



2019 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, et seq., requires the California Department of Transportation (Caltrans) to meet specified usage amounts of crumb rubber modifier in asphalt pavement. The law also requires the Secretary of the California State Transportation Agency (CalSTA) 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 2019, diverting an estimated 4.2 million waste tires from landfills and tire stockpiles. The crumb rubber modifier usage requirements involved four major pavement project categories: pavement preservation (maintenance), rehabilitation, capital preventive maintenance, and new capacity/safety/temporary detours.

Caltrans used an average of 14.02 pounds of crumb rubber modifier per metric ton of all asphalt pavement. This exceeded the statutory minimum requirement of 11.58 pounds of crumb rubber modifier per metric ton of the total asphalt paving materials used beginning January 1, 2013.

Public Resources Code Section 42703(c)(1)(C) requires the CalSTA Secretary to prepare an analysis comparing the cost differential between asphalt with crumb rubber and conventional asphalt. To meet this requirement, Caltrans uses an existing departmental process for determining life-cycle costs for various pavement treatments that incorporates data from the annual Automated Pavement Condition Survey. Caltrans anticipates having the results of this analysis in 2021.

The cost per metric ton of asphalt paving material containing crumb rubber was \$17.18 more, or 17.3 percent higher, than the cost of conventional asphalt overall for all project categories. For pavement preservation (maintenance) projects, the cost of asphalt containing crumb rubber was 8.2 percent more than the cost of conventional asphalt; for rehabilitation projects it was 20.2 percent higher; for capital preventive maintenance it was 4.2 percent more; and for new capacity/safety/temporary detour projects it was 16.4 percent higher.

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 Caltrans uses in paving projects.

Public Resources Code Sections 42703 and 42801.7, give the terms “crumb rubber” and “crumb rubber modifier” the same meaning: rubber granules derived from a waste tire that are less than or equal to one-quarter inch or six millimeters in size. This report will follow this practice.

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 percent 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 asphalt binder in the asphalt paving material depends on the application, as follows:
 - a. Gap-graded rubberized hot-mix asphalt contains 7.5 percent 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 percent 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 percent 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.

Using the above data, Caltrans calculated that rubberized hot mix asphalt had to account for 35 percent of the total asphalt paving materials Caltrans placed in calendar year 2019. Caltrans used this 35 percent target (see Table 1, page 2) as the factor for 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 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 crumb rubber modifier 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 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 pounds of crumb rubber modifier per metric ton is met (<i>Rounded 32.8 percent up to 35 percent</i>)	35%

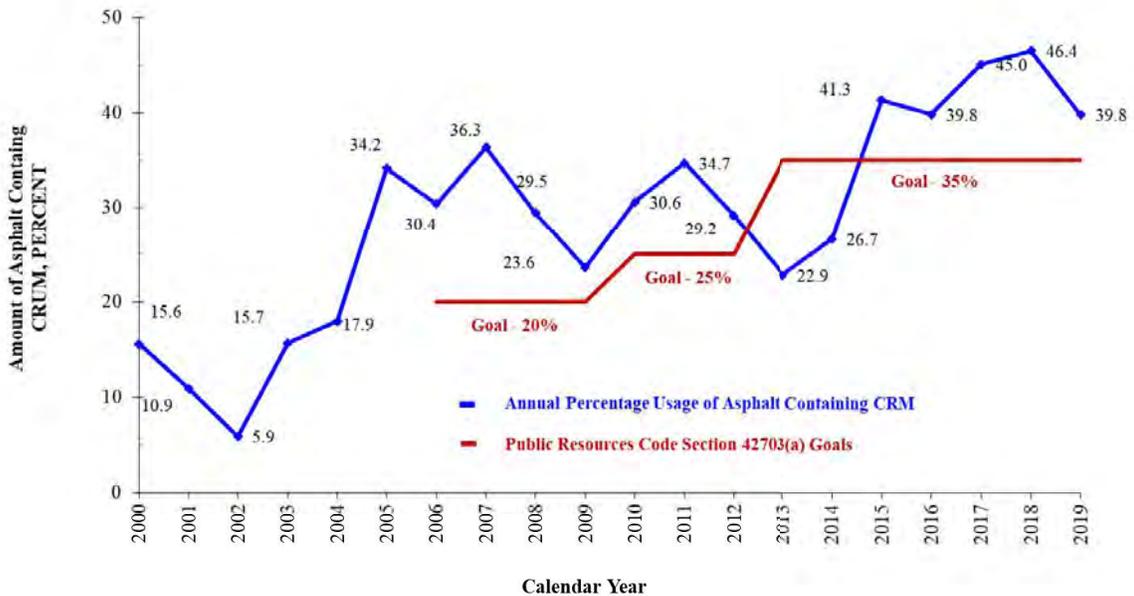
Results of the crumb rubber usage analysis are shown in Table 2 (page 3) and in the chart (page 3). Data for this analysis were compiled from 421 construction paving projects in calendar year 2019.

Table 2. 2019 Crumb Rubber Usage

Quantity of Asphalt Placed

Total Asphalt	3,860,363 metric tons
Conventional Asphalt	2,325,696 metric tons
Asphalt Containing Crumb Rubber	1,534,667 metric tons
Percent of Asphalt Containing Crumb Rubber to Total Asphalt Paving	39.75%
Crumb Rubber Placed (Average Pounds)	54,133,231
Pounds of crumb rubber modifier Per Metric Ton of Total Asphalt Placed (Calculated)	14.02 pounds

CHART 1. PERCENT OF ASPHALT CONTAINING CRUMB RUBBER MODIFIER USED BY CALTRANS



The following chart shows the percent of asphalt containing crumb rubber modifier Caltrans used each calendar year from 2000 to 2019 and demonstrates Caltrans' compliance with the requirements in Public Resources Code Section 42703(a). The statutory goal beginning in 2007, was 20 percent; in 2010, 25 percent; and since 2013, 35 percent.

CHART 2. PERCENT OF ASPHALT CONTAINING CRUMB RUBBER MODIFIER

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	2019: 39.8 percent
2006: 30.4 percent	2013: 22.9 percent	

Caltrans estimates asphalt containing crumb rubber diverted more than 4.2 million waste tires from landfills and tire stockpiles in 2019, 1.3 million fewer tires than in 2018. Of the approximate 3.86 million metric tons of paving asphalt Caltrans used in 2019, about 1.53 million metric tons contained crumb rubber, more than 39 percent of the total. Rubberized hot mix asphalt accounted for all the asphalt containing crumb rubber. Caltrans used an average of 54.13 million pounds of crumb rubber modifier in rubberized hot mix asphalt, or 14.02 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, page 8).

Table 3. Amount of Asphalt Placed In 2019 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)	1,279,172	559,622	719,551	56.25
Rehabilitation	935,189	763,371	171,817	18.37
Capital preventative maintenance	805,770	357,001	448,769	55.69
New capacity/safety/temporary detours	840,232	645,702	194,530	23.15
TOTAL	3,860,363	2,325,696	1,534,667	39.75

Caltrans' total usage of asphalt containing crumb rubber modifier met statutory requirements, but declined from 2.01 million metric tons in 2018 to 1.53 million metric tons in 2019, a reduction of more than 23 percent. This decline was primarily due to reduced usage of asphalt containing crumb rubber modifier in the following three pavement project categories: pavement preservation (maintenance), which declined by more than 0.33 million metric ton; capital preventive maintenance, which declined by more than 0.2 million metric ton; and rehabilitation, which declined by more than 0.06 million metric ton.

In 2019, a greater percentage of total asphalt was placed on new capacity, safety, temporary, and detour projects as compared to 2018. In many cases, these types of projects require deeper hot mix asphalt lifts than the other types of projects, which contain less rubber because the lower layers cannot be rubberized, due to material constraints. This results in a lower overall percentage of crumb rubber usage from these types of projects compared to the other types of projects.

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 statute's usage requirement. In calendar year 2019, Caltrans used only rubberized hot mix asphalt to meet statutory minimums.

POLICIES AND GUIDELINES

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

- Index 631.3: "Gap graded HMA 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): "The following [(d)] enhancements shall be incorporated into all flexible pavements designed using the empirical method with a design life greater than twenty years:"
- Index 633.1(3)(d): "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."

Caltrans updated the 2015 *Revised Standard Specifications* in 2017, 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 also updated the *Caltrans Construction Manual* in 2018 to reflect crumb rubber modifier reporting requirement changes.

Caltrans is reviewing all asphalt pavement projects in the planning and design phases to determine the amount of asphalt containing crumb rubber used during a 3-year period to enable estimation of future use before project construction.

Caltrans' asphalt pavement guidelines, such as the *Highway Design Manual*, were updated in 2017, to allow use of conventional asphalt by exception only, and in 2020, to include the stormwater treatment Best Management Practices for National Pollutant Discharge Elimination System compliance. Exceptions to using asphalt containing crumb rubber may be considered during construction to accommodate factors such as the availability of asphalt concrete, constructability, environmental factors, and cost. Exceptions 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 ambient air 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.
- When crumb rubber is not suitable due to environmental factors, such as a stormwater treatment Best Management Practices for National Pollutant Discharge Elimination System compliance.

COST COMPARISON ANALYSIS

The cost comparison analysis in calendar year 2019 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' 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 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 1-inch minimum thickness under the maintenance preservation program.
 - Rehabilitation. Pavement rehabilitation projects funded from the State Highway Operation and Protection Program.
 - Capital Preventive Maintenance. Pavement thinner than rehabilitation strategies, and usually double the thickness of pavement preservation (maintenance) treatments, funded from the State Highway Operation and Protection Program.
 - 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, comparisons must comprise 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 uses an existing departmental process for determining life-cycle costs for various pavement treatments that incorporates data from the annual Automated Pavement Condition Survey. Caltrans anticipates having results of this 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 20 years for new construction projects.

4. Maintenance costs for asphalt containing crumb rubber and conventional asphalt were considered to be equal 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 for projects in this cost comparison analysis. The results shown in Table 4 (below) are segregated by the four major pavement project categories.

Table 4. 2019 Cost Comparison in Dollars Per Metric Ton					
Type of Asphalt	Pavement Preservation (Maintenance)	Rehabilitation	Capital Preventive Maintenance	New Capacity/ Safety/ Temporary Detours	All Project Categories
Asphalt paving material containing crumb rubber	\$121.16	\$97.95	\$113.78	\$120.11	\$116.27
Conventional asphalt paving material	\$111.94	\$81.47	\$109.20	\$103.19	\$99.09
Cost Difference (Line 1 – Line 2)	\$9.22	\$16.48	\$4.58	\$16.92	\$17.18
Cost Difference (Percentage)	8.2%	20.2%	4.2%	16.4%	17.3%

The cost of asphalt containing crumb rubber per metric ton was \$17.18 more, or 17.3 percent, than the cost of conventional asphalt for all pavement project categories combined. The cost of asphalt containing crumb rubber was more than the cost of conventional asphalt in each individual pavement project category.

- Pavement preservation (maintenance) projects had a cost difference of \$9.22 between the two types of asphalt, about 8.2 percent more for the cost of asphalt containing crumb rubber.
- Rehabilitation projects had a cost difference of \$16.48 between the two types of asphalt, about 20.2 percent more for the cost of asphalt containing crumb rubber.
- Capital preventive maintenance projects had a cost difference of \$4.58 between the two types of asphalt, about 4.2 percent more for the cost of asphalt containing crumb rubber.
- New capacity/safety/temporary detours projects had a cost difference of \$16.92 between the two types of asphalt, about 16.4 percent more for the cost of asphalt containing crumb rubber.

Although these data show that asphalt pavement containing crumb rubber initially costs more per metric ton than conventional asphalt pavement for all project categories, research undertaken in 2007 for Caltrans by the University of California Pavement Research Center, and compiled in the "Reflective Cracking Study: Summary Report," concluded that asphalt pavement containing crumb rubber overlays is cost-effective when used to resist reflective cracking. This research found 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.

Caltrans initiated this research to determine lifetime performance and maintenance costs for rubberized hot mix asphalt versus application-comparable hot mix asphalt. The research also found that some modified binder mixes (regardless of half or full thickness) have an increased risk of rutting under slow, heavy loads and hot conditions, compared with the full-thickness conventional overlay. Caltrans will continue to use sound engineering judgment to determine when and where asphalt containing crumb rubber is used.

FINDINGS

In calendar year 2019:

1. Caltrans used an average of 14.02 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 39 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 more and 20.2 percent higher 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 4.2 million waste tires from landfills and tire stockpiles during calendar year 2019, less than the 5.5 million waste tires diverted in calendar year 2018. Information about additional waste tire applications used by Caltrans is available on the Internet at <https://dot.ca.gov/programs/maintenance/pavement/pavement-programming>.
5. Caltrans is reviewing all asphalt pavement projects in the planning and design phases to determine the amount of asphalt containing crumb rubber used during a 3-year period, so such usage can be estimated 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.

APPENDIX

PUBLIC RESOURCES CODE SECTION 42703

DIVISION 30. WASTE MANAGEMENT [40000–49620]

PART 3. STATE PROGRAMS [42000–42999]

CHAPTER 14. Paving Materials [42700–42705]

ARTICLE 1. Recycled Materials [42700–42704.5]

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 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 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.