



2017 CRUMB RUBBER REPORT

Cost Differential Analysis Between Asphalt Containing Crumb Rubber and Conventional Asphalt

Public Resources Code Section 42703

Prepared by



July 2019

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SUMMARY

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. Caltrans met required usage amounts in calendar year 2017, and Caltrans' projects that used asphalt containing crumb rubber diverted more than 4.5 million waste tires from landfills and tire stockpiles.

This report addresses section 42703(a)(3), 42703(b)(3), 42703(c)(1)(C), and 42703(c)(2); see Appendix for the full text of section 42703. The four major pavement project categories used in the analysis for this report were pavement preservation (maintenance), rehabilitation, capital preventive maintenance (CAPM), and new capacity/safety/temporary detours.

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 amount of asphalt paving materials used. This amount is a calculated target of 35 percent. Of the approximate 3.68 million metric tons of paving asphalt Caltrans used in 2017, crumb rubber was contained in about 1.66 million metric tons, more than 45 percent of the total. All of the asphalt containing crumb rubber was rubberized asphalt concrete. Caltrans used an average of 58.46 million pounds of CRM in rubberized asphalt concrete, or 15.88 pounds of CRM per metric ton. (See table 1 and the chart on page 2.)

Public Resources Code section 42703(b)(3) allows that on and after January 1, 2015, Caltrans may use any material meeting the definition of asphalt containing crumb rubber, with respect to product type or specification, to comply with section requirements. In calendar year 2017, Caltrans used only rubberized asphalt concrete to comply with requirements and for this analysis.

Caltrans is still in the process of collecting data from three annual pavement condition surveys of asphalt concrete and rubberized asphalt concrete to calculate and determine the life span and duration of asphalt concrete, as required by section 42073(c)(1)(A). The third annual pavement condition survey data was collected in 2018. The results of

these surveys will be analyzed and reported in the 2018 Crumb Rubber Report, due January 1, 2020.

In order to perform the analysis required by 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 varied for specific project categories. For pavement preservation projects, the initial cost of asphalt containing crumb rubber was 6.6 percent less than the cost of conventional asphalt; for rehabilitation projects, 10.8 percent more; for CAPM, 0.8 percent less; and for new capacity/safety/temporary detour projects, 13.7 percent more. (See table 3 on page 7.)

In 2017 Caltrans updated the 2015 *Revised Standard Specifications* and in 2018 incorporated them into the 2018 *Standard Specifications*, including CRM reporting requirements where contractors work with resident engineers to document and report on the weight, in pounds, of CRM used in contracts. The *Construction Manual* was updated in 2018 to reflect these CRM reporting requirement changes. In addition, Caltrans is exploring whether to require the incorporation of small amounts of CRM in asphalt binders to be used in all highway asphalt paving materials.

A 2007 report by the University of California Pavement Research Center indicates 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 shall be placed.

CRUMB RUBBER USAGE ANALYSIS

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 amount of asphalt paving materials used.

Caltrans' Division of Construction Contract Administration System Progress Payment Database provided the pavement project costs and the total tonnage placed of asphalt containing crumb rubber and conventional asphalt during calendar year 2017. 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:
 - a. 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.
 - b. 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.
 - c. 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 section 42703(a)(3), the target for calendar year 2017 of 35 percent was calculated based on Caltrans' use of CRM per metric ton of the total amount of asphalt paving materials used and the annual average mandate of 11.58 pounds for 2013 and beyond.

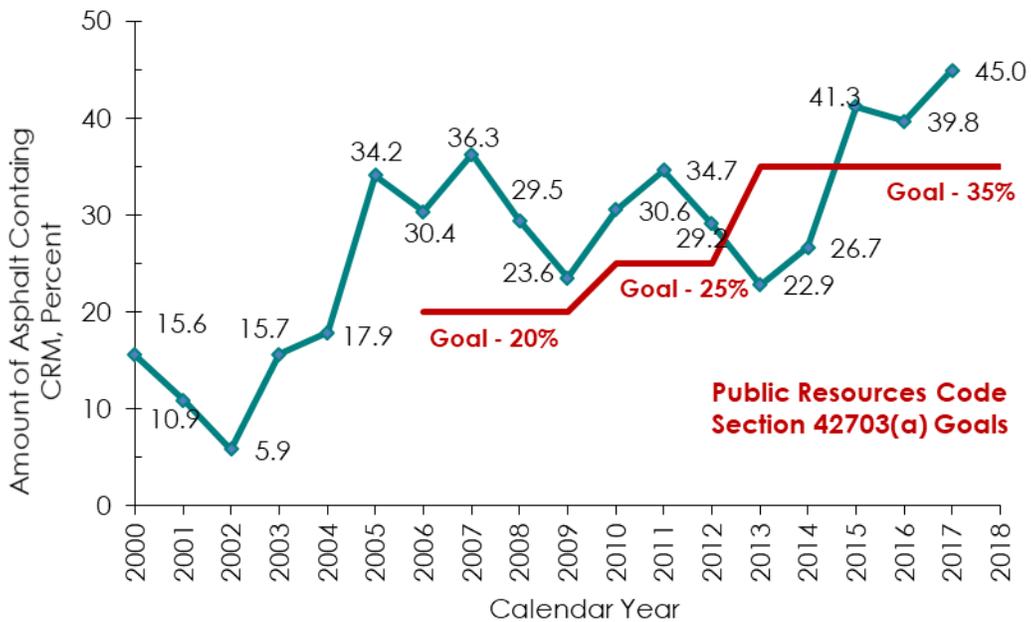
Results of the crumb rubber usage analysis are shown in table 1 and in the chart below. Data compiled for this analysis was based on 437 projects in construction with paving in calendar year 2017.

Table 1. 2017 CRUMB RUBBER USAGE

Quantity of Asphalt Placed

Total Asphalt	3,680,478 metric tons
Conventional Asphalt	2,023,236 metric tons
Asphalt Containing Crumb Rubber	1,657,242 metric tons
Percent of Asphalt Containing Crumb Rubber to Total Asphalt Paving	45.03%
Crumb Rubber Placed (Average Pounds)	58,456,877
Pounds of CRM Per Metric Ton of Total Asphalt Placed (Calculated) ...	15.88 pounds

PERCENT OF ASPHALT CONTAINING CRM USED BY CALTRANS



This chart shows the percent of asphalt containing CRM Caltrans used in each calendar year from 2000 to 2017 and the Public Resources Code section 42703(a) mandated goals beginning in 2007, 2010, and 2013. The mandated goal beginning in 2007 was 20 percent; beginning in 2010, 25 percent; and beginning in 2013, 35 percent.

The percent of asphalt containing CRM Caltrans used in each calendar year is as follows:

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

In 2017 Caltrans projects using asphalt containing crumb rubber diverted more than 4.5 million waste tires from landfills and tire stockpiles. Of the approximate 3.68 million metric tons of paving asphalt Caltrans used in 2017, crumb rubber was contained in about 1.66 million metric tons, more than 45 percent of the total. All of the asphalt containing crumb rubber was rubberized asphalt concrete. Caltrans used an average of 58.46 million pounds of CRM in rubberized asphalt concrete, or 15.88 pounds of CRM per metric ton.

Table 2 lists CRM usage per metric ton for asphalt containing CRM versus conventional asphalt. The data is listed for the four major pavement project categories used in the analysis for this report: pavement preservation (maintenance), rehabilitation, CAPM, and new capacity/safety/temporary detours. Descriptions of these categories can be found in this report under Cost Comparison Analysis.

TABLE 2 2017 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)	869,715	351,711	518,004	59.56
Rehabilitation	454,880	386,557	68,323	15.02
CAPM	1,098,245	290,062	808,183	73.59
New capacity/safety/temporary detours	1,257,637	994,906	262,731	20.89
TOTAL	3,680,477	2,023,236	1,657,241	45.03

The total percent of asphalt containing CRM increased from 39.8 percent in 2016 to more than 45 percent in 2017. This overall increase is primarily due to increased amounts of asphalt containing CRM used in three major pavement project categories: usage in pavement preservation (maintenance) increased more than 10 percent; in CAPM, more than 14 percent; and in new capacity/safety/temporary detours, more than 12 percent. Use of asphalt containing CRM decreased more than 18 percent in the rehabilitation category.

In 2016 Caltrans placed more than 4.34 million metric tons of asphalt throughout the state; in 2017, 3.68 million metric tons. Because of this decrease in the total amount of asphalt used, in 2017 the number of tires diverted from landfills and tire stockpiles decreased by 0.2 million from 2016.

Public Resources Code section 42703(b)(3) allows that on and after January 1, 2015, Caltrans may use any material meeting the definition of asphalt containing crumb rubber, with respect to product type or specification, to comply with section requirements. In calendar year 2017, Caltrans used only rubberized asphalt concrete to comply with requirements and for this analysis.

POLICIES AND GUIDELINES

In 2017 Caltrans updated the 2015 *Revised Standard Specifications* and in 2018 incorporated them into the 2018 *Standard Specifications*, including CRM reporting requirements where contractors work with resident engineers to document, report, and verify the weight, in pounds, of CRM used in contracted projects each month. The *Construction Manual* was updated in 2018 to reflect CRM 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 three-year period so such usage can be predicted before project construction. These projections may become part of this report in the future.

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 items such 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.

In addition, Caltrans is exploring whether to require the incorporation of small amounts of CRM in asphalt binders to be used in all highway asphalt paving materials.

COST COMPARISON ANALYSIS

The cost comparison analysis for calendar year 2017 was segregated by the four major pavement project categories: pavement preservation (maintenance), rehabilitation, CAPM, 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 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 from 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/Temporary Detours. All other program projects not listed in the above categories (such as safety, landscape, State Transportation Improvement Program, and protective betterment projects).

These first two assumptions 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. Similar types of strategies need to be compared for an accurate cost

comparison between asphalt containing crumb rubber and conventional asphalt.

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

This third assumption was necessary because pavement life span data, which can be used to predict pavement life cycles, is still under development in Caltrans' Pavement Management System. Caltrans anticipates refining these pavement life cycles in 2019. 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, after Caltrans completes data collection from three annual pavement condition surveys of the State Highway System, 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). The results of these surveys will be analyzed and reported in the 2018 Crumb Rubber Report, due January 1, 2020.

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

This fourth 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 2017 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/Temporary Detours
Asphalt containing crumb rubber	\$103.33	\$86.51	\$89.88	\$90.48
Conventional asphalt	\$110.59	\$78.08	\$90.63	\$79.56

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

- Pavement preservation (maintenance) projects had a cost difference of \$7.26 between the two types of asphalt, about 6.6 percent less for the cost of asphalt containing crumb rubber.
- Rehabilitation projects had a cost difference of \$8.43 between the two types of asphalt, about 10.8 percent more for the cost of asphalt containing crumb rubber.
- CAPM projects had a cost difference of \$0.75 between the two types of asphalt, about 0.8 percent less for the cost of asphalt containing crumb rubber.
- New capacity/safety/temporary detours projects had a cost difference of \$10.92 between the two types of asphalt, about 13.7 percent more 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 two 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 indicates 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 shows 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 shall be placed.

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 2017:

1. Caltrans used an average of 15.88 pounds of CRM per metric ton of total asphalt paving materials, exceeding 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' use of asphalt containing crumb rubber was more than 45 percent of the total paving asphalt used.
2. Caltrans used rubberized asphalt concrete exclusively to comply with the requirements of section 42703(b)(3).
3. The initial cost per metric ton of asphalt containing crumb rubber varies between 6.6 percent less and 13.7 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' projects using asphalt containing crumb rubber diverted more than 4.5 million waste tires from landfills and tire stockpiles during calendar year 2017, less than the 4.7 million waste tires diverted in calendar year 2016. Information about additional waste tire applications used by Caltrans is available on the Internet at <http://www.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 three-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 shall be placed.

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 [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 [sic] 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.)