



2020 CRUMB RUBBER REPORT

Cost Differential Analysis Between Asphalt Containing Crumb Rubber and Conventional Asphalt

Public Resources Code Section 42703

Prepared by



2021

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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 2020, diverting an estimated 3.8 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 14.57 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. This report compares initial bid item costs per tonnage between asphalt with crumb rubber and conventional asphalt to meet the requirement. Caltrans is completing a study to compare the performance and life expectancy between rubberized asphalt and conventional asphalt pavements. The 2021 Crumb Rubber Report will utilize the findings of the study in the life cycle cost differential analysis.

Based on 2020 project data, the average cost per metric ton of asphalt paving material containing crumb rubber was \$7.85 more, or 7.42 percent higher than the average cost of conventional asphalt. For pavement preservation (maintenance) projects, the cost of asphalt containing crumb rubber was 9.86 percent lower than the cost of conventional asphalt; for rehabilitation projects it was 14.33 percent higher; for capital preventive maintenance it was 11.75 percent higher; and for new capacity/safety/temporary detour projects it was 1.09 percent lower.

CRUMB RUBBER USAGE ANALYSIS

Results of the statewide crumb rubber usage are shown in Table 1 (page 1) below. Data for this analysis were compiled from 443 construction paving projects in calendar year 2020. Charts 1 and 2 (page 1 and 2) show the percent of asphalt containing crumb rubber modifier Caltrans used each calendar year from 2000 to 2020

Table 1. 2020 Crumb Rubber Usage

Quantity of Asphalt Placed

Total Asphalt	3,405,088 metric tons
Conventional Asphalt	1,998,613 metric tons
Asphalt Containing Crumb Rubber	1,406,475 metric tons
Percent of Asphalt Containing Crumb Rubber to Total Asphalt Paving	41.31%
Crumb Rubber Placed (Average Pounds)	49,611,420
Pounds of crumb rubber modifier Per Metric Ton of Total Asphalt Placed (Calculated)	14.57 pounds

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

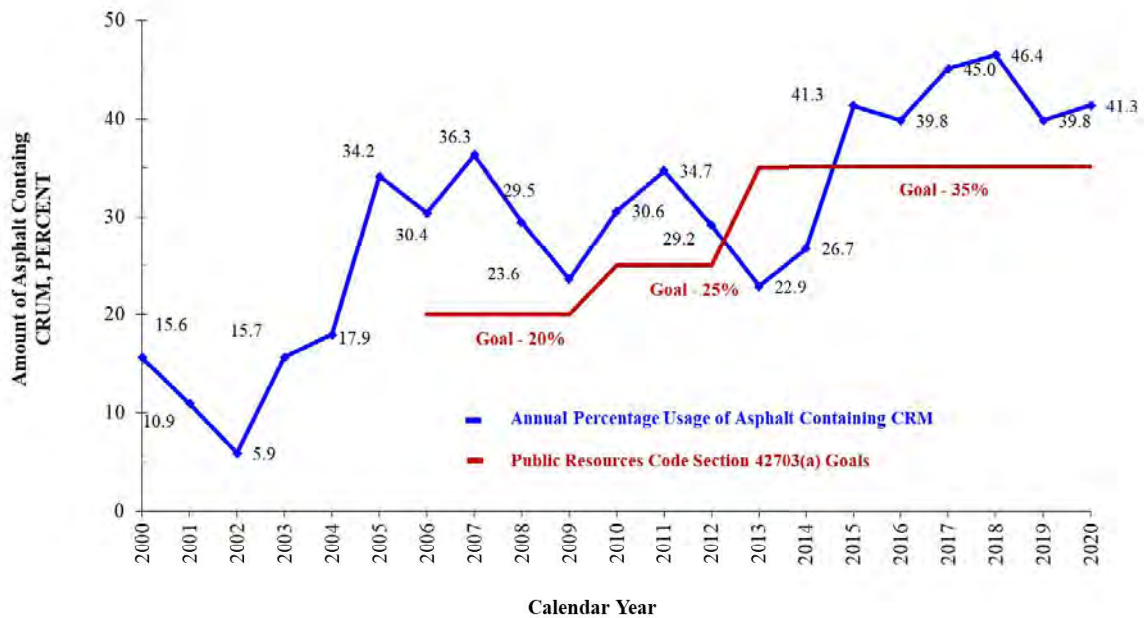


CHART 2. PERCENT OF ASPHALT CONTAINING CRUMB RUBBER MODIFIER

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	2020: 41.3 percent

The above 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.

Caltrans estimates that asphalt containing crumb rubber diverted more than 3.8 million waste tires from landfills and tire stockpiles in 2020. Of the approximate 3.41 million metric tons of paving asphalt Caltrans used in 2020, about 1.41 million metric tons contained crumb rubber, more than 41 percent of the total. Caltrans used an average of 49.61 million pounds of crumb rubber modifier in rubberized hot mix asphalt, or 14.57 pounds per metric ton.

Table 2 (page 3) lists the breakdown of asphalt containing crumb rubber modifier usage in 2020 for the four major pavement project categories: pavement preservation (maintenance), rehabilitation, capital preventive maintenance, and new capacity/safety/temporary detours. (Descriptions of these categories can be found under Cost Comparison Analysis, page 4).

Table 2. Amount of Asphalt Placed In 2020 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)	660,621.38	311,509.39	349,111.99	52.85
Rehabilitation	895,847.39	679,687.54	216,159.86	24.13
Capital preventative maintenance	1,245,715.29	506,897.59	738,817.70	59.31
New capacity/safety/temporary detours	602,903.55	500,518.56	102,384.99	16.98
TOTAL	3,405,087.61	1,998,613.08	1,406,474.54	41.31

Caltrans' total usage of asphalt containing crumb rubber modifier met statutory requirements in 2020. The amount of crumb rubber usage per metric ton of asphalt placed increased from 2019 to 2020, however the total asphalt containing rubber declined from 1.53 million metric tons in 2019 to 1.41 million metric tons in 2020. This decline was due to a reduced total asphalt usage in 2020 than 2019 which in turn also resulted in the reduced usage of asphalt containing crumb rubber modifier.

Rubber usage for the following two pavement project categories: pavement preservation (maintenance), declined by more than 0.37 million metric ton; and new capacity/safety/temporary detours, declined by more than 0.09 million metric ton. On the other hand, there was an increase in rubber usage in two pavement projects categories: rehabilitation projects, which increased by more than 0.04 million metric ton; and capital preventative maintenance projects, which increased by more than 0.29 million metric ton. A greater percentage of total rubberized asphalt was placed on these two pavement projects categories: rehabilitation and capital preventative maintenance projects which led to the overall increase in percentage from 39.75 percent in 2019 to 41.3 percent in 2020. It also resulted in the number of pounds of

crumb rubber modifier per metric ton of total asphalt usage to increase from 14.02 pounds in 2019 to 14.57 pounds in 2020.

COST COMPARISON ANALYSIS

The cost comparison analysis in calendar year 2020 was segregated by 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 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 major categories of projects that utilize asphalt containing crumb rubber:
 - 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).

- The life spans of rehabilitation strategies with asphalt containing crumb rubber and of conventional asphalt were considered the same for this analysis. Caltrans is completing a study to compare the performance and life expectancy between rubberized asphalt and conventional asphalt pavements. The 2021 Crumb Rubber Report will utilize the findings of the study in the life cycle cost differential analysis.

The asphalt life span was assumed to be three years to five years for pavement preservation (maintenance) projects, ten to twenty years for rehabilitation projects, five years to ten years for capital preventive maintenance projects, and 20 years for new construction projects.

- The maintenance strategies and treatments utilized for rubberized asphalt pavement and conventional asphalt are the same. Thus, the pavement maintenance costs for asphalt containing crumb rubber and conventional asphalt are estimated to be similar.

Caltrans used progress payment data for projects in its cost comparison analysis. The results shown in Table 3 (below) are segregated by the four major pavement project categories.

Table 3. 2020 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	\$106.22	\$104.42	\$119.62	\$115.41	\$113.65
Conventional asphalt paving material	\$117.84	\$91.33	\$107.04	\$116.69	\$105.80
Cost Difference (Line 1 – Line 2)	-\$11.62	\$13.09	\$12.58	-\$1.28	\$7.85
Cost Difference (Percentage)	-9.86%	14.33%	11.75%	-1.09%	7.42%

The cost of asphalt containing crumb rubber per metric ton was, on average, \$7.85 more, or 7.42 percent higher than the cost of conventional asphalt.

- Pavement preservation (maintenance) projects had a cost difference of \$11.62 between the two types of asphalt, about 9.86 percent more for the cost of conventional asphalt.
- Rehabilitation projects had a cost difference of \$13.09 between the two types of asphalt, about 14.33 percent more for the cost of asphalt containing crumb rubber.
- Capital preventive maintenance projects had a cost difference of \$12.58 between the two types of asphalt, about 11.75 percent more for the cost of asphalt containing crumb rubber.
- New capacity/safety/temporary detours projects had a cost difference of \$1.28 between the two types of asphalt, about 1.09 percent more for the cost of conventional asphalt.

Research undertaken in 2007 for Caltrans by the University of California Pavement Research Center, that was compiled in the "Reflective Cracking Study: Summary Report," concluded that asphalt pavement containing crumb rubber overlays can be 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 of conventional mix.

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 2020:

1. Caltrans used an average of 14.57 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 41 percent of the total paving asphalt used, an increase from 39 percent last year.
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 9.9 percent lower and 14.3 percent higher than the cost of conventional asphalt, depending on the project category. Research has shown that asphalt pavement containing crumb rubber overlays can be cost-effective when used to resist reflective cracking.
4. Caltrans' estimates using asphalt containing crumb rubber diverted more than 3.8 million waste tires from landfills and tire stockpiles during calendar year 2020. The total amount of asphalt placed throughout the state decreased in 2020, which resulted in a decline of total crumb rubber usage. 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 for using asphalt containing crumb rubber may be considered to accommodate items such as the availability of asphalt concrete, constructability, environmental factors, and cost.

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.

CRUMB RUBBER CALCULATION METHOD

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 is based on the following assumptions:

1. Rubberized hot-mix asphalt binder consists of 18 percent to 22 percent crumb rubber modifier; calculations in this report used 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 used 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 used 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 used 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 2020. Caltrans used this 35 percent target (see Table 4, page 10) as the factor for calculating, reporting, and monitoring crumb rubber modifier usage.

Table 4. 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>)	2,205 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%

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.