NonPoint Source Category – Asphalt Paving

Proposed Update of EPA Emission Estimation Method for 2014 NEI

# Purpose and Approach for Assessing Existing Method

The EPA's existing default method for estimating emissions from asphalt paving is based on an AP-42 process description, calculation parameters representative of process emission conditions in the early 1990's, and asphalt usage for 2008. That method results in annual county-level emission estimates for VOC and several HAPs (hazardous air pollutants) from the process of applying cutback and emulsified asphalt paving materials.

The existing method is assessed here and a modest update is proposed and to use for estimating emissions for the 2014 NEI. The minimal desired outcome is to have a method that EPA and agencies (S/L/T) can apply using updated and well-documented reference information - obtained at little or no ($) expense - for a technically reasonable approximation of annual county-level emissions for this category to use in the 2014 National Emissions Inventory (NEI).

The assessment was guided by these type of questions:

* How well does the existing method represent today’s operating conditions and technology for the processes that emit air pollutants?
* Different types of asphalt and the VOC and HAP (hazardous air pollutant) content
* Emissions conditions in or near year 2014
* Expected pollutants
* Seasonal and temporal variations
* Local conditions
* Can modest improvements be achieved in the short term, i.e., in 2-3 months, or is longer-term investigation and expertise needed?
* What are the expected benefits from modest method improvements?

The following activities were part of the method update process.

* Conduct NOMAD peer-review of proposed method update (Overview to NOMAD on Sept 16, 2015)
* Make contacts with industry to further investigate better process information
* Seek consensus to finalize method update
* Apply updated method to estimate 2014 NEI emissions within the current development schedule
* Notify NEI list serve or via EIS regarding the updated data available for the 2014 NEI

## Contents

### [Compare existing method and proposed updates](#_Toc428829848)

[*Existing EPA Default Method - Summary* 3](#_Toc428829849)

[Table 1a. Sources of Activity Data and Related Parameters – Existing Method 3](#_Toc428829850)

[Table 1b. Sources of Emission Factors, Related Parameters, and Emissions – Existing Method 4](#_Toc428829851)

[Table 1c. Existing Method - Source Category Codes (SCCs), Emission Factors, Expected Pollutants 4](#_Toc428829852)

[*Proposed Method Update - Summary* 5](#_Toc428829853)

[Table 2a. Sources of Activity Data and Related Parameters – Proposed Update 5](#_Toc428829854)

[Table 2b. Sources of Emission Factors, Related Parameters, and Emissions – Proposed Update 6](#_Toc428829855)

[Table 2c. Proposed Method Update - Source Category Codes (SCCs), Emission Factors, Expected Pollutants 6](#_Toc428829856)

[Activity Assessment 6](#_Toc428829857)

[Activity Distribution to County 9](#_Toc428829858)

[Assess Emission Factors 10](#_Toc428829859)

[Calculation for the existing cutback emission factor 10](#_Toc428829860)

[The existing emulsified emission factor 10](#_Toc428829861)

[Calculation for updated emission factors 11](#_Toc428829862)

[Compare emission factors - proposed vs existing 12](#_Toc428829863)

[Recommendations for the 2014 NEI 13](#_Toc428829864)

[*Apply updated emissions factors for cutback and emulsified paving* 13](#_Toc428829865)

[*Apply state-level 2008 activity used in existing method and updated technique to distribute to counties* 13](#_Toc428829866)

[*Develop county-level estimates, document and distribute for S/L/T review* 13](#_Toc428829867)

[*QA of state/local/tribal agencies’ NEI submissions to EIS* 14](#_Toc428829868)

[Additional steps for further improvement 14](#_Toc428829869)

[Pollutant emission summaries by state 15](#_Toc428829870)

[Compare emissions for cutback and emulsified paving - existing default method and the proposed update 15](#_Toc428829871)

[2011 NEI emissions comparison with proposed method update 17](#_Toc428829872)

[Asphalt Usage 19](#_Toc428829873)

[2008 Activity by State for cutback and emulsified used in the existing method 19](#_Toc428829874)

[2013 Estimated Hot-Mix and Warm-Mix Asphalt Paving Material by State, FHWA/NAPA Annual Survey 2009-2013 19](#_Toc428829875)

[APPENDICES 21](#_Toc428829876)

[Terms 21](#_Toc428829877)

[Descriptions of paving industry practices today 25](#_Toc428829878)

[List of possible contacts for more information 28](#_Toc428829879)

[MSDS information examples and summary 30](#_Toc428829880)

Reading first some Appendix sections can provide familiarity with industry practice descriptions and terminology.

# Compare existing method and proposed updates

## *Existing EPA Default Method - Summary*

### Table 1a. Sources of Activity Data and Related Parameters – Existing Method

Parameter = G (Given) or C (Computed)

|  |  |  |
| --- | --- | --- |
| **Activity – Existing Method** | | |
|  | **Parameter** | **Source Reference\_Use Note** |
| G | Quantity of asphalt used by state, by asphalt type – cutback, emulsified  Annual 2008 national tons | 2008 Asphalt Usage Survey, purchased from Asphalt Institute, www.asphaltinstitute.org  The state-level 2008 activity was used for the 2008 and the 2011 NEI. Tons.  This asphalt use is assumed to be for asphalt cement, rather than for asphalt concrete which is composed of both aggregate (~95% by wgt) and asphalt cement (~5%by wgt). |
| G | State-Level annual VMT | FHWA's *Highway Statistics 2007* report, http://www.fhwa.dot.gov/policyinformation/statistics/2007/ |
| C | State paved road VMT | Paved road VMT was calculated by subtracting the State/roadway class unpaved road VMT from total State/roadway class VMT. |
| C | State unpaved road VMT | The calculation of state unpaved road VMT is based on a multitude of interim calculation steps, numerous FHWA reports, and growth assumptions from a 1996 FHWA report no longer published. The documentation may be found in the estimation method description for the source category – unpaved roads, e.g., <roads\_unpaved\_2011.xlxs> located on ftp://ftp.epa.gov/EmisInventory/2011nei/doc/. |
| C | County-level annual VMT | The county-level total VMT by roadway class was previously developed by E.H. Pechan and Associates, Inc. to support the onroad national emissions inventory.  E.H. Pechan & Associates, Inc. “Documentation for the Onroad National Emission Inventory (NEI) for Base Years 1970 - 2002,” report prepared for U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, NC. January 2004.  ftp://ftp.epa.gov/EmisInventory/finalnei99ver3/haps/documentation/onroad/nei\_onroad\_jan04.pdf |
| C | County paved road VMT | State-level paved road VMT was spatially allocated to counties according to the fraction of total VMT in each county for the specific roadway class, see equation. |
| C | County-Level Asphalt Use | State-level usage data were allocated to county-level usage according to the fraction of paved road VMT in each county. |

### Table 1b. Sources of Emission Factors, Related Parameters, and Emissions – Existing Method

Parameter = G (Given) or C (Computed)

|  |  |  |
| --- | --- | --- |
| **Emission Factors / Emissions – Existing Method** | | |
|  | **Parameter** | **Source Reference\_Use Note** |
| G/C | Emission Factors VOC | EIIP, Volume 3, Chapter 17, p. 17.5-8, Asphalt Paving, January 2001  Cutback factor based on 1989 usage data from Asphalt Institute.  See specific factors in table below and equations in method discussion section.  Emulsified factor was developed for the Northeastern Illinois Planning Commission for use with 1982 Ozone SIP. |
| G | VOC / HAP speciation factors | Cutback VOC-to-HAP speciation factors were applied for the EPA’s 1999 NTI, and originated from CARB’s ‘Speciation Manual’ August 1991. |
| G | Asphalt consumption | 1989 cutback usage = 1 million barrels. 1989 solvent consumption used for cutback asphalt = 96 million pounds. Asphalt Institute. |
| G | Diluent (s) and Average pct in asphalt | Primary diluent indicated as ‘napthas’.  Average diluent content of 35 percent by volume. AP-42. |
| G | Density of diluent (s) | Naptha diluent density is not specifically noted in the reference text and is assumed  ~ 6.32 lb/gal, for naptha VMP.  (Naptha VMP density, http://www.industrialchemcorp.com/conversionchart.html) |
| G | Pct by wgt of volatile emitted in product | 95% of total solvent was assumed emitted; with 5% of total solvent assumed retained in the product, based on cutback RC. (http://www.epa.gov/ttn/chief/ap42/ch04/final/c4s05.pdf) |
| G | Density of asphalt | Density of asphalt assumed similar to that of water, 8.34 lbs/gal |
| G | Volume, barrel of asphalt | To convert tons of asphalt reported in the 2008 Asphalt Usage Survey to barrels, the density of asphalt was assumed similar to that of water, 8.34 lbs/gal, and that one barrel equals 42 gallons. |
| G | Weight, barrel of asphalt | One barrel of asphalt weighs approximately 350 pounds. |
| C | Barrels of asphalt | Barrel of Asphalt = (tons of asphalt \* 2000 lbs / 8.34 lbs/gal) / (42 gal/barrel) |
| C | Emissions | Emissions = County-Level Asphalt Usage \* Emission Factors |

### Table 1c. Existing Method - Source Category Codes (SCCs), Emission Factors, Expected Pollutants

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **SCC** | **Description** | **Pollutant** | **EIS Code** | **Emission Factor** | **Note** |
| 2461021000 | Cutback Asphalt,  Total: All Solvent Types | Volatile  Organic Compounds | VOC | 88.0 lbs/barrel |  |
|  |  | Ethyl Benzene | 100414 | 2.02 lbs/barrel | 2.3 pct wgt VOC |
|  |  | Toluene | 108883 | 5.63 lbs/barrel | 6.4 pct wgt VOC |
|  |  | Xylenes (Mixed Isomers) | 1330207 | 10.74 lbs/barrel | 12.2 pct wgt VOC |
| 2461022000 | Emulsified Asphalt,  Total: All Solvent Types | Volatile  Organic Compounds | VOC | 9.2 lbs/barrel |  |

Percent weight fractions are from VOC speciation profile applied for the EPA National Toxic Inventory, e.g., 1999.

|  |  |  |  |
| --- | --- | --- | --- |
| **SCC** | **Full Description** |  |  |
| 2461021000 | Solvent Utilization | Misc Non-industrial: Commercial, Cutback Asphalt | Total: All Solvent Types |
| 2461022000 | Solvent Utilization | Misc Non-industrial: Commercial, Emulsified Asphalt | Total: All Solvent Types |

*Proposed Method Update - Summary* (*This summary for Cutback applies also to Emulsified)*

### Table 2a. Sources of Activity Data and Related Parameters – Proposed Update

Parameter = G (Given) or C (Computed)

|  |  |  |
| --- | --- | --- |
| **Activity – Proposed Method Update** | | |
|  | **Parameter** | **Source Reference\_Use Note** |
| G | Quantity of asphalt used by state, by asphalt type – cutback, emulsified  Annual 2008 national tons | 2008 Asphalt Usage Survey, purchased from Asphalt Institute, www.asphaltinstitute.org  The state-level 2008 activity was used for the 2008 and the 2011 NEI. Tons.  This asphalt use is assumed to be for asphalt cement, rather than for asphalt concrete which is composed of both aggregate (~95% by wgt) and asphalt cement (~5%by wgt). |
| G | State VMT2013 FHWA Roads | State-level annual vehicle miles traveled (VMT) by FHWA road class, 2013. FHWA Report VM-2, 2013. http://www.fhwa.dot.gov/policyinformation/statistics/2013 |
| C | County VMTFHWA Roads for 2014 NEI | Estimate of county-level annual VMT by FHWA road class, for 2014 NEI.  This approximation of county-level annual VMT for 2014 is based on the equation: County VMTFHWA Road Type for 2014 NEI = 2011NEIv2 CountyVMTMOVES\_NEI Road Type x (2013 StateVMTFHWA Road Type /2013 State MOVES\_NEI Road Type) See EIAG's NEI documentation file: <README\_VMTfor2014NEInptCals\_20150728.docx> |
| C | County VMT fraction  of State VMT | Estimate of county fraction of the state VMT by FHWA road class, for 2014 NEI.  This approximation is based on the equation: (2014 County VMTFHWA Road / 2013 State VMTFHWA Road )  = (County VMT/ State VMT)FHWA Road for 2014 NEI |
| G | State Lane-Miles2013 FHWA Roads | State lane-miles by FHWA road class, 2013. FHWA Report HM-60, 2013. http://www.fhwa.dot.gov/policyinformation/statistics/2013 |
| G | State Paved  Road Miles2013 FHWA Roads | State paved road miles by FHWA road class, 2013. FHWA Report HM-51, 2013. http://www.fhwa.dot.gov/policyinformation/statistics/2013 |
| C | State Paved  Lane-Miles2013 FHWA Roads | Estimate of state lane-miles that are paved by FHWA road class, for 2013 based on the equation:  [state paved road miles2013 FHWA Road / (state paved + unpaved road miles)2013 FHWA Road ] x state lane-miles2013 FHWA Road  = state paved lane-miles2013 FHWA Road |
| C | State Utilization  Paved2013 FHWA Roads | Estimate of state-level utilization measure for paved road surface by FHWA road class, for 2013 based on the equation:  (stateVMT2013 FHWA Road /state paved lane-miles2013 FHWA Road) = state utiliztn paved roads2013 FHWA Road |
| C | County Utilization  Paved2013 FHWA Roads | Estimate of the county-level utilization measure for paved road surface by FHWA road class is calculated by applying the county/state VMT fraction to the state paved road utilization measure. (county VMT/ state VMT)FHWA Road for 2014 NEI x (state utilization paved roads2013 FHWA Road)  = county utilization paved roads2013 FHWA road |
| C | County Utilization Sum2013 County-to-State Utiliz Sum2013 | Sum the county utilization by FHWA roads to county total and sum the county totals to state total. |
| C | County Utilization Fraction  of State Utilization | Estimate of county fraction of the state utilization measure for paved road surface is based on the equation: (county utilization paved2013/ CountyToStateSum utilization paved2013) |
| C | County Asphalt Usage for 2014NEI | County-level cutback asphalt usage estimated by allocating state-level usage data to county based on the estimate of county utilization paved roads2013 using the equation: (state-level asphalt usage x (county utilization paved2013/ CountyToStateSum utilization paved2013) = county asphalt usage for 2014NEI |

### Table 2b. Sources of Emission Factors, Related Parameters, and Emissions – Proposed Update

Parameter = G (Given) or C (Computed)

|  |  |  |
| --- | --- | --- |
| **Emission Factors / Emissions – Proposed Method Update** | | |
|  | **Parameter** | **Source Reference\_Use Note** |
| C | Emission Factor VOC, HAPs | Emission factors are updated for 2014 NEI. Basis includes: 2008 annual asphalt cement use data from Asphalt Institute; average chemical composition information from available online MSDS – specific diluent, % wgt fraction; and assumed %wgt emitted.  See factors in table below and equations in method discussion section. |
| G | Asphalt cement consumption  Annual 2008 national tons | The 2008 activity usage by state (2008 Asphalt Usage Survey, from Asphalt Institute) is summed to national. Cutback usage = 187,328 tons; Emulsified usage = 1,350,999 tons. |
| G | Diluent(s) and Average pct of each diluent in asphalt cement | Determination that likely multiple diluents are present in asphalt cement (binder) and an average wgt percent of diluent in asphalt cement is assumed based on MSDS information.  Specific diluent and properties are referenced in method discussion section. |
| G | Density of asphalt | The density of asphalt is assumed similar to that of water, 8.34 lbs/gal which seems reasonable based on relative density information in MSDS. |
| G | Density of diluent (s) | Density measures for each diluent are referenced in method discussion section. While density measures were gathered/recorded, they are not used for wgt % calculations. |
| G | Pct by wgt of volatile (diluent) emitted in product | 95% of total solvent is assumed emitted; with 5% of total solvent assumed retained in the product. |
| C | Emissions | Emissions = County-Level Asphalt Usage \* Emission Factors |

### Table 2c. Proposed Method Update - Source Category Codes (SCCs), Emission Factors, Expected Pollutants

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **SCC** | **Description** | **Pollutant** | **EIS Code** | **Emission Factor** |
| 2461021000 | Cutback Asphalt,  Total: All Solvent Types | Volatile Organic Compounds | VOC | 813.96 lb/ton |
|  |  | Benzene | 71432 | 3.61 lb/ton |
|  |  | Ethylbenzene | 100414 | 9.31 lb/ton |
|  |  | Naphthalene | 91203 | 11.02 lb/ton |
|  |  | Toluene | 108883 | 11.21 lb/ton |
|  |  | Xylenes (Mixed Isomers) | 1330207 | 18.81 lb/ton |
|  |  | Hydrogen Sulfide | 7783064 | 1.71 lb/ton |
| 2461022000 | Emulsified Asphalt,  Total: All Solvent Types | Volatile Organic Compounds | VOC | 190.0 lb/ton |
|  |  | Naphthalene | 91203 | 5.51 lb/ton |
|  |  | Hydrogen Sulfide | 7783064 | 1.71 lb/ton |

|  |  |  |  |
| --- | --- | --- | --- |
| **SCC** | **Full Description** |  |  |
| 2461021000 | Solvent Utilization | Misc Non-industrial: Commercial, Cutback Asphalt | Total: All Solvent Types |
| 2461022000 | Solvent Utilization | Misc Non-industrial: Commercial, Emulsified Asphalt | Total: All Solvent Types |

## Activity Assessment

Asphalts are used in two ways. They are either mixed with aggregates at plants and hauled to the paving site and compacted on the road, or they are sprayed in relatively thin layers with or without aggregates. Plant mixed asphalt products are called asphalt concrete mix. These can be produced and laid down hot, using asphalt cements, or cold, using emulsions or cutbacks. These mixes usually contain about 5% asphalt and 95% aggregates by weight. Aggregates give the mix most of its ability to carry or resist loads while the asphalt coats and binds the aggregate structure.

Hot laid mixes, also called hot mix asphalt, are produced by mixing heated aggregates and asphalt cements in special mixing plants. These very strong, stiff mixes are usually used for surface and subsurface layers in highways, airports, parking lots, and other areas which carry heavy or high volume traffic.

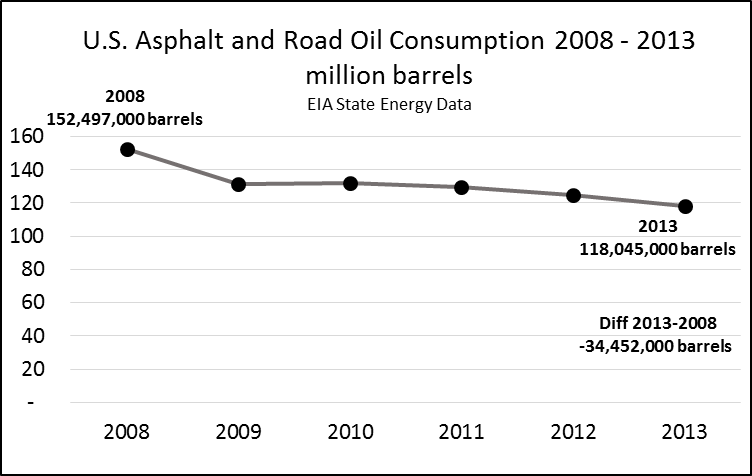
Cold asphalt mixes are produced by mixing damp, cold aggregates with emulsions or cutbacks at mixing plants — either stationary plants or portable ones brought to the site. Although not as strong and stiff as hot mix, cold mixes may be more economical and flexible, and less polluting. Cold mix is sometimes used for base course construction and is also commonly used for patching and repairing pavement.

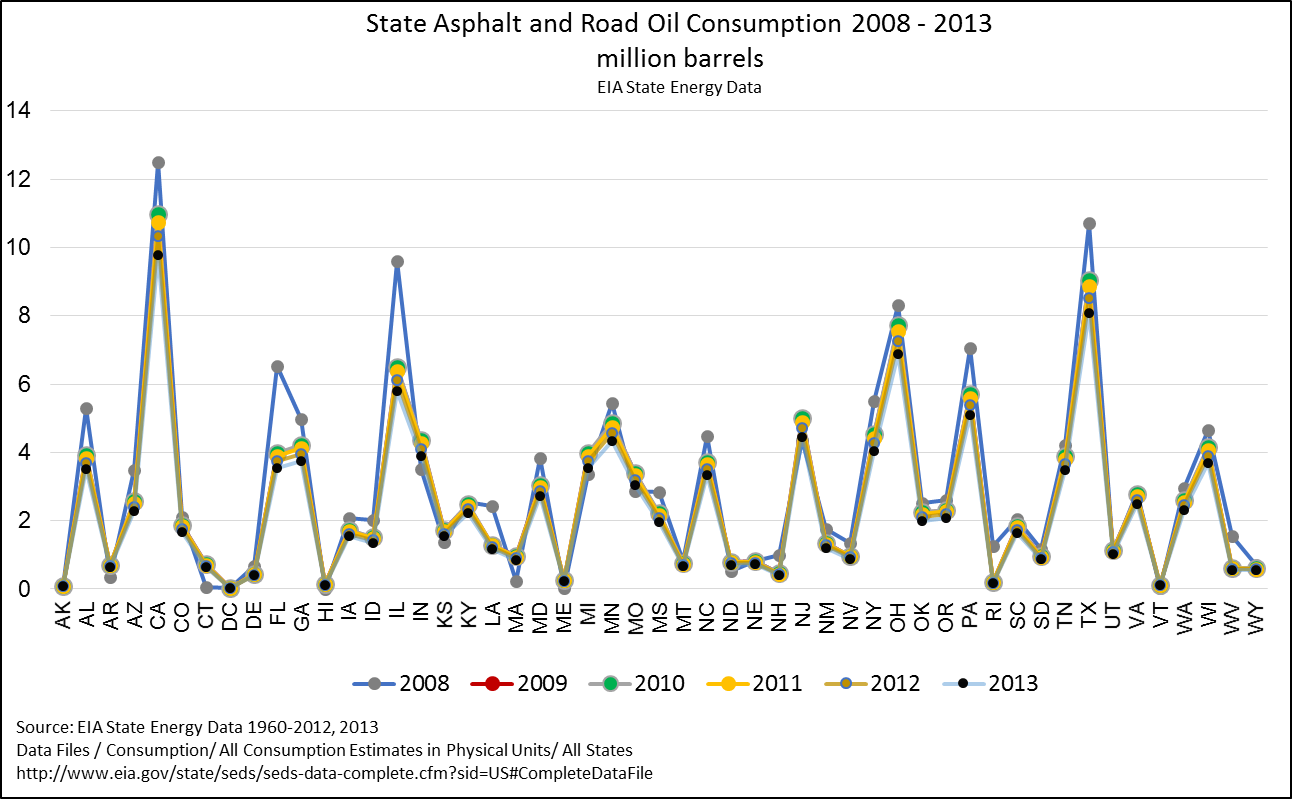
However, it is difficult to compact thoroughly and in general is not as durable as HMA.

A new, third type of mix, warm-mix asphalt (WMA), has become increasingly popular. In this type of mixture, various different methods are used to significantly reduce mix production temperature by 30 to over 100°F. These methods include (1) using chemical additives to lower the high-temperature viscosity of the asphalt binder; (2) techniques involving the addition of water to the binder, causing it to foam; and (3) two-stage processes involving the addition of hard and soft binders at different points during mix production. WMA has several benefits, including lower cost (since significantly less fuel is needed to heat the mix), lower emissions and so improved environmental impact, and potentially improved performance because of decreased age hardening.

Additional description of asphalt paving practices and terminology is included in the Appendix.

The 2008 data by the Asphalt Institute is the emissions activity basis for EPA’s existing estimation method for paving using cutback or emulsified asphalt cement. That data for *many states has zero usage for cutback asphalt*, specifically AK, CT, DE, DC, HI, ME, MD, MA, NH, NJ, NY, NC, RI, SC, VT, and WV. Some of those states also have zero usage for emulsified asphalt. The survey report acknowledges that manufacturers or resellers in some states may have not reported or under-reported due to confidentiality concerns. While general on-line data searches did not yield more recent and available information on cutback and emulsified asphalt usage, recent data may be available for purchase from Freedonia (e.g., $5,500 USD) or by contacting industry associations such as the Asphalt Institute. Several information sources indicate that the Asphalt Institute which performed periodic surveys through 2008, stopped surveys efforts of that type after 2008. For this project, the EPA contacted the Asphalt Institute to see if more recent activity data is available and was provided the copyright protected 2014 survey report (FINAL 2014 Asphalt Usage Survey.pdf). While that data is not presented here, there is little difference between the national-level 2008 and the 2014 use amount for cutback asphalt and there is a larger increase in the national 2014 emulsified usage compared to the 2008 use value, i.e., a 20 percent change from 2008.

The rate of growth pattern for asphalt use between 2008 and 2014 was also reviewed by looking at several on-line sources such as Freedonia brochures and the U.S. Energy Information Administration (EIA) State Energy Data System (SEDS). Freedonia suggests that demand for asphalt in the United States will rebound from the sharp declines in the 2007-2012 period, driven by stronger economic growth and increased construction activity, though demand in 2017 is expected to remain below the 2007 level. The US and Canada are significant consumers of asphalt for roofing products; demand for those products will rise with increased building construction expenditures. The study says demand for asphalt in both paving and roofing applications will be driven by the recovering US economy and increasing construction activity in the country. Review of the EIA SEDs data to determine the trend in asphalt product sales and consumption since 2008, specifically the petroleum end-use industrial sector of asphalt and road oil - indicates that state-level consumption of asphalt and road oil between the years of 2008-2013 has experienced a general decline or approximately flat growth.



The FHWA (Federal Highway Administration) is also a potential source of activity data via contract with the National Paving Association to survey states about their use of asphalt and reclaimed materials. The FWHA and National Paving Association survey of 2013 state-level asphalt usage cites an increased use of warm-mix asphalt and recycled content. There is no discussion of the amount of solvent that may be attributed to the HMA (hot-mix) or WMA. The objective of the survey is to quantify the use of recycled materials and WMA produced by the asphalt pavement industry in each state. The results include an estimate of 351 million tons of HMA/WMA plant mix asphalt produced in 2013, of which WMA is 106 million tons. In the Appendix that 2013 state summary is compared to the 2008 usage for cutback and emulsified asphalt that EPA last obtained from the Asphalt Institute. *Unlike the 2008 data usage, there are no states with an estimated zero HMA/WMA asphalt production for 2013.* The survey also notes that in 2013, WMA was more than 30 percent of the total asphalt mixture market. WMA use increased by nearly 22 percent from 2012 to 2013, and about 533 percent since 2009. Plant foaming is used most often in producing WMA, with 87 percent of the market and WMA additives accounted for about 13 percent of the market.

Because many of the states indicated with zero use in the 2008 survey are in the northeast and mid-atlantic, contact from the Mid-Atlantic Regional Air Management Association (MARAMA, www.marama.org) suggested looking at the 2007 MANE-VU emissions inventory to help confirm zero values. Submissions to the 2011 NEI v2 were also reviewed for the same states. Based on those comparisons – see the box summary, it appears that the proposed estimates for the 2014 NEI asphalt emissions may under-estimate (zero emissions) for the MARAMA states when many have those states have emissions in the 2007 MANE-VU inventory and in the 2011 NEI v2. Nationally, the emulsified asphalt emissions may be more generally under-estimated based on the large increase in the national 2014 emulsified usage given in the 2014 Asphalt Institute survey compared to the 2008 use value.

Cutback VOC tons  
Asphalt survey 2008 indicated 16 states with zero and 9 of the 16 states are in northeast & mid-atlantic.

For the 13 MANU-VU states, with D.C.:

MANE-VU 2007 inv has data for 8 states: 8,554.

EPA 2011 v2 has data for 6 states: 7,654.

2008 spreadsheet tool has data for 2 states: 6912.

2014 draft has data for same 2 states: 11,198.

Emulsified VOC tons

Asphalt survey 2008 indicated 10 states with zero and 7 of the 10 states are in northeast & mid-atlantic.

For the 13 MANU-VU states, with D.C.:

MANE-VU 2007 inv has data for 11 states: 10,790.

EPA 2011 v2 has data for 8 states: 6,984.

2008 spreadsheet tool has data for 6 states: 3,859.

2014 draft has data for same 6 states: 14,361.

Many state and or local jurisdictions restrict or ban the use of highly evaporative asphalt mixtures such as cutback asphalt during months of potentially poor air quality, i.e., typically in the warmer, sunny months. Paving using cutback asphalt may be scheduled and resume in other parts of the year when evaporation of the VOC content will not influence ozone formation as much. For the purposes of the NEI annual county-level estimate, it may be assumed that the county allocation of asphalt usage will eventually be used at some point during the year, rather than assuming emissions are ‘zeroed-out’ – unless bans are in place. If agencies are developing an inventory for SIP purposes, a monthly inventory could be calculated to account for monthly variations in process activity, unless restricted use or bans. EPA’s processing of the annual emission inventory for regional air quality modeling may not take that into account unless county, SCC-specific spatial and temporal factors can be developed and applied, which is typically outside of the scope of limited resources unless the SCC emissions are particularly significant.

### Activity Distribution to County

*While the 2008 asphalt usage from the existing method is proposed for use with the 2014 NEI, the procedure for distributing the state asphalt use to county-level usage* *is updated* with the intent to simplify the method by using ready available FHWA data reports to develop a utilization measure for paved roads. The utilization measure focuses on the quantity of travel on paved roads. The existing EPA distribution procedure applies 10+ year old FHWA data no longer published concerning traffic volume with conversion to VMT (vehicle miles travelled) using assumed speeds. The desired update outcome is to develop a state-to-county activity distribution factor that is computationally more stream-lined, requires less operating assumptions, and uses current and routinely available FHWA highway statistics reports rather than carrying forward and building a factor upon old data (1996) as a surrogate for information no longer published (HM-67 Miles By Surface Type And Average Daily Traffic Volume Group, last published in 1997). There may be other ways (like the previous method), but the update tries to allocate paving to areas with the highest travel. This isn’t a perfect methodology as all roads get paved at some point in time, even low-usage rural roads on their own maintenance schedule, but it may be a reasonable approximation.

The update considers the following performance measures and definitions that may be applied by state DOTs and MPOs.

Reference: http://ops.fhwa.dot.gov/publications/fhwahop08054/sect2.htm; Traffic Analysis Toolbox Volume VI: Definition, Interpretation, and Calculation of Traffic Analysis Tools Measures of Effectiveness (MOEs), Tables 6 and 7.

Dimension Performance Measure Definition

Quantity of Travel Vehicle miles traveled Average Annual Daily Traffic \* Length

Utilization Vehicles per lane-mile Average Annual Daily Traffic \* Length/lane miles

*See Table 2a for the list of specific activity parameters, data source, and equations for the updated approach.*

The general steps are as follows.

Step 1. Develop state road utilization measure by road surface –

Utilization measure = VMT/ lane-miles

*By FHWA road type*, the amount of lane-miles that are paved may be expressed as:

(state paved road miles/ state paved + unpaved road miles) x state lane-miles = state paved lane-miles

State utilization measure for paved road surface = (state VMT / (state paved lane-miles)

Step 2. Compute county-to-state fraction for quantity of travel, i.e., vehicle miles traveled -

*By FHWA road type*, the county-to-state fraction, vehicle miles traveled = County VMT/ State VMT

Estimate of annual county VMT based on MOVES mobile source model is provided by EPA.

Step 3. Compute county-level utilization measure for paved roads -

*By FHWA road type*, apply the county/state VMT fraction (Step 2) to the state road utilization measure by paved road type (Step 1) to obtain the county-level road utilization measure for paved roads.

County utilization paved roads = (County VMT/state VMT) x (State utilization measure for paved road surface)

Step 4. Sum the county utilization by FHWA roads to county total and sum the county totals to state total.

Step 5. Estimate the county fraction of the state utilization measure for paved road surface as:

County utilization paved roads / county-to-state\_sum utilization paved

This county fraction of state utilization measure is multiplied by the state asphalt usage to distribute the state-level asphalt use to county usage.

Operating assumption – the county-level paved road utilization is similar to the calculated state-level paved road utilization measure, and may be related based on the county VMT fraction of state VMT.

## Assess Emission Factors

The current method applies emission factors for cutback and emulsified asphalt usage which were obtained from the Technical Report Series produced by the U.S. EPA’s Emission Inventory Improvement Program (EPA 2001, EIIP). Those emission factors are found in Procedures for the Preparation of Emission Inventories for Carbon Monoxide and Precursors of Ozone Volume 1: General Guidance for Stationary Sources, EPA-450-4-91-016; May, 1991. The sources and parameters used to derive the emission factors for the existing method are listed in Table 1b.

Calculation for the existing cutback emission factor*, in terms of lbs/ barrel asphalt:*

Cutback usage = 1 million barrels; 42 gals/ barrel; = 42 million gallons.

42 million gallons x .35 (avg pct by vol diluent) = 14.7 million gallons diluent.

Naptha diluent - density ~ 6.32 lb/gal.

14.7 million gallons diluent x 6.32 lb/gal = 92.9 lb x .95 (pct volatile assumed emitted in product)

= 88.25 lb VOC emitted/ barrel cutback asphalt used.

The existing emulsified emission factor *was taken from the following, the calculation was not specified:*

A composite VOC emission factor of 9.2 lbs/barrel (0.22 lbs/gal) of emulsified asphalt was developed for the Northeastern Illinois Planning Commission for use with 1982 Ozone SIP.

Additional reference information indicates three types of cutback asphalt cement with the attributes:

(EPA 1996, AP42 - http://www.epa.gov/ttn/chief/ap42/ch04/final/c4s05.pdf)

|  |  |  |  |
| --- | --- | --- | --- |
| Cutback Type | Diluent | VOC Evap Loss Estimate | Note |
| Rapid Cure (RC) | gasoline or naphthas | 95% by weight diluent | highest diluent content and emissions |
| Medium Cure (MC) | kerosene | 70% by weight diluent |  |
| Slow Cure (SC) | low volatility fuel solvents | 25% by weight diluent |  |

*An update of the existing factors is proposed using the parameters listed in Table 2b.*

Material Safety Data Sheets (MSDS) for cutback and emulsified asphalt were searched on-line and to review as a general way to assess the physical parameters used in the existing emission factor calculation and for potential update – regarding material composition, percent concentrations, and density measures. The MSDS typically cover a range of graded asphalts and note that petroleum asphalt is mixed with varying proportions of solvent, fuel oils, kerosene, and/or petroleum residues and the composition varies depending on source of crude and specifications of final product. Information from several MSDS are included as Appendix and summarized below. Based on the MSDS information and comparison to calculation parameters used to derive existing emission factor, the following values are proposed as average composite surrogates. The information for cutback is based primarily on rapid cure though ethylbenzene is cited for presence in medium and slow cure mixtures. In the MSDS, the units of the concentration percent is seldom confirmed as whether percent by volume or percent by weight. When it was specified on the emulsified and cutback sheets reviewed, it was percent by weight. The information in Appendix includes references for several ASTM (American Society for Testing and Materials) standard methods for sampling and testing the composition of bituminous paving materials which were reviewed to form the assumption that the concentration percentages are mass percentages.

|  |  |  |  |
| --- | --- | --- | --- |
| Cutback Asphalt |  |  |  |
| Chemical Composition, i.e., VOCs, HAPs | Avg % by Wgt | Density | Note |
| Asphalt | 60-90 | 8.34 lb/gal | Relative Density ~ 0.9-.99, water=1 |
| Naptha, i.e., VM&P, Stoddards solv | 40 | 6.3 lb/gal | 15C/60F (CDC/NIOSH) |
| Naphthalene | 0.49 (0.58 w PAH) | 9.5 lb/gal | 20C/68F (CDC/NIOSH), SG 1.16 |
| Toluene | 0.59 | 7.2 lb/gal | 20C/68F (CDC/NIOSH) |
| Xylene | 0.99 | 7.2 lb/gal | 20C/68F (CDC/NIOSH) |
| Benzene | 0.19 | 7.3 lb/gal | 20C/68F (CDC/NIOSH) |
| Ethylbenzene | 0.49 | 7.2 lb/gal | 20C/68F (CDC/NIOSH) |
| Polycyclic Aromatic Hydrocarbons | 0.09 |  | Add to wgt % as napthalene |
| Hydrogen Sulfide | 0.09 | 8.3 lb/ gal | SG 1.19 (gas) |

|  |  |  |  |
| --- | --- | --- | --- |
| Emulsified Asphalt |  |  |  |
| Chemical Composition/ i.e., VOCs, HAPs | Avg % by Wgt | Density | Note |
| Asphalt | 25-75 | 8.34 lb/gal | Relative Density ~ 0.9-1.0, water=1 |
| Naptha, i.e., VM&P, Stoddards solv | 10 | 6.3 lb/gal | 15C/60F (CDC/NIOSH) |
| Naphthalene | 0.2 (0.29 w PAH) | 9.5 lb/gal | 20C/68F (CDC/NIOSH), SG 1.16 |
| Polycyclic Aromatic Hydrocarbons | 0.09 |  | Add to vol % as napthalene |
| Hydrogen Sulfide | 0.09 | 8.3 lb/ gal | SG 1.19 (gas) |

Calculation for updated emission factors*, lbs pollutant emitted/ ton asphalt, cutback or emulsified:*

lbs/yr cutback (or emulsified) cement x avg % wgt diluent = lbs/yr diluent

lbs/yr diluent x avg wgt % volatile emitted = lbs/yr diluent emitted

annual mass emission rate: (lbs poll emitted/yr) / (tons asphalt used/yr) = lb/ton

Because the percent concentration of the diluents, i.e., solvents, is applied as weight percent, the use of the material densities are recorded though not used to convert to volume measures.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Qty Cutback | Chemical species | Chemical  Density | % Wgt | % Wgt  Volatilized | EF calculation, Cutback Asphalt |
| 187,328 tons | Naptha | 6.3 lb/gal | 40 | 95 | 187,328 tons/yr x 2000 lbs/ton x .40 x (.95) = 142,369,280 lbs/yr  (142,369,280 lbs/yr) / (187,328 tons/yr) = 760 lbs/ton |
|  | Naphthalene | 9.5 lb/gal | 0.58 | 95 | 187,328 tons/yr x 2000 lbs/ton x .006 x (.95) = 2,064,355 lbs/yr  ( 2,064,355 lbs/yr) / (187,328 tons/yr) = 11.02 lbs/ton |
|  | Toluene | 7.2 lb/gal | 0.59 | 95 | 187,328 tons/yr x 2000 lbs/ton x .006 x (.95) = 2,099,947 lbs/yr  (2,099,947 lbs/yr) / (187,328 tons/yr) = 11.21 lbs/ton |
|  | Xylene | 7.2 lb/gal | 0.99 | 95 | 187,328 tons/yr x 2000 lbs/ton x .01 x (.95) = 3,523,640 lbs/yr  (3,523,640 lbs/yr) / (187,328 tons/yr) = 18.81 lbs/ton |
|  | Benzene | 7.3 lb/gal | 0.19 | 95 | 187,328 tons/yr x 2000 lbs/ton x .002 x (.95) = 676,254 lbs/yr  (676,254 lbs/yr) / (187,328 tons/yr) = 3.61 lbs/ton |
|  | Ethylbenzene | 7.2 lb/gal | 0.49 | 95 | 187,328 tons/yr x 2000 lbs/ton x .005 x (.95) = 1,744,024 lbs/yr  (1,744,024 lbs/yr) / (187,328 tons/yr) = 9.31 lbs/ton |
|  | VOC |  |  |  | Add lbs above = 152,477,499 lbs/yr. / (187,328 tons/yr  = 813.96 lbs/ton |
|  | Hydrogen Sulfide | 8.3 lb/gal | 0.09 | 95 | 187,328 tons/yr x 2000 lbs/ton x .001 x (.95) = 320,331 lbs/yr  (320,331 lbs/yr) / (187,328 tons/yr) = 1.71 lbs/ton |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Qty Emulsified | Chemical species | Chemical  Density | % Wgt | % Wgt  Volatilized | EF calculation, Emulsified Asphalt |
| 1,350,999 tons | Naptha | 6.3 lb/gal | 10 | 95 | 1,350,999 tons/yr x 2000 lb/ton x .10 x (.95) = 256,689,810 lbs/yr  (256,689,810 lbs/yr) / (187,328 tons/yr) = 190.0 lbs/ton |
|  | Naphthalene | 9.5 lb/gal | 0.29 | 95 | 1,350,999 tons/yr x 2000 lb/ton x .003 x (.95) = 7,444,004 lbs/yr  (7,444,004 lbs/yr) / (187,328 tons/yr) = 5.51 lbs/ton |
|  | VOC |  |  |  | Add lbs above = (264,133,814 lbs/yr). / (187,328 tons/yr)  = 195.5 lbs/ton |
|  | Hydrogen Sulfide | 8.3 lb/gal | 0.09 | 95 | 1,350,999 tons/yr x 2000 lb/ton x .001 x (.95) = 2,310,208 lbs/yr  (2,310,208 lbs/yr) / (187,328 tons/yr) = 1.71 lbs/ton |

### Compare emission factors - proposed vs existing

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **SCC** | **Description** | **Pollutant** | **EIS Code** | **EF update** | **EF existing** |
|  |  |  |  | **lb/ton** | **lb/barrel** |
| 2461021000 | Cutback Asphalt,  Total: All Solvent Types | Volatile Organic Compounds | VOC | 813.96 | 88.0 |
|  |  | Benzene | 71432 | 3.6 |  |
|  |  | Ethylbenzene | 100414 | 9.3 | 2.02 |
|  |  | Naphthalene | 91203 | 11.0 |  |
|  |  | Toluene | 108883 | 11.2 | 5.63 |
|  |  | Xylenes (Mixed Isomers) | 1330207 | 18.8 | 10.74 |
|  |  | Hydrogen Sulfide | 7783064 | 1.7 |  |
| 2461022000 | Emulsified Asphalt,  Total: All Solvent Types | Volatile Organic Compounds | VOC | 195.5 | 9.2 |
|  |  | Naphthalene | 91203 | 5.5 |  |
|  |  | Hydrogen Sulfide | 7783064 | 1.7 |  |

The units of the existing and proposed updated emission factor are different. A conservative conversion of the existing lbs/ barrel value to terms of lbs/ton may be using conversion factor: 5.5 barrels road oil / ton

(Reference: EIA SEDS - www.eia.gov/state/seds/sep\_prices/notes/pr\_petrol.pdf; Data sources for quantities used in calculating weighted average prices include: Asphalt Institute, 2008 Asphalt Usage Survey for the United States and Canada, table titled “U.S. Asphalt Usage.”)

88 lbs VOC/ barrel x 5.5 barrels/ton = 484 lb VOC/ ton

The proposed update includes emission factors for (three) additional HAPs (hazardous air pollutants) based on review of current MSDS composition information. The existing HAP factors are based on a percent weight of VOC from the EPA 1996 NTI (National Toxics Inventory).

# Recommendations for the 2014 NEI

To develop the default EPA estimates of county emissions from asphalt paving, use of the following calculation parameters are recommended.

## *Apply updated emissions factors for cutback and emulsified paving*

The updated emission factors are recommended for application in the EPA’s default emission estimation method for the 2014 NEI. The annual mass emission rate factors are updated with the 2008 asphalt consumption (activity) and MSDS composition information thought to reflect cutback and emulsified paving mixtures used today.

## *Apply state-level 2008 activity used in existing method and updated technique to distribute to counties*

*The use of 2008 activity data as a surrogate for the 2014 NEI likely under-estimates some states’ use of cutback and emulsified asphalts, more so for emulsified.*

The emulsified asphalt emissions may be more generally under-estimated based on the increase in the national 2014 emulsified usage given in the Asphalt Institute (copyright protected) 2014 survey compared to the 2008 use, i.e., a 20 percent change from 2008. The 2008 activity data is from the Asphalt Institute 2008 survey and many states have zero usage for cutback asphalt- specifically AK, CT, DE, DC, HI, ME, MD, MA, NH, NJ, NY, NC, RI, SC, VT, and WV. Some of those states also have zero usage for emulsified asphalt. In the FHWA/ NAPA survey results, unlike the 2008 data usage, there are no states with an estimated zero HMA/WMA asphalt production for 2013, though it is unclear what amount of HMA/WMA may include cutback or emulsified asphalt. Based on comparison of the 2008 activity with the MANE-VU 2007 inventory and the 2011 NEI v2, it appears that the proposed estimates for the 2014 NEI asphalt emissions may under-estimate (zero emissions) for the MARAMA states when many have those states have emissions in the 2007 MANE-VU inventory and in the 2011 NEI v2.

Industry growth patterns were assessed and suggest low or flat growth between 2008 and 2013. The more recent estimated state-level use of WMA/HMA from the FHWA/ NAPA survey also indicates a flat or small decline in use for 2009-2013.

The updated technique to distribute state-level usage to counties uses ready available FHWA data reports to develop a utilization measure for paved roads. The utilization measure focuses on the quantity of travel on paved roads and seems to provide a reasonable approximation to allocate paving to county areas with the highest travel.

## *Develop county-level estimates, document and distribute for S/L/T review*

Once county-level emission estimates have been developed using the recommended parameters and documented in MS Excel spreadsheet, the county estimates should be loaded in EIS or made available in some other way for agencies (state/local/tribes) to review.

Request S/L/T comments:

- Do they accept the EPA default county estimates as their county estimates?

- Can they validate zero state activity where indicated?

- If not accepting EPA default estimates, do they use different estimation approaches from acquisition and development of local data?

## *Update EPA list of expected pollutants for nonpoint and the emission range check values*

This update to EPA’s list of expected pollutants for nonpoint categories will add some HAPs and adjust the maximum emission values per EPA updated default estimates.

## *QA of state/local/tribal agencies’ NEI submissions to EIS*

The following EIS checks of county SCC pollutant emission submissions should be done to determine:

- Value equal to EPA default estimates where acceptance was indicated

- That both activity and emission factor is provided where EPA default estimates were not accepted

- Replacement of submissions with EPA default estimates where

* Emissions are submitted without either activity or emission factor
* The emission factors are documented as the previous (old) EPA default factors
* The expected HAPs per EPA default estimates are not all present
* Emissions are null or zero when EPA default estimate is greater than zero

## Additional steps for further improvement

In general, these additional steps may help validate and further improve EPA’s default estimates for this source category though may not be timely for the 2014 NEI schedule already underway and pending available resources.

For this assessment, contacts were made with the FHWA, the Asphalt Institute, and the NAPA. FHWA staff responded that they do not collect nor track information on cutback and emulsified asphalt usage on the National Highway System and that emulsions are generally used in maintenance activities and not new construction or re-construction. Staff from the Asphalt Institute responded to provide their copyright protected 2014 survey report with request that it not be further distributed. As of this writing, response was not received from the NAPA.

It was thought that the FHWA may be able to obtain information from their paving industry partners, i.e., NAPA, about an amount of WMA and HMA that may be cutback with solvents and whether there are additional amounts of cutback and emulsified not covered by their annual survey purpose – that might improve both activity and composition information for emission factor calculations. NAPA also conducts FHWA co-sponsored research of which on-line brochure indicates that NAPA drafted a report comparing criteria air pollutant emissions of warm-mix technologies and hot-mix technologies - available upon request from NAPA and that the report was not released to the public because additional stack emissions testing is needed to determine the extent of criteria air pollutant reduction with the use of warm-mix technologies. Current asphalt use (activity) data may also be available for purchase from Freedonia.

More in-depth on-line literature searches, e.g., Science Direct, could also be conducted to see if research results exist that describe measured volatile composition of asphalt mixtures used today. That could be another way to further assess emission characteristics of the VOC and individual chemical species.

The Appendix includes a list of some possible contacts for more information.

## Pollutant emission summaries by state

### Compare emissions for cutback and emulsified paving - existing default method and the proposed update





### 

### 2011 NEI v2 emissions comparison with proposed method update

**Cutback comparison**

*Update for 2014 NEI*

VOC: general increase over 2011 v2

HAP: general decrease over 2011 v2

HAPs (5) = benzene, ethylbenzene, napthalene, toluene, xylenes;

HAPsum/VOC ratio =0.07

New HAP: benzene, napthalene,

hydrogen sulfide

*2011 NEI v2*

HAPs (3) = ethylbenzene, toluene, xylenes

Data Sources, 2011v2:

* EPA estimates for VOC and/or HAP

- 34 states/ locals (HAPsum/VOC ratio = 0.15)

* State/ Local submissions

- 7: VOC and HAPs (HAPsum/VOC ratio = 0.2)

- 6: VOC only



**Emulsified comparison**

*Update for 2014 NEI*

VOC: general increase over 2011 v2

HAP: general increase over 2011 v2

HAPs (1) = napthalene

*2011 NEI v2*

HAPs (1) = napthalene

Data Sources, 2011v2:

* EPA estimates for VOC only

- 31 states

* State/ Local submissions

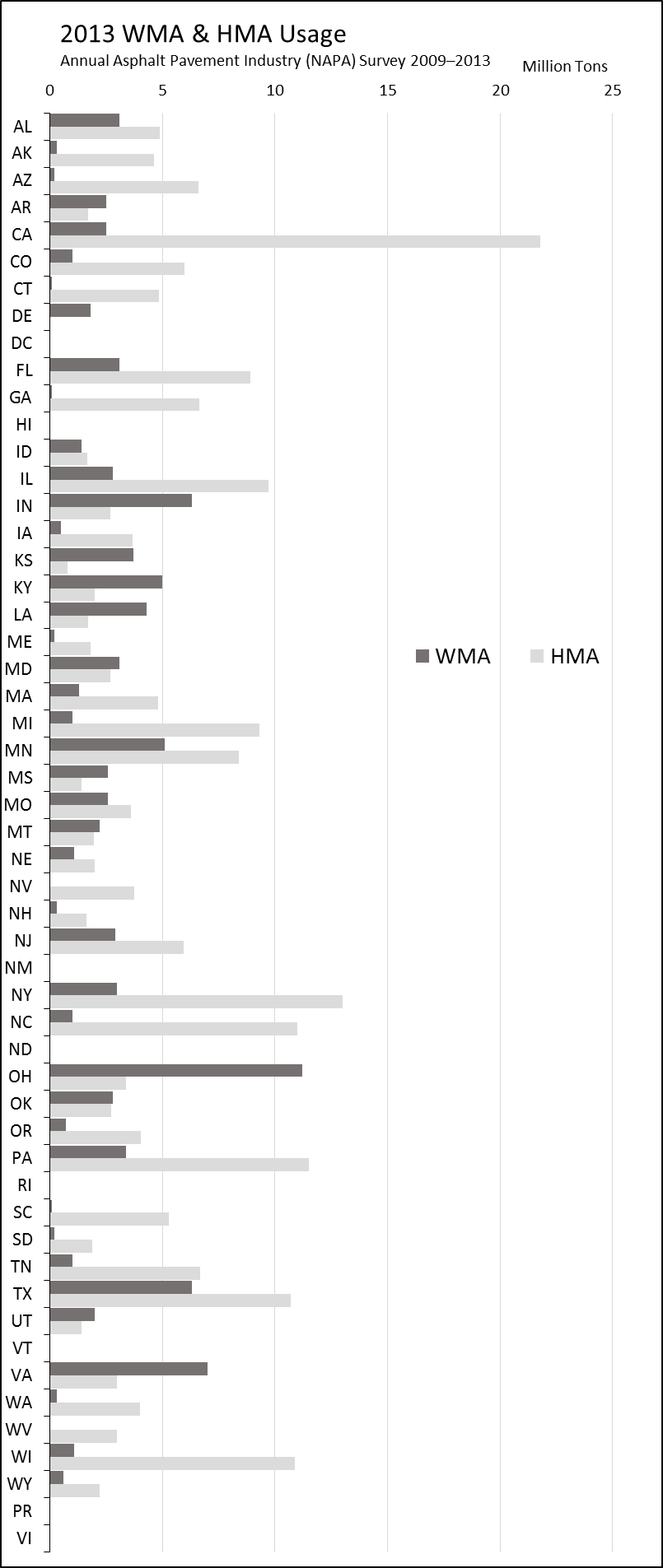
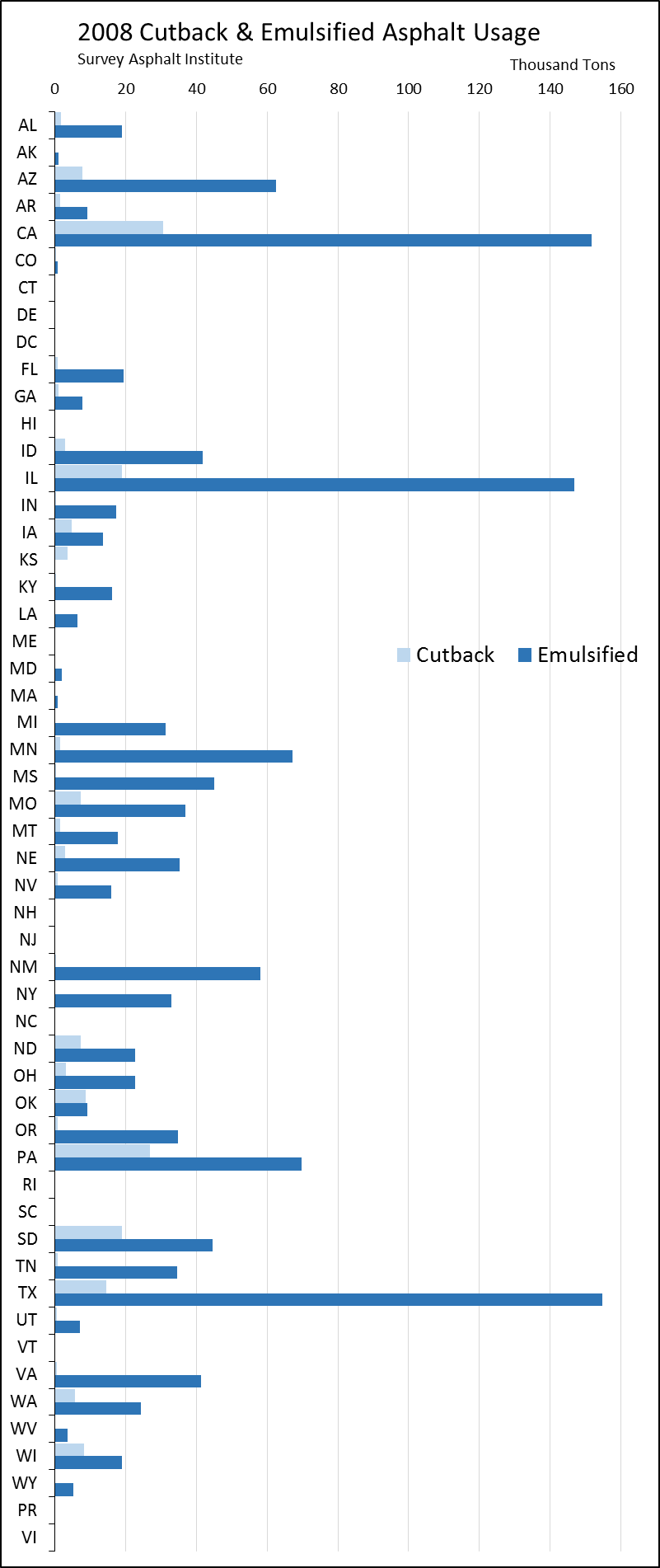
- 2: VOC and HAP

- 15: VOC only

## Asphalt Usage

### 2008 Activity by State for cutback and emulsified used in the existing method

### 2013 Estimated Hot-Mix and Warm-Mix Asphalt Paving Material by State, FHWA/NAPA Annual Survey 2009-2013

****

# APPENDICES

## Terms

Reference for following descriptions: Wisconsin Transportation Bulletin • No. 1, Understanding and Using Asphalt

Asphalt types

Three general types of asphalts are used in construction today: asphalt cement, emulsified asphalt, and cutback asphalt. Asphalt cement, also called paving asphalt, is a component of hot mix asphalt which is primarily used to construct flexible pavements (blacktop). This material is different from the other two types of asphalt because it is semi-solid and highly viscous (resistant to flow) at normal air temperatures. Asphalt cement is liquefied by heating then mixed with aggregates to produce hot mix. The mix is kept hot until it is spread on the road and compacted. Being very sticky, sticky, asphalt cement adheres to the aggregate particles and binds them together. After cooling to normal air temperature, hot mix makes a very strong paving material which can sustain heavy traffic loads.

Emulsified asphalt, or emulsion, is made from asphalt cement. It is tiny particles of asphalt cement mixed with water and an emulsifying agent — usually a detergent. Emulsions were first developed in the early 1900s and began being widely used in 1920s for dust control. Emulsions are called liquid asphalts because, unlike asphalt cements, they are liquid at normal air temperatures and therefore do not require heat to liquefy. To produce emulsions, hot asphalt cement and water containing the emulsifying agent are pumped at high pressure through a colloid mill. The emulsifying agent coats the asphalt particles and puts an electric charge on their surfaces. This charge causes the asphalt droplets to repel one another so they don’t combine. These charges are used to categorize emulsions as cationic (positive charge) or anionic (negative charge). Charges are important because they affect the compatibility of emulsion with mineral aggregates. An anionic emulsion should be used with limestone aggregate that usually bears a positive surface charge. A cationic emulsion should be used with siliceous gravel and sandstone because these aggregates usually bear a negative surface charge. All emulsions are further graded according to their setting rate: rapid setting (RS), medium setting (MS), and slow setting (SS). The type and amount of emulsifying agent controls the rate of setting. Select and use emulsions according to their setting rates. ASTM Standard D3628 recommends that RS emulsions be used for seal coats and penetration macadam pavements. The MS emulsions are recommended for open-graded cold asphalt-aggregate mixtures. SS emulsions are used for tack coats, slurry seals, and dense-graded cold asphalt-aggregate mixtures.

Cutback asphalt is another liquid asphalt that can be used at normal air temperatures without heating. Cutbacks are produced by adding (cutting back) petroleum solvents to asphalt cements instead of water. Cutback asphalts set when the solvent evaporates after being applied to the aggregate. The evaporation rate depends on the type and amount of solvent used in the cutback. Cutbacks have three grades based on relative evaporation rates. Rapid-curing (RC) is produced by adding a high volatility solvent such as gasoline or naphtha. Medium-curing (MC) is produced by adding an intermediate volatility solvent such as kerosene. Slow-curing (SC) is produced by adding an oil of low volatility such as diesel or other gas oil. RC cutbacks set faster than MC which in turn set faster than SC. Cutbacks come in different grades that vary significantly in their consistency. Specifications are given in the ASTM Standards: D2026 for SC, D2027 for MC, and D2028 for RC. Cutbacks are increasingly being replaced by emulsions due to environmental regulations and other concerns. Emulsions release far fewer volatiles into the atmosphere and aren’t as wasteful of high-energy, high cost products. Cutbacks have low flash points and are less effective than emulsions when applied to damp aggregate, pavements or soils. In some areas, cutback use is restricted or banned in specific (hot) months.

Main uses of asphalts

Asphalts are used in two ways. They are either mixed with aggregates at plants then hauled to the paving site and compacted on the road, or they are sprayed in relatively thin layers with or without aggregates. Plant mixed asphalt products are called asphalt concrete mix. These can be produced and laid down hot, using asphalt cements, or cold, using emulsions or cutbacks. These mixes usually contain about 5% asphalt and 95% aggregates by weight. Aggregates give the mix most of its ability to carry or resist loads while the asphalt coats and binds the aggregate structure.

Hot laid mixes, also called hot mix asphalt, are produced by mixing heated aggregates and asphalt cements in special mixing plants. These very strong, stiff mixes are usually used for surface and subsurface layers in highways, airports, parking lots, and other areas which carry heavy or high volume traffic.

Cold asphalt mixes are produced by mixing damp, cold aggregates with emulsions or cutbacks at mixing plants — either stationary plants or portable ones brought to the site. Although not as strong and stiff as hot mix, cold mixes may be more economical and flexible, and less polluting. They are used for areas with intermediate and low traffic, for open graded mixes, and for patching.

Sprayed asphalt applications include asphalt-aggregate applications, usually called surface treatments or seal coats, and asphalt-only applications such as tack coat, prime coat, fog seal, and dust prevention.

Aggregates for asphalt mixtures

The amount of aggregate in an asphalt paving mixture is generally 90%-95% by weight or 75%-85% by volume. Asphalt pavement performance is heavily influenced by aggregates which carry most of the traffic loading. Their suitability for construction depends on size, gradation, toughness, cleanliness, shape, absorption, and affinity to asphalt. Size and gradation (mix of various sizes) are the most important. When aggregates of different sizes are combined, then mixed with asphalt and compacted, the resulting structure should have a reasonable amount of voids. These voids, also called voids in the mineral aggregates (VMA), provide space for asphalt coating and for expansion from temperature changes.

ASPHALT TERMINOLOGY

References for following terms:

http://www.pavementinteractive.org/glossary/

http://www.apai.net/cmdocs/apai/designguide/Chapter\_2B.pdf

On-line Design Guide, Asphalt Paving Association of Iowa, date unspecified

nchrp\_rpt\_673\_HotMixDesignManual2011

Aggregate

A collective term for the mineral materials such as sand, gravel and crushed stone that are used with a binding medium (such as water, bitumen, portland cement, lime, etc.) to form compound materials (such as asphalt concrete, portland cement concrete, etc.).

Asphalt

A dark brown to black cementitious material in which the predominating constituents are bitumens, which occur in nature or are obtained in petroleum processing.

Asphalt binder

The principal asphaltic binding agent in HMA. “Asphalt binder” includes asphalt cement as well as any material added to modify the original asphalt cement properties.

Asphalt cement

Asphalt is produced in a variety of types and grades ranging from hard-brittle solids to near water-thin liquids. The semi-solid form known as asphalt cement is the basic material used in Asphalt Concrete pavements. Liquid asphalt is produced when asphalt cement is blended or 'cut back' with petroleum distillates or emulsified with water and an emulsifying agent.

Asphalt Concrete

Asphalt Concrete is known by many different names: hot mix asphalt, plant mix, bituminous mix, bituminous concrete, and many others. It is a combination of two primary ingredients - aggregates and asphalt cement. The aggregates total 90 to 95 percent of the total mixture by weight. They are mixed with 5 to 10 percent asphalt cement to form Asphalt Concrete.

Asphaltenes

The high molecular weight hydrocarbon fraction precipitated from asphalt by a designated paraffinic naphtha solvent at a specified solvent-asphalt ratio.

Bitumens

A class of black or dark-colored (solid, semi-solid or viscous) cementitious substances, natural or manufactured, composed principally of high molecular weight hydrocarbons, of which asphalts, tars, pitches, and asphaltenes are typical.

Breaking

The phenomenon when asphalt and water separate in an asphalt emulsion, which is the beginning of the curing process.

Cold mix asphalt

Is normally handled, placed, and compacted without heating. This material can be handled cold because it uses liquid asphalts in the form of emulsions and cutbacks that are fluid at room temperature. Once placed, cold mix made with cutback asphalts gradually cure as the solvent evaporates from the asphalt concrete. Many engineers now avoid the use of cutback asphalts because of environmental concerns. Cold mix is economical because it does not require large amounts of energy to heat the mix during production and placement. However, it is difficult to compact thoroughly and in general is not as durable as HMA. Cold mix is sometimes used for base course construction and is also commonly used for patching and repairing pavement.

Composite pavements

Combination HMA and PCC (portland cement concrete) pavements. Occasionally, they are initially constructed as composite pavements, but more frequently they are the result of pavement rehabilitation (e.g., HMA overlay of PCC pavement). Officially, the FHWA “composite pavement” category is defined as a “mixed bituminous or bituminous penetration roadway” of more than 25 mm (1 inch) of compacted material on a rigid base (from the FHWA).

Cutback asphalts are blends of asphalt binder and petroleum solvents.

Dynamic viscosity (also called “absolute viscosity”)

A measure of the viscosity of asphalt with respect to time, measured in poises, conducted at 60°C (140°F).

Emulsion

A suspension of small asphalt cement globules in water. The suspension is assisted by an emulsifying agent.

Emulsifying agent

A substance used in asphalt emulsions to assist the formation of small asphalt cement globules in water by imparting an electrical charge to the surface of the asphalt cement globules so that they do not coalesce.

Flexible pavement

Pavements that are surfaced with bituminous (or asphalt) materials as the surface course. These can be either in the form of pavement surfaces such as a bituminous surface treatment (BST) generally found on lower volume (or lower traffic) roads, or hot mix asphalt (HMA) surfaces generally used on higher volume roads. These types of pavements are called “flexible” since the total pavement structure “bends” or “deflects” due to traffic loads.

Full-depth asphalt

An HMA pavement structure using HMA products for all components. The base material and surface courses are made of HMA instead of aggregate or other material.

HMA

Hot Mix Asphalt. A high quality, thoroughly controlled hot mixture of asphalt binder and aggregate that can be compacted into a uniform dense mass.

Laydown

The portion of the HMA paving process where the HMA is actually placed or “laid down” by the paving machine.

NAPA

National Asphalt Pavement Association. NAPA supports an active research program designed to improve the quality of HMA pavements and paving techniques used in the construction of roads, streets, highways, parking lots, airports, and environmental and recreational facilities. The Association provides technical, educational, and marketing materials and information to its Members, as well as product information to users and specifiers of paving materials. The Association, whose members number more than 1,100 companies, was founded in 1955.

NCAT

National Center for Asphalt Technology. NCAT was established at Auburn University in 1986 with an endowment set up by the NAPA Research and Education Foundation. Its mission is to improve HMA performance through research, education, and information services.

Perpetual pavement

Long-lasting HMA pavement.

Prime coat

An application of asphalt primer to an absorbent surface. Often used to prepare an untreated base for an asphalt surface. The prime coat penetrates or is mixed into the surface of the base and plugs the voids, hardens the top and helps bind it to the overlying asphalt course.

RAP

Reclaimed Asphalt Pavement. RAP is typically generated by (1) milling machines in rehabilitation projects or (2) a special crushing plant used to break down large pieces of discarded HMA pavement.

Seal coat

A collective term for several different kinds of thin surface treatments used to improve the surface texture and protect an HMA surface. Seal coats include fog seals, slurry seals, micro surfacing, and BSTs.

Slurry seal

A homogenous mixture of emulsified asphalt, water, well-graded fine aggregate and mineral filler. Slurry seals are used to fill existing pavement surface defects as either a preparatory maintenance or as a wearing course.

Superpave

Superior Performing Asphalt Pavements. An overarching term for the results of the asphalt research portion of the 1987 – 1993 Strategic Highway Research Program (SHRP). Superpave consists of (1) an asphalt binder specification, (2) an HMA mix design method and (3) HMA tests and performance prediction models. Each one of these components is referred to by the term “Superpave”.

Surface course

The top pavement layer and the layer that comes in contact with traffic.

Tack coat

Asphalt oil, usually an emulsion, applied to existing pavement during repairs or overlay paving to create a bond between the old and new asphalt (NPCA).

Warm-mix asphalt (WMA)

A new, third type of mix, has recently become increasingly popular. In this type of mixture, various different methods are used to significantly reduce mix production temperature by 30 to over 100°F. These methods include (1) using chemical additives to lower the high-temperature viscosity of the asphalt binder; (2) techniques involving the addition of water to the binder, causing it to foam; and (3) two-stage processes involving the addition of hard and soft binders at different points during mix production. WMA has several benefits, including lower cost (since significantly less fuel is needed to heat the mix), lower emissions and so improved environmental impact, and potentially improved performance because of decreased age hardening.

## Descriptions of paving industry practices today

The following is a typical example of current available on-line description of cutback and emulsified asphalt use.

Reference: http://onlinemanuals.txdot.gov/txdotmanuals/scm/selection\_of\_binder.htm#i1001471

All asphalts used in the United States are products of the distillation of crude petroleum. Asphalt is produced in a variety of types and grades ranging from hard and brittle solids to almost water-thin liquids. Asphalt cement is the basis of all of these products. It can be made fluid for spraying from an asphalt distributor by heating, by adding a solvent, or by emulsifying it. When a petroleum solvent, such as naphtha or kerosene, is added to the base asphalt to make it fluid, the product is called a cutback asphalt. When asphalt is broken into minute particles and dispersed in water with an emulsifier, it becomes an emulsified asphalt. The tiny droplets of asphalt remain dispersed until the emulsified asphalt breaks. All three of these forms (asphalt cement, cutbacks, and emulsions) may be used for seal coat and surface treatment work.

Reference: nchrp\_rpt\_673\_HotMixDesignManual2011.pdf

Materials Used in Making Asphalt Concrete

Asphalt concrete is composed primarily of aggregate and asphalt binder. Aggregate typically makes up about 95% of a hot-mix asphalt (HMA) mixture by weight, whereas asphalt binder makes up the remaining 5%. *By volume, a typical HMA mixture is about 85% aggregate, 10% asphalt binder, and 5% air voids*. Small amounts of additives and mixtures are added to many HMA mixtures to enhance their performance or workability.

Asphalt binder holds the aggregate in HMA together—without asphalt binder, HMA would simply be crushed stone or gravel. Asphalt binder is the thick, heavy residue remaining after kerosene, gasoline, diesel oil, and other fuels and lubricants are refined from crude oil. Asphalt binder consists mostly of carbon and hydrogen, with small amounts of oxygen, sulfur, and several metals. The physical properties of asphalt binder vary tremendously with temperature. At high temperatures, asphalt binder is a fluid with a consistency similar to that of motor oil. At room temperature most asphalt binders will have the consistency of putty or soft rubber. At subzero temperatures, asphalt binder can become very brittle—asphalt samples stored in a freezer will shatter like glass if dropped on a hard surface. Many asphalt binders contain small percentages of polymer to improve their physical properties; these materials are called polymer-modified binders. Much of the current asphalt binder specification used in the United States was designed to control changes in consistency with temperature.

Asphalt Concrete Mixtures

Asphalt concrete mixtures can be classified in many different ways. Perhaps the most general type of classification is by whether or not the mix must be heated prior to transport, placement, and compaction. HMA concrete, or simply HMA, must be thoroughly heated during mixing, transport, placement, and compaction. The asphalt binder used in HMA is quite stiff at room temperatures, so that once this type of asphalt concrete cools it becomes stiff and strong enough to support heavy traffic. Cold mix asphalt, on the other hand, is normally handled, placed, and compacted without heating. This material can be handled cold because it uses liquid asphalts in the form of emulsions and cutbacks that are fluid at room temperature. Asphalt emulsions are mixtures of asphalt, water, and special chemical additives called surfactants that allow the other two materials to be blended into a stable liquid. When blended with aggregate, the emulsion “breaks,” meaning the asphalt separates from the water and thoroughly coats the aggregate. Cutback asphalts are blends of asphalt binder and petroleum solvents. Once placed, cold mix made with cutback asphalts gradually cure as the solvent evaporates from the asphalt concrete. Many engineers now avoid the use of cutback asphalts because of environmental concerns. Cold mix is economical because it does not require large amounts of energy to heat the mix during production and placement. However, it is difficult to compact thoroughly and in general is not as durable as HMA. Cold mix is sometimes used for base course construction and is also commonly used for patching and repairing pavement. A new, third type of mix—called warm-mix asphalt (WMA)—has recently become increasingly popular. In this type of mixture, various different methods are used to significantly reduce mix production temperature by 30 to over 100°F. These methods include (1) using chemical additives to lower the high-temperature viscosity of the asphalt binder; (2) techniques involving the addition of water to the binder, causing it to foam; and (3) two-stage processes involving the addition of hard and soft binders at different points during mix production. WMA has several benefits, including lower cost (since significantly less fuel is needed to heat the mix), lower emissions and so improved environmental impact, and potentially improved performance because of decreased age hardening. There is some concern that WMA might in some cases be more susceptible to moisture damage, but this has yet to be clearly demonstrated.

Asphalt Concrete Pavements

Asphalt concrete pavements are engineered structures composed of several different layers. Because asphalt concrete is much more flexible than portland cement concrete, asphalt concrete pavements are sometimes called flexible pavements. The visible part of an asphalt concrete pavement, the part that directly supports truck and passenger vehicles, is called the surface course or wearing course. It is typically between about 40 and 75 mm thick and consists of crushed aggregate and asphalt binder. Surface course mixtures tend to have a relatively high asphalt content, which helps these mixtures stand up better to traffic and the effects of sunlight, air, and water. Surface course mixtures are usually made using maximum aggregate sizes less than 19 mm, which helps to provide for a quiet ride. Also, using aggregate sizes larger than 19 mm can make it more difficult to obtain mixtures with sufficient asphalt binder contents to provide adequate durability for surface course mixtures, since the lower aggregate surface area of these aggregates results in a lower demand for asphalt binder. On the other hand, the lower binder content needed for these mixtures can make them more economical than mixtures made using smaller aggregates. Below the surface course of a flexible pavement is the base course. The base course helps provide the overall thickness to the pavement needed to ensure that the pavement can withstand the projected traffic over the life of the project. Base courses may be anywhere from about 100 to 300-mm thick. In general, the higher the anticipated traffic level on a pavement, the thicker the pavement must be, and the thicker the base course. Sometimes an intermediate course is placed between the surface and base courses of a flexible pavement system. This is sometimes called a binder course. Typically 50 to 100 mm in thickness, it consists of a mixture with intermediate aggregate size and asphalt binder content. *The surface, base, and intermediate courses together are referred to as bound material or bound layers, because they are held together with asphalt binder*. In a typical asphalt concrete pavement, the bound layers are supported by a granular sub-base that in turn lays over the subgrade.

The asphalt binder contained in reclaimed asphalt product (RAP) is likely much harder than new asphalt binders used in HMA mix designs and, when significant amounts of RAP are added to a mix, the binder from the RAP will blend with the new asphalt binder added to the mix to produce a blended binder that can be substantially harder than the new binder added to the HMA mixture. For this reason, the amount of RAP that can be added to a mixture can be limited not only by variability, but also by the blended binder grade.

Types of Asphalt pavement

http://www.pavementinteractive.org/2010/10/26/warm-mix-a-hot-topic/

How warm mix differs from hot mix asphalt

Warm mix asphalt (WMA) can be thought of as Hot Mix Asphalt’s cooler relative… based on the temperature required to produce it. Warm mix asphalt is produced in the 212 to 275 degrees Fahrenheit range, while hot mix is made between 275 to 350 degrees Fahrenheit. This is made possible by a change in production process, either using a foaming technique, or including an additive, both of which provide the desired effect of reducing the production temperature of the mix.

How warm mix is made

As mentioned, there are two main methods to produce warm mix asphalt. One method involves foaming, which works by adding a small amount of water to the asphalt mix. Water expands dramatically in volume when it turns to steam, which expands the binder through foaming and reduces the mix viscosity. Foaming can be achieved by different methods, the most widely adopted involves injecting water through a pump or nozzle.

The second main method to produce warm mix is through additives. These can be either organic or chemical. Organic additives are typically a type of wax that is added to the asphalt binder which reduces the asphalt binder viscosity. Chemical additives tend to be surfactants, which improve the adhesion between the binder and aggregate. Some additives are added to the mix as an emulsion in water, and will also have a foaming effect upon the asphalt binder.

Superpave

Reference: www.clemson.edu/t3s/workshop/2004/pdf files/Superpave-PG...

October 30, 2003 T3S - Superpave for Low Volume Roads - R. Horan 1 Performance Graded Asphalt Binders Bob Horan, P.E. Consulting Engineer Mechanicsville, VA

Hot-mix asphalt seems to be making more use of performance grade (PG) binders that specify performance results in a temperature range through which the asphalt must meet certain physical properties to resist rutting and cracking. The ‘Superpave’ asphalt binder specification is a performance grading system is based on climate conditions. Performance graded binder specifications have resulted in higher quality binders that allow appropriate grade of binder for a specific location based on air and pavement temperature, loading conditions, and traffic speed.

http://www.asphaltpavement.org/ThinIsIn

U.S. sees spike in use of warm mix asphalt

On-line article by National Asphalt Pavement Association, January 29, 2014

In the latest survey of the use of recycled materials and warm-mix asphalt usage by the U.S. asphalt pavement industry, nearly a quarter of all asphalt mixtures produced in the 2012 construction season were produced using warm-mix asphalt (WMA) technologies. The survey, conducted by the National Asphalt Pavement Association (NAPA) under contract to the Federal Highway Administration (FHWA), found that the 1,141 U.S. asphalt plants queried produced about 86.7 million tons of WMA during the 2012 construction season. This marks a 416 percent increase in the use of warm mix since the survey was first conducted in 2009. A copy of the full survey is available at www.AsphaltPavement.org/recycling. Because WMA is produced at a lower temperature than traditional asphalt mixes, it uses less energy to produce, reduces emissions, improves worker safety, and offers construction benefits. U.S. Secretary of Transportation Anthony Foxx commented in January during the 2014 Transportation Research Board Annual Meeting that the use of WMA is expected to save $3.6 billion in energy costs alone by 2020. Asphalt pavements also continue to use increasing amounts of recycled and reclaimed materials. The survey found that about 68.3 million tons of reclaimed asphalt pavement (RAP) and 1.86 million tons of recycled asphalt shingles (RAS) were used in new asphalt pavement mixes in the United States during in 2012. For the first time since the start of this survey in 2009, the amount of RAP and RAS used by producers exceeded the amount collected. The use of RAP and RAS during the 2012 paving season translates to a savings of 21.2 million barrels of liquid asphalt binder, saving taxpayers some $2.2 billion. When reclaimed asphalt pavement and shingles are reprocessed into new pavement mixtures, the liquid asphalt binder in the recycled material is reactivated, reducing the need for virgin asphalt binder. Using reclaimed materials also reduces demands on aggregate resources. “Ensuring high performance roads at a cost-effective price has always been a goal for the asphalt pavement industry. It has spurred us to continue to look for new solutions and to put innovations into practice,” said NAPA President Mike Acott. “This survey reflects how the industry is rapidly putting sustainable innovations, such as warm-mix asphalt, to use to ensure that drivers get the smooth, dependable roads they want at a price taxpayers can afford.” Compared to previous surveys, conducted annually since the 2009 construction season, the use of recycled materials has continued to increase. In 2012, RAS usage reached 1.86 million tons — a 56 percent increase over 2011, and a 165 percent increase since 2009. Since 2009, RAS usage has been reported in 37 states. RAS includes both manufacturer scrap shingles and post-consumer roofing shingles. RAP usage also continued to climb, increasing to 68.3 million tons in 2012, a nearly 22 percent increase from 2009. More than 99 percent of asphalt pavement reclaimed from roads went back into new roads. In the survey, 98 percent of producers reported using RAP in their mixes. The 2012 survey also asked for the first time about the use of ground tire rubber, steel and blast furnace slags, and other recycled materials. Although national estimates of these products’ usage were not calculated, more than 1 million tons of other recycled materials was reported as being incorporated into asphalt mixtures. The survey was conducted in mid-2013. Results from 213 companies with 1,141 plants in 48 states and Puerto Rico, along with data from 36 State Asphalt Pavement Associations, were used to calculate industry estimates for total tonnage.

FHWA (2013). Every Day Counts: Warm Mix Asphalt. Federal Highway Administration. Washington, DC.

https://www.fhwa.dot.gov/everydaycounts/technology/asphalt/intro.cfm

http://www.fhwa.dot.gov/pavement/sustainability/resources.cfm

http://www.fhwa.dot.gov/everydaycounts/events/trb/docs/wma/industry\_wma\_article\_published.pdf

http://www.fhwa.dot.gov/pavement/asphalt/index.cfm

Warm-mix asphalt is a viable alternative to traditional hot-mix asphalt that reduces air emissions, fuel consumption and provides other benefits to our clients and communities. Through variations in the production process, warm-mix asphalt (WMA) stiffness is reduced, relative to hot-mix asphalt (HMA) at the same temperature, allowing it to be placed and compacted at lower temperatures during paving operations. Warm-mix asphalt is typically produced at temperatures that are 50° F to 100° F lower than those used for traditional hot-mix asphalt. Typically, asphalt paving temperatures are in the range of 280 to 320°F. Warm-mix technologies offer ways to lower these temperatures by 50°F or more, saving fuel and reducing production of greenhouse gases and other emissions. Working in cooperation with the Federal Highway Administration, state Departments of Transportation, and other key stakeholders, implementation of warm-mix asphalt technologies is rapidly gaining ground across the country.

Guidelines for Using Prime and Tack Coats

Publication No. FHWA-CFL/TD-05-002 July 2005; FHWA - Central Federal Lands Highway Division

http://www.cflhd.gov/resources/materials/documents/PrimeTackCoats.pdf

## List of possible contacts for more information

FHWA

http://www.fhwa.dot.gov/everydaycounts/events/trb/docs/wma/industry\_wma\_article\_published.pdf

For more information, contact Matthew Corrigan at 202–366–1549 or matthew.corrigan@dot.gov,

Dave Newcomb at 301–731–4748, ext. 104, or dnewcomb@hotmix.org

Matthew Corrigan is an asphalt pavement engineer with FHWA’s Office of Pavement Technology. He is FHWA’s coordinator for investigation and implementation of WMA technologies, cochairman of the Warm Mix Asphalt technical Working Group, and manager of the Mobile Asphalt Lab. Corrigan is a graduate of The Pennsylvania State University with a degree in civil engineering and is a licensed professional engineer in the Commonwealth of Virginia

Dave Newcomb is the vice president for research and technology at NAPA. He is a licensed professional engineer in Minnesota.

National Asphalt Pavement Association

Annual Asphalt Pavement Industry Survey on Recycled Materials and Warm-Mix Asphalt Usage: 2009–2013 Oct 2014

FHWA Contracted Report, Contract or Grant No.DTFH61-13-H-00027

Office of Asset Management, Pavement and Construction; 1200 New Jersey Ave.SE; Washington, DC 2059

NAPA authors:

Kent R. Hansen, P.E. Director of Engineering Ext. 125

Audrey Copeland, Ph.D., P.E Vice President for Engineering, Research & Technology Ext. 104

audrey@asphaltpavement.org

khansen@asphaltpavement.org

National Asphalt Pavement Association; 5100 Forbes Blvd.; Lanham, MD USA 20706-4407; 888.468.6499

NAPA research brochure (http://www.asphaltpavement.org/PDFs/NAPA\_Research\_Brochure\_2015.pdf) lists a project targeted through August 2015 to ‘Develop an Industry Average Environmental Product Declaration’; with purpose to create an industry average Environmental Product Declaration for asphalt mixtures

Funding Level: $100,000, Research Lead: Amlan Mukherjee

Another project is listed in the NAPA research brochure has a goal to compare and contrast asphalt plant stack emissions using warm-mix technologies. Multiple field trials were conducted to compare asphalt plant stack emissions running various warm mix technologies with control hot-mix emissions. While reduction in fuel consumption and carbon dioxide emissions were apparent, reduction in other criteria air pollutant emissions were less noticeable and that emissions of all criteria air pollutants were observed to generally decrease using warm-mix technologies. It indicates that NAPA drafted a Special Report comparing criteria air pollutant emissions of warm-mix technologies and hot-mix technologies - available upon request from NAPA and that the report was not released to the public because additional stack emissions testing is needed to determine the extent of criteria air pollutant reduction with the use of warm-mix technologies.

National Center for Asphalt Technology (NCAT) in Auburn, Alabama, which originally was endowed by industry and today is directed by a public-private partnership. With its 1.7-mile pavement test track and its 40,000-square-foot research facility, NCAT conducts a productive, $5 million per year research program that focuses on innovations that directly affect and improve the roads we drive on every day

The Asphalt Institute, http://www.asphaltinstitute.org/about-us/

The Asphalt Institute is the international trade association of petroleum asphalt producers, manufacturers and affiliated businesses. Our mission is to promote the use, benefits and quality performance of petroleum asphalt, through engineering, research, marketing and educational activities, and through the resolution of issues affecting the industry.

Founded in 1919, the Institute’s members represent 90% of the liquid asphalt produced in North America and an increasing percentage in international markets. We provide five essential areas of strategic focus to support our members in the following areas: Member Connectivity; Asphalt Promotion; Environmental Oversight; Technical Leadership; Educational Expertise

## MSDS information examples and summary

An on-line search for Material Data Safety Sheets (MDSD/ SDS) for different paving products was done to help validate the chemical composition information applied in the EPA existing emissions estimation method for paving using cutback or emulsified asphalt. Such information can be useful to establish national default emission factors. The following table summarizes chemical composition data from several MSDS available on-line. While the table summary for cutback focuses on RC, rapid cure - some MSDS information for medium and slow-cure types of cutback asphalt are included below the summary table and indicates chemical composition typically includes asphalt, kerosene, diesel fuel, recycled tire rubber – all with less evaporative rates than the rapid cure.

The chemicals in Stoddard solvent are similar to those in white spirits. Stoddard solvent is a mixture commonly referred to as dry cleaning safety solvent, naphtha safety solvent, petroleum solvent, PD-680, varnoline, and spotting naphtha. Other synonyms are: Petroleum Distillates; Petroleum Naphtha; Naphtha, Solvent; Mineral Spirits. It also goes by the registered trade names Texsolve S and Varsol 1.

Density is 6.4-6.7 lb/gal (http://www.safety-kleen.com/File%20Library/msds/82341rev8-12.pdf)

In the MSDS, the units of the concentration percent is seldom confirmed on the sheet as whether percent by volume or percent by weight.

The following references help form the assumption that the concentration percentages are mass percentages.

Concentration, percent by weight is assumed unless otherwise confirmed.

http://compass.astm.org/EDIT/html\_annot.cgi?D4124+09#s00061

ASTM DESIGNATION: D140/D140M – 15 Standard Practice for Sampling Bituminous Materials

Scope

1.1 This practice applies to the sampling of bituminous materials at points of manufacture, storage, or delivery.

ASTM DESIGNATION: D1461 – 11 Standard Test Method for Moisture or Volatile Distillates in Bituminous Paving Mixtures

Significance and Use

3.1 This test method is used for determining either the amount of moisture or the amount of volatile petroleum distillates in bituminous paving mixtures.

Calculate diluent % per wgt of sample

Report the moisture content as the weight percent water content in accordance with 9.1.

Report the volatile distillates as the weight percent diluent content in accordance with 9.2.

D6307 – 10 Standard Test Method for Asphalt Content of Hot-Mix Asphalt by Ignition Method

Significance and Use

This test method can be used for quantitative determination of asphalt content in HMA paving mixtures and pavement samples for quality control, specification acceptance, and mixture evaluation studies. This test method does not require the use of solvents.

Report Mass of HMA sample before and after ignition (nearest 0.1 g), Measured asphalt content

DESIGNATION: D4125/D4125M – 10 Standard Test Methods for Asphalt Content of Bituminous Mixtures by the Nuclear Method

The asphalt content of a material expressed as a percentage, is the ratio of the mass of asphalt in a given mass of material to the total mass of the sample or to the mass of the solid material particles.

DESIGNATION: D4124 – 09 Standard Test Method for Separation of Asphalt into Four Fractions

Scope

1.1 This test method covers the separation of four defined fractions from petroleum asphalts. The four fractions are defined as saturates, naphthalene aromatics, polar aromatics, and iso-octane insoluble asphaltenes. This method can also be used to isolate saturates, naphthene aromatics, and polar aromatics from distillate products such as vacuum gas oils, lubricating oils, and cycle stocks. These distillate products usually do not contain asphaltenes.

Calculation and Report

12.1 Calculate the mass percentages recovered for each fraction collected, and the total recovered material, based on the mass of the original sample, asphalt, as follows.... Report fraction mass percentages to the nearest 0.1-%mass.

Distillation test is used to separate the asphalt cement from the diluent (solvent). It determines the amount of condensate driven off at specified temperatures and shows both the volatility characteristics of the diluent and its quantity. The asphalt residue from RC and MC cutbacks is then tested for penetration, ductility, and solubility. For SC cutbacks only the total condensate is measured, and only kinematic viscosity is measured on the residue. SC cutbacks are also tested for solubility.

http://www.pavementinteractive.org/article/Binder-Content/

http://www.pavementinteractive.org/article/mixture-characterization-tests/

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Asphalt Cement |  |  |  |  |  |  |
| Product Supplier | Product Name | MSDS/SDS ID  Date | Chemical Family | Ingredients/  Relative Density (SG) | CAS | Concentration% |
| Marathon | Marathon Petroleum Asphalt (1) | 0108MAR019, 05/27/2015 | Asphalt | Asphalt  Asphalt, Air-rectified  Styrene/butadiene Copolymer  Sulfur Compounds  Polyphosphoric Acids  Polyamine  Naphthalene  Hydrogen sulfide  Polycyclic Aromatic Hydrocarbons  Specific Gravity / Relative Density0.95-1.13 @ 15.6°C /60F (ASTM D70) | 8052-42-4  64742-93-4  9003-55-8  Mixture  8017-16-1  Proprietary  91-20-3  7783-06-4  Mixture | 80-100 (wgt, all)  0-20  0-9  1-5  0-1  0-1  0.01-0.15  <0.1  <0.01 |
| Asphalt & Fuel Supply | Asphalt Cement (2) | 918446 V 01  01/27/2014 | Asphalt Cement | Asphalt  Asphalt, oxidized  Distillates, petroleum residues  Vaccum Tower Bottoms  Hydrogen sulfide  Polycyclic Aromatic Hydrocarbons  Specific gravity0.9 - 1.5 | 8052-42-4  64742-93-4  68955-27-1  64741-56-6  7783-06-4  130498-29-2 | 0 – 100 (wgt)  0 - 100  0 – 100 (vol)  0 – 100 (vol)  <0.1 (vol)  <0.1 (vol) |
| TESORO | Asphalt (3) | 888100004477 V1.12  11/29/2010 |  | Asphalt  Hydrogen Sulfide  Density: 0.9 – 1.05 g/mL (approx. 8.34 lb/gal) | 8052-42-4  7783-06-4 | 100  Trace |
|  |  |  |  |  |  |  |
| **Cutback RC Asphalt** | Also see MSDS values below for MC and SC |  |  |  |  |  |
|  |  |  |  |  |  |  |
| Valero | RC Cutback Asphalt (4) | 2013 V04  01/10/2013 |  | Asphalt  Naphtha (petroleum), heavy straight-run  Sulphur  Xylene  Toluene  Naphthalene  Benzene  Hydrogen sulfide  Polycyclic Aromatic Hydrocarbons  Specific gravity0.933-0.969 (Water=1) | 8052-42-4  64741-41-9  7704-34-9  1330-20-7  108-88-3  91-20-3  71-43-2  7783-06-4  130498-29-2 | 70-90  10-30  <1  <1  <0.6  <0.5  <0.2  <0.1  <0.1 |
| Asphalt Emulsion Industries | Cutback Asphalt, Rapid-Cure (RC), All Grades (5) | CUT-SDS-1  06/01/2015 |  | Petroleum Asphalt  Stoddard Solvent  Hydrogen Sulfide  Polycyclic Aromatic Hydrocarbons  Relative Density >1 (Water = 1) | 8052-42-4  8052-41-3  7783-06-4  130498-28-2 | 60-90  10-40  0-0.1  <0.1 |
|  |  |  |  |  |  |  |
| Martin Asphalt Company | RC-250 | Jan 2007 | PETROLEUM ASPHALT / PETROLEUM SOLVENT BLEND | Asphalt  Mineral Spirits  Naptha  Specific Gravity: 0.9-.99 | 8052-42-4  64742-88-7  64742-95-6 | 50-80  5-20  5-15 |
| Mohawk Asphalt Emulsions | Petroleum Asphalt RC Cutback | UN1999  06/04/2009 |  | Asphalt  Solvent naphtha (petroleum),  light aliphatic  Specific Gravity: 1.0 @ 60°F (Approx) | 8052-42-4  64742-89-8 | 50-80  20-50 |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |
| **Emulsified Asphalt** |  |  |  |  |  |  |
|  |  |  |  |  |  |  |
| Marathon | Marathon Petroleum Anionic Emulsified Asphalt (6) | 0137MAR019  05/19/2015 |  | Asphalt  Distillates (petrolm), straight-run middle Sulfur Compounds  Polymer Modifier (SBS or SBR)  Anionic Emulsifier  Polyamine  Naphthalene  Polycyclic Aromatic Hydrocarbons  Hydrogen sulfide  Relative Density0.95-1.05 @ 15.6°C | 8052-42-4  64741-44-2  Mixture  Mixture  Mixture  Proprietary  91-20-3  Mixture  7783-06-4 | 30-75 (wgt, all)  0-40  0.5-5.0  0-5  0.1-4  0-1  0.01-0.2  <0.1  0-0.1 |
| Marathon | Marathon Petroleum Cationic Emulsified Asphalt (7) | 0138MAR019  05/19/2015 |  | Asphalt  Stoddard Solvent  Sulfur Compounds  Polymer Modifier (SBS or SBR)  Cationic Emulsifier (contains alkylamines) Naphthalene  Polycyclic Aromatic Hydrocarbons  Hydrogen sulfide  Relative Density0.9-1.05 | 8052-42-4  8052-41-3  Mixture  Mixture  Mixture  91-20-3  Mixture  7783-06-4 | 25-75  0-10  0-5  0-5  0.1-3.0  0.01-0.2  < 0.1  0-0.1 |
| Asphalt Emulsion Industries | Emulsified Asphalt,Cationic, All Grades (8) | EMU-SDS-1,  06/01/2015 |  | Petroleum Asphalt  Water  Fuel Oil Flux  Stoddard Solvent  Hydrochloric Acid  SBR Co-Polymer  Dispersion Polymer Modifier  Fatty Amine Emulsifier  Hydrogen Sulfide  Relative Density>1 (Water = 1) | 8052-42-4  7732-18-5  68334-30-5  8052-41-3  7647-01-0  9003-55-8  Mixture  Mixture  7783-06-4 | 38-72  62-28  0-6  0-6  0.1-2.5  0-4.5  0-5  0.1-2.5  0-0.1 |
| U.S. Oil & Refining Co. | Asphalt Emulsions, All Grades (9) | 951,  09/03/2009 |  | Petroleum Asphalt  Water  Naphtha  Polymer Additive  Organic Amine Emulsifier Hydrochloric Acid  Hydrogen Sulfide  SPECIFIC GRAVITY:1.0 to 1.3 (Water = 1) (@ 60°F) | 8052-42-4  7732-18-5  64741-46-4  Mixture  Mixture  7647-01-0  7783-06-4 | 57 – 75  55 – 75  0 – 10  0 – 5  0 – 6  0 - 5  Trace |

Product name synonyms include:

1. Asphalt Cement (ACs); Asphalt Flux; Penetration Grade Asphalts (Pen); Roofing Flux; Recycling Agents (RAs); Marathon PERFORMAC™ Asphalt Binder; PERFORMAC™ PG82-22PM; PERFORMAC™ 500; PG46-28; Performance Graded Asphalt Binder ; PG46-34, PGxx-xx; …

Additional information: Petroleum Asphalt is a solid carbon material produced from high temperature vacuum distillation of crude oil. Composition varies depending on source of crude and specifications of final product. Can contain minor amounts of sulfur, nitrogen and oxygen compounds as well as trace amounts of heavy metals such as nickel, vanadium and lead. Composition varies depending on source of crude. Polycyclic aromatic hydrocarbons (3-7 ring) have been found to be present in trace concentrations (<0.01%).

2. PG Grade Asphalt, Pen Grade Asphalt, VTB, Saturant, Flux. Additional information:All concentrations are in percent by weight unless ingredient is a gas. Gas concentrations are in percent by volume.

3. Pitch, Paving Asphalt, Performance Graded Asphalt, (PG) PG 52-28, PG 58-22, PG 64-25, 888100004477

4. Rapid Cure Asphalt, RC Asphalt, Cutback Asphalt, RC-250, RC-800, RC-3000, Road Asphalt, Bitumen, Road Oil. Additional information: Physical state is liquid.

5. Rapid Cure Asphalt, RC Asphalt, Cutback Asphalt, Road Asphalt, Road Oil, RC-70, RC-250, RC-400, RC-800, RC-3000. Additional information: Liquid above 140oF. Viscous liquid at 70oF.

6. Anionic Emulsified Asphalt; AE-F; AE-P; AE-PL; AE-T; AE-3; AE-60; AE-90; AE-150; AE-200; AE-300; EA-90; EA-150; EA-300; HFE-90; HFE-150; HFE-300; HFMS-2; HFP; HFRS-1; HFRS-2; HFRS-2P; MS-2; MS-3; MWS-90; MWS-150; MWS-300; PEA; PEP; RS-1; RS-2; RS-2L; RS-2P; RS-3; SS-1; SS-1H; SS-1HL; SS-1HP; SS-1M; HF Series.

Additional information: This product is an Anionic Emulsified Asphalt mixed with varying proportions of No. 2 fuel oil and an anionic emulsifier. May contain polymer modifiers. Composition varies depending on source of crude and specifications of final product. May contain minor amounts of sulfur, nitrogen and oxygen containing compounds.

7. AE-TC; CMS-2 (E-5); CMS-2R; CMS-2S; CRS-1P; CRS-2; CRS-2 (E-3); CRS-2 PM, (E-3M); CRS-2L; CRS-2P; CRSP; CSS-H (E-8C); CSS-1; CSS-1H; E-12.

Additional information: Physical state is liquid.

8. CRS-1, CRS-1h, CRS-2, CRS-2h, CRS-2L, CRS-2P, CMS-2, CMS-2N, CSS-1h, CQS-1hLM, CQS-1hLM Flex, Novabond™, Thimaco, Fibermat™, Tack Coat, Tack Coat (diluted 30-50% with water), NTT, Non-Tracking Tack, Cold In-Place Recycling Emulsion, IPR Emulsion

9. Asphalt Emulsions (all grades), Emulsified Asphalts (all grades), Cationic Emulsified Asphalt (all grades). Additional information: Physical state is liquid.

**Cutback Asphalt - Medium, Slow Cure**

MC All Grades, SC All grades

SDS, Marathon, SDS IN No: 0148MAR019, 05/19/2015

Specific Gravity / Relative Density0.87-1.12 @ 15.6°C (60F) (ASTM D70)

Ingredients: CAS %

Asphalt 8052-42-4 50-85

Residues (petroleum), Vacuum 64741-56-6 0-50

Fuel Oil, Residual 68476-33-5 0-50

Kerosine, Petroleum 8008-20-6 0-45

Distillates (petroleum), straight-run middle 64741-44-2 0-30

Sulfur Compounds Mixture 0.5-5

Polyamine Proprietary 0-1

Polycyclic Aromatic Hydrocarbons Mixture <1

Naphthalene 91-20-3 0.01-0.2

Hydrogen sulfide 7783-06-4 0-0.1

MC Cutback Asphalt, All Grades

MSDS #211, Asphalt & Fuel Supply,

Specific Gravity 0.96 to 1.01 (Water = 1)

Ingredients: CAS %

Asphalt 8052-42-4 50 - 85

Distillates (petroleum), light hydrocracked gasoil 64741-77-1 0 - 50

Distillates, petroleum residues vacuum 68955-27-1 0 - 45

Light Cycle Oil 64741-59-9 0 - 15

Distillates (petroleum), light naphthenic 64741-52-2 0 - 15

Distillates (petroleum), heavy naphthenic 64741-53-3 0 - 15

Xylene (o,m,p isomers) 1330-20-7 <1

Toluene 108-88-3 <1

Ethylbenzene 100-41-4 <0.5

Hydrogen Sulfide 7783-06-4 <0.3

Naphthalene 91-20-3 <0.2

Benzene 71-43-2 <0.2

Polycyclic Aromatic Hydrocarbons 130498-29-2 <0.1

MC and SC Cutback Asphalts, varying grades

MSDS Meigs Paving Asphalts & Emulsions, May 9 2007

Density: 7.9 – 9.4 lbs/gal

Volatile Compounds (by volume) <50%

Ingredients: CAS %

Petroleum Asphalt 8052-42-4 55-96

Hydrogen Sulfide 7783-06-4 <1

Polynuclear Aromatic Hydrocarbons (PAHs) N/A trace

Petroleum Distillate N/A 0-45

MC Cutback Asphalt, multiple grades

MSDS #211, Valero, 01-10-2013

Specific gravity0.96 - 1.01 (Water=1)

Ingredients: CAS %

Asphalt 8052-42-4 50 - 85

Distillates (petroleum), Light Hydrocracked 64741-77-1 0 - 50

Distillates (petroleum), petroleum residues vacuum 68955-27-1 0 - 45

Distillates (petroleum), heavy naphthenic 64741-53-3 0 - 15

Light cycle oil 64741-59-9 0 - 15

Light naphthenic distillate (petroleum) 64741-52-2 0 - 15

Toluene 108-88-3 <1

Xylene 1330-20-7 <1

Ethylbenzene 100-41-4 <0.5

Hydrogen sulfide 7783-06-4 <0.3

Benzene 71-43-2 <0.2

Naphthalene 91-20-3 <0.2

Polycyclic Aromatic Hydrocarbons 130498-29-2 <0.1

Cutback Asphalt, Slow Cure

SC-70 Liquid Asphalt

MSDS# 53472E, Shell, 06/28/2007

Density: ca. 1.018 g/cm3 at 25 °C / 77 °F

Ingredients: CAS %

Distillates (petroleum), vacuum 70592-78-8 4 0.00 - 100.00%

Distillates (petroleum), heavy naphthenic 64741-53-3 0.00 - 40.00%

Distillates (petroleum), straight-run, middle 64741-44-2 0.00 - 35.00%

Kerosine 8008-20-6 0.00 - 35.00%

Residues (petroleum), vacuum 64741-56-6 0.00 - 60.00%

SC Cutback Asphalt, multiple grades

MSDS #210 Valero, 01-10-2013

Specific gravity0.96 - 1.01 (Water=1)

Ingredients: CAS %

Asphalt 8052-42-4 0 - 100

Gas oil 64741-44-2 2 0 - 60

Kerosine (Petroleum) 8008-20-6 2 - 10

Naphthalene 91-20-3 0 - 3

Nonane 111-84-2 0 - 3

Heptane 142-82-5 0 - 2

Hexane (Other Isomers) Mixture 0 - 2

Octane 111-65-9 0 - 2

n-Hexane 110-54-3 0 - 2

Ethylbenzene 100-41-4 <0.5

Hydrogen sulfide 7783-06-4 <0.5

Toluene 108-88-3 <0.5

Xylene 1330-20-7 <0.5

Benzene 71-43-2 <0.3

Polycyclic Aromatic Hydrocarbons 130498-29-2 <0.