the State Highway System. The data collected can

be analyzed under the process being developed to predict the life span and duration of asphalt materials, as required by Public Resources Code section 42073(c)(1)(A).

Caltrans anticipates having results of the analysis in 2021.

The asphalt life span was assumed to be three years to five years for pavement preservation (maintenance) projects, ten years for rehabilitation projects, five years to seven years for capital preventive maintenance projects, and twenty years for new construction projects.

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

This estimate 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. This makes accurate calculation of maintenance cost differences for the two types of paving materials difficult. Consequently, maintenance costs were not included in the analysis and were assumed the same for asphalt containing crumb rubber and conventional asphalt.

Caltrans used progress payment data from the Division of Construction's Contract Administration System in this cost comparison analysis. The results shown in Table 4 (Page 10) are segregated by the four major pavement project categories.

TABLE 4				
2018 COST COMPARISON IN DOLLARS PER METRIC TON				
Type of Asphalt	Pavement Preservation (Maintenance)	Rehabilitation	Capital Preventive Maintenance	New Capacity/ Safety/ Temporary Detours
Asphalt containing crumb rubber	\$112.32	\$81.15	\$98.56	\$100.16
Conventional asphalt	\$104.15	\$74.94	\$91.91	\$104.60
Cost Difference (Line 1 – Line 2)	\$8.17	\$6.21	\$6.65	-\$4.44
Cost Difference (Percentage)	7.8%	8.3%	7.2%	-4.2%

For pavement preservation (maintenance), rehabilitation and capital preventive maintenance project, the initial cost of asphalt containing crumb rubber was more than the cost of conventional asphalt, but it was less for new capacity/safety/temporary detours projects.

- Pavement preservation (maintenance) projects had a cost difference of \$8.17 between the two types of asphalt, about 7.8 percent more for the cost of asphalt containing crumb rubber.
- Rehabilitation projects had a cost difference of \$6.21 between the two types of asphalt, about 8.3 percent more for the cost of asphalt containing crumb rubber.
- Capital preventive maintenance projects had a cost difference of \$6.65 between the two types of asphalt, about 7.2 percent more for the cost of asphalt containing crumb rubber.
- New capacity/safety/temporary detours projects had a cost difference of \$4.44 between the two types of asphalt, about 4.2 percent less for the cost of asphalt containing crumb rubber.

While asphalt pavement containing crumb rubber does initially cost more per metric ton than conventional asphalt pavement for three project categories, research has shown that asphalt pavement containing crumb

rubber overlays is cost-effective when used to resist reflective cracking.¹ A University of California Pavement Research Center report completed for Caltrans in 2007 indicated that when used as thin overlays on cracked pavement, asphalt mixes containing rubber at half the thickness of conventional pavement performed better with respect to reflective cracking than the full-thickness conventional mix.²

The same study showed test results indicating that some modified binder mixes (regardless of half or full thickness) have a greater risk of rutting under slow, heavy loads and hot conditions compared with the full-thickness conventional overlay.³

Caltrans will continue to use sound engineering judgment to determine when and where asphalt containing crumb rubber is used.

¹ David Jones, John Harvey, and Carl Monismith, "Reflective Cracking Study: Summary Report" (UCPRC-SR-2007-01), University of California Pavement Research Center, December 2007, pp 62.

² Ibid.

³ Ibid, p. 63.

FINDINGS

In calendar year 2018:

1. Caltrans used an average of 16.38 pounds of crumb rubber modifier per metric ton of total asphalt paving materials, exceeding the Public Resources Code section 42703(a)(3) requirement of 11.58 pounds of crumb rubber modifier per metric ton of total asphalt paving material used. Caltrans' use of asphalt containing crumb rubber was more than 46 percent of the total paving asphalt used.
2. Caltrans used rubberized asphalt concrete exclusively to comply with the requirements of Public Resources Code section 42703(b)(3).
3. The initial cost per metric ton of asphalt containing crumb rubber varies between 4.2 percent less and 8.3 percent more than the cost of conventional asphalt, depending on the project category. Research has shown that asphalt pavement containing crumb rubber overlays are cost-effective when used to resist reflective cracking.
4. Caltrans' estimates using asphalt containing crumb rubber diverted more than 5.5 million waste tires from landfills and tire stockpiles during calendar year 2018, more than the 4.5 million waste tires diverted in calendar year 2017. Information about additional waste tire applications used by Caltrans is available on the Internet at <http://website.dot.ca.gov/design/bill/sb876.html>.
5. Caltrans' Division of Design is reviewing all asphalt pavement projects to determine the amount of asphalt containing crumb rubber used during a 3-year period so such usage can be predicted before project construction. Asphalt pavement guidelines were updated in 2017 to allow the use of conventional asphalt by exception only. During construction, exceptions to using asphalt containing crumb rubber may be considered to accommodate items such as the availability of asphalt concrete, constructability, environmental factors, and cost.
6. Caltrans will continue to use sound engineering judgment to determine when and where asphalt containing crumb rubber is used.

APPENDIX

PUBLIC RESOURCES CODE SECTION 42703

DIVISION 30. WASTE MANAGEMENT [40000–49620]

(Division 30 added by Stats. 1989, Ch. 1096, Sec. 2.)

PART 3. STATE PROGRAMS [42000–42999]

(Part 3 added by Stats. 1989, Ch. 1096, Sec. 2.)

CHAPTER 14. Paving Materials [42700–42705]

(Chapter 14 added by Stats. 1990, Ch. 35, Sec. 22.)

ARTICLE 1. Recycled Materials [42700–42704.5]

(Article 1 heading added by Stats. 1995, Ch. 605, Sec. 2.)

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 the Transportation Agency 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 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.

(Amended by Stats. 2018, Ch. 198, Sec. 1. (AB 3246) Effective January 1, 2019.)