West Coast Climate
& Materials Management Forum

ASPHALT

Climate Friendly Purchasing Toolkit

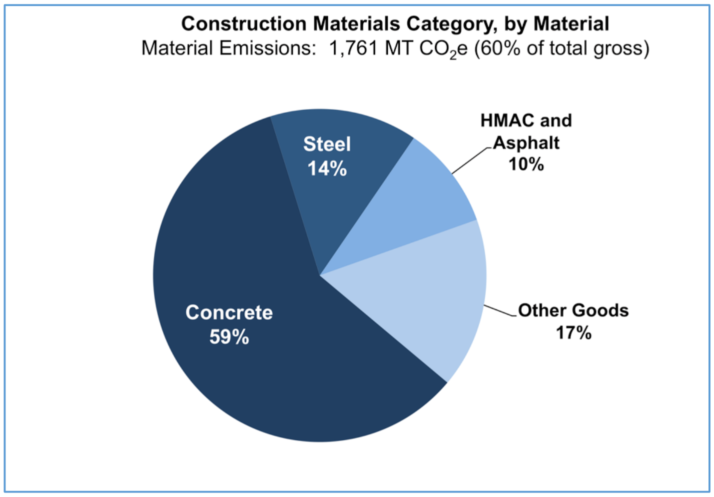
WEST COAST CLIMATE & MATERIALS MANAGEMENT FORUM

Asphalt Concrete Pavement

Local governments are responsible for a wide-variety of construction activities building and maintaining a city's infrastructure, such as roads, pipes, and public buildings. These types of construction commonly use large quantities of concrete and asphalt. Not surprisingly, construction and maintenance activities, and specifically emissions associated with the production of concrete and asphalt, are a common, significant source of indirect GHG emissions for local governments.

This section of the Climate-Friendly Purchasing Toolkit is focused on two currently available and largely accepted measures for reducing GHG emissions from asphalt pavement production:

- Warm Mix Asphalt Concrete Pavement (WMAC or WMA)
- Reclaimed Asphalt Pavement (RAP)



Good Company on behalf of Portland Bureau of Transportation (2009). *Vancouver Bridge Lifecycle GHG Assessment*

Why Asphalt Concrete Pavement?

Asphalt concrete is commonly used in road construction by state and local governments. It's made up of roughly 95% aggregate, such as sand, gravel, and crushed rock, and 5% binder which is typically made of bitumen, a semi-solid form of petroleum. Hot mix asphalt concrete (HMAC) has been the standard for road surfacing and is widely used, understood, and well tested for performance and durability.

Sources of energy use and GHG emissions from asphalt production include:

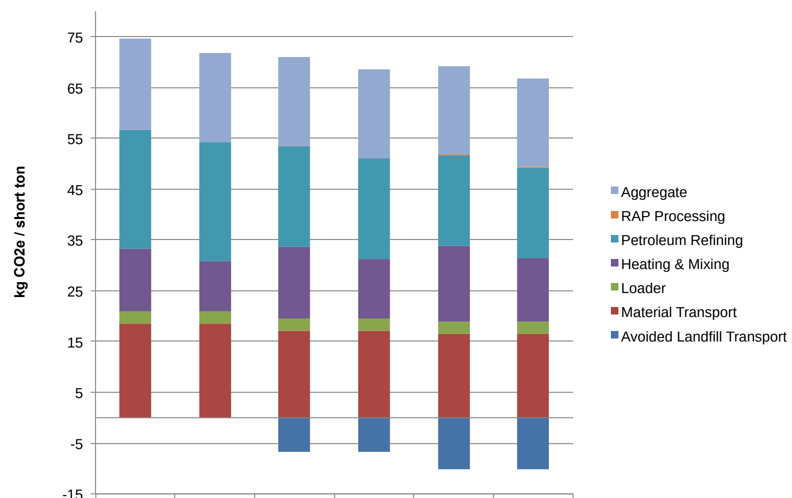
- Crude oil extraction, transport, and refining for the asphalt binder
- Quarrying, hauling, crushing, and screening of aggregates
- Handling, storing, drying, mixing, and preparation of materials for installation[i].
- Transportation of the asphalt from the producer's gate to the job site.

HMAC is an energy and GHG-intensive material and process because it requires heating the binder to between 300° and 350° Fahrenheit (F). There is also considerable energy used to extract and refine the petroleum-based binder. Therefore the immediate focus of GHG emissions reduction measures for asphalt concrete involves reducing the processing temperature and identifying lower-carbon binder substitutes.

GHG Comparisions

Figure 1 is a summary of greenhouse gas emissions and credits relative to baseline conditions (i.e. virgin materials) for various mixes using WMAC and RAP. As can be seen on Figure 2, Net emissions are lowest for those scenarios with the greatest percentages of recycled content. A pavement mixture using 30% RAP and warm-mix processing provides a 24% reduction compared to a mix using 100% virgin asphalt binder and hot-mix processing.

Figure 1: Comparison of GHG emissions for RAP / WMA (WMAC) asphalt mixes.



	Virgin	WMA	20% RAP	WMA 20% RAP	30% RAP	WMA 30% RAP
Aggregate	17.9	17.5	17.5	17.5	17.2	17.2
RAP Processing	0.0	0.0	0.1	0.1	0.2	0.2
Petroleum Refining	23.5	23.5	19.7	19.7	17.8	17.8
Heating & Mixing	12.2	9.8	14.1	11.7	15.0	12.6
Loader	2.4	2.4	2.4	2.4	2.4	2.4
Material Transport	18.6	18.6	17.1	17.1	16.4	16.4
Avoided Landfill Transport	0.0	0.0	-6.7	-6.7	-10.1	-10.1

Figure 2: Difference in GHG intensity Virgin materials vs. RAP/WMA (WMAC) asphalt mixes.

Emissions Source	Virgin	WMA	20% RAP	WMA 20% RAP	30% RAP	WMA 30% RAP
Net Emissions	74.7	71.8	64.2	61.8	59.0	56.6
Emissions Savings (relative to Virgin)		**-2.9**	**-10.5**	**-12.9**	**-15.7**	**-18.1**
% Savings (relative to Virgin)		-4%	-14%	-17%	-21%	-24%

Note: The above figures were created using data from Booz | Allen | Hamilton's 2013 report for the EPA titled, *Analysis of Recycling of Asphalt Shingles in Pavement Mixes from a Life Cycle Perspective*.

Warm Mix Asphalt Concrete (WMAC)

EPA's *Analysis of Recycling Asphalt* finds that the net emissions for the "virgin" asphalt mix scenario is 164.5 lbs CO2e / ton of material produced (or 0.075 MT CO_2e / ton). The "heating and mixing" portion of this carbon intensity is 29 lbs CO2e / ton of material produced (or 0.012 MT CO2e / ton) for the virgin mix and 158.3 lbs CO2e / ton of material produced (or 0.072 MT CO_2e / ton) for the WMAC mix for a savings of 0.003 MT CO2e / ton or 4% of total emissions. Note that this value may change depending on the WMAC process used; asphalt plant fuel mix; and other plant-specific factors.

Reclaimed Asphalt Pavement (RAP)

EPA's *Analysis of Recycling Asphalt* finds that the net emissions for the "virgin" asphalt mix scenario is 164.5 lbs CO2e / ton of material produced (or 0.075 MT CO_2e / ton). The net emissions of the 20% RAP mix are reported as 0.064 MT CO2e / ton (for a savings of -0.011 MT CO2e / ton or 14%) and the 30% mix are reported as 0.059 MT CO2e / ton (for a savings of -0.016 MT CO2e / ton or 21%).

Warm Mix Asphalt Concrete + Reclaimed Asphalt Pavement

Combining use of RAP and WMAC increases GHG savings to 17% per ton for 20% RAP + WMAC and 24% per ton for the 30% RAP + WMAC.

Strategy #1

Warm Mix Asphalt Concrete (WMAC) Pavement

Introduction

"Warm Mix" is a misnomer as this product is still produced at a high temperature in order to bring the oils to the proper viscosity and achieve acceptable mixing of the materials. Warm mix asphalt concrete (WMAC) is similar to hot mix asphalt concrete (HMAC) but is produced with a different process that is used to lower its mixing temperature by 50° to 100°F degrees compared to conventional HMAC (or a processing temperature of between 212° - 275° F). This reduction in process temperature reduces the quantity of fuel required to produce a single unit of asphalt concrete thereby reducing the carbon intensity of production as well as production costs.

There are two general methods to achieve WMAC – the "water foaming" process that uses plant modifications to inject a controlled amount of water into the hot oil and the additive process that uses a chemical additive to allow production of the mix at lower temperatures. Generally, the chemical additive method results in lower temperatures.

Figure 2: Summary of WMAC benefits and concerns.

Benefits	Concerns
• Reduced energy use and GHG emissions • Cost savings from lower energy use • Improved working conditions • Long term quality	• New equipment investment by asphalt plants or costs associated with proprietary materials • Unfamiliarity with product

WMAC specification best practices:

- Be aware of the availability of WMAC in local area and the method(s) used to produce the WMAC. If WMAC is not available, contact local suppliers to determine the reason.
- Adopt a specification that achieves the desired quality and is available in the area.
- Require quality control and quality assurance to verify the quality of the materials and the placement of pavement.

Selecting the appropriate mix design and specifications for the conditions is necessary regardless of the type of asphalt pavement used. Oftentimes, perceived failures of materials can be traced back to mix design selection rather than the materials themselves.

Considerations

Cost

Of concern is the initial cost for asphalt plants to purchase warm-mix equipment and/or additives. This cost can vary, but is relatively small compared to normal operation costs and the purchase can quickly pay for itself.

The WMAC process generates a net savings of $1.29 / short ton compared to HMAC. This net savings was estimated by multiplying the fuel savings (0.41 gallons of diesel / short ton)[ii] of WMAC compared to HMAC[ii] by the average 2013 cost of diesel[iii] ($3.90 / gallon)[iii] and adding the cost chemical additives cost (0.30 / short ton)[iv].

Use of the plant foaming process requires a capital expenditure to modify an existing plant. In 2015, the Asphalt Pavement Association of Oregon (APAO) reports that it's about $30,000 to get a system up and operational, which is down substantially from 5 to 6 years ago when it was in the neighborhood of $50,000. APAO also reports that most producers seem to prefer the plant foaming process as it represents a one-time expenditure and the plant can produce hot or warm mix asphalt pavement "at a flip of a switch".

Operational Effects

Besides reducing energy costs, lower heating temperatures are beneficial to the health of construction workers, neighbors, and passersby since fewer oils are volatized and emitted into the nearby air. The lower temperatures make for a more comfortable work environment;

particularly in areas with hot summer temperatures or areas with little airflow, like tunnels. WMAC cools more slowly, compared to HMAC, due to a smaller difference between the temperature of WMAC and the ambient air temperature. This extends the paving season since pavement can be laid in cooler temperatures. In addition, warm-mix asphalt can be hauled over longer distances, and freshly paved roads can return to operation sooner than if they were paved with HMAC.

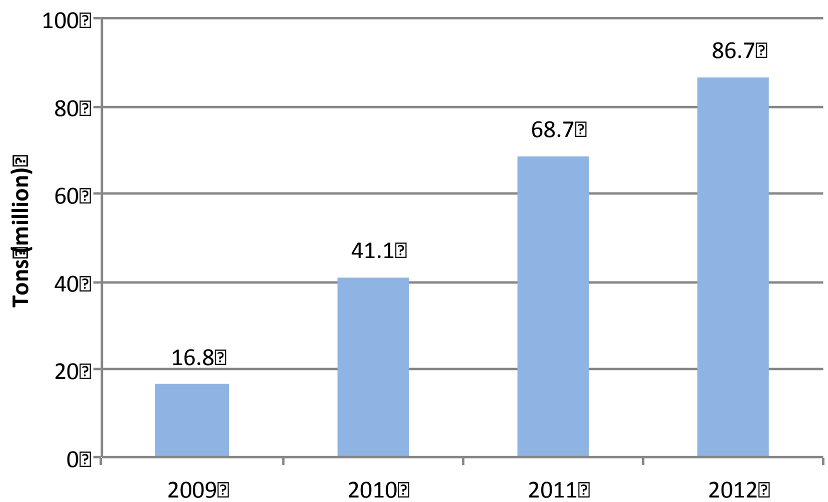
Selecting the appropriate mix design is critical to the use of asphalt concrete materials. Staff involved in the purchasing materials or bidding projects that include these materials, should select the mix design properties needed for the environmental conditions, traffic loading and available materials. Quality control testing to ensure longevity of the project is important.

Local Availability

In order for municipal governments to specify and purchase WMAC for construction projects, local asphalt production plants within a certain geographic radius need to have WMAC production capacity. While the initial capital investment for the warm mix equipment is relatively small, the investment risk from the plant's perspective may be large. In order to make such an investment the plant will need to be confident in the scale and timing of local demand for a warm mix product. It becomes a bit of a "chicken or the egg" problem. In order to build understanding and acceptance of warm mix products by public works department and local contracts they need production capacity in order to complete test projects to increase demand for warm mix products. On the flip side, asphalt producers don't want to make the investment until the demand exists to support the investment.

These challenges are evidently being overcome as the tons of WMAC being consumed in the U.S. has steadily increased between 2009 and 2012.

Figure 3: Use of WMAC in the U.S., 2009-2012



The City of Eugene, Oregon (see the case study) has had success in implementing WMAC in its projects due to local circumstances. The City of Eugene is the largest local consumer of asphalt products in their area. Once they made the decision to begin specifying WMAC on its projects, all three local asphalt plants invested in the warm mix equipment.

Strategy #2

Use of Reclaimed Asphalt Pavement (RAP)

Introduction

Reclaimed asphalt pavement is a material, not a process like warm mix asphalt concrete (WMAC), and thus can be used with either hot mix asphalt concrete (HMAC) or WMAC. RAP is the recycling of asphalt pavement from existing roadways or parking lots into new asphalt through milling it into virgin sized aggregate particles and reheating the material into a new batch of asphalt concrete. Since RAP still contains the original binder, using RAP can lower the need for virgin materials – both binder and aggregate, cutting costs and GHG emissions.

Figure 3: Summary of RAP benefits and concerns.

Benefits	Concerns
• Widely used and proven technique • Reduces costs, energy use and GHGs • Can be used in a variety of asphalt mixes • Improves strength and durability[v] • Reduces consumption of natural resources	• RAP can result in a very stiff and difficult to apply mixture[v]. • Variability among RAP stockpiles[vi]

RAP specifications best practices include:

- Be aware of the availability and materials properties of RAP.
- Adopt a specification that achieves the desired quality with the materials available in the area.
- Require quality control and quality assurance to verify the quality of the materials.

As mentioned in the warm mix section, selecting the appropriate mix design and specifications for the conditions is necessary regardless of the type of asphalt pavement used. Oftentimes, perceived failures of materials can be traced back to mix design selection rather than the materials themselves.

Considerations

Cost

To establish a baseline price for asphalt, 2013 average Department of Transportation[vii],[viii],[ix] price bids for HMAC were collected from California, Oregon, and Washington, as seen in Figure 6 (Baseline), which were used to calculate an average. A variety of sources indicate the cost savings for a 30% RAP mix compared to using virgin materials are between $6 and $10 per ton.[x,xi,xii,xiii] For this study we used average of $8 per ton. The majority of this cost savings comes from replacing the virgin asphalt binder, which is the most expensive component of asphalt. It’s important to note that the costs used for this analysis represent “first costs” only and do not include costs associated with maintenance or adjustments for differences in the expected lifespan of the material. Lifecycle costs should be considered in a future version of this document.

For the WMAC with 30% RAP substitution in Figures 5 and 6 the emissions cost savings are added together.

Operational Impacts

One of the great benefits of RAP is that it's a tried and true technique and has been widely used since the 1970, so there is already an understanding of its use in asphalt mixtures. In fact, asphalt pavement is recycled at a rate of over 99 percent, making it the most recycled material in the U.S. [xiv]. The reuse of asphalt reduces the amount of required aggregate and virgin binder, thus reducing energy costs and GHG emissions. RAP can be used in any asphalt mix and can typically represents between 10 - 30% of any asphalt mixture. Another benefit of RAP is that because of its increased stiffness, it can help to prevent deformations in asphalt such as rutting[v].

However, there are some concerns that can impact the operations of using RAP. There is a great variability among RAP stockpiles, stockpiles properties should be considered on an individual basis in developing a mix design[vi]. Some of the stockpile variability is due to oxidization of the RAP by sunlight and the atmosphere while it was asphalt, resulting in RAP material that can be a very stiff and difficult material to work with. This can also increase the possibility of fractures and cracking as the RAP asphalt becomes brittle. This is a particular problem in areas that experience low temperatures, but is dependent on the quality of the RAP[v].

Selecting the appropriate mix design is critical to the use of asphalt concrete materials. Staff involved in the purchasing materials or bidding projects that include these materials, should select the mix design properties needed for the environmental conditions, traffic loading and available materials. Quality control testing to ensure longevity of the project is important.

Local Availability

RAP is generally available, though it is dependent on several factors, such as how much RAP is generated in the area[xv]. A majority of asphalt plants have the necessary machinery to capitalize on this resource and if a street is being repaved, municipalities can reclaim the asphalt pavement of the old street and use it in the repaving process.

Measurement, Resources and Case Studies

Measurement Resources

There are a variety of publically available resources and tools online that can be used to measure greenhouse gas reductions associated with the use of warm mix asphalt concrete (WMAC) and reclaimed asphalt pavement (RAP). The following bullets provide a list of the available resources on this topic and a brief description of the way in which they might be used.

- **Resources**
  - **Environmental Product Declarations (EPDs):** EPDs are standardized ways of reporting the life-cycle environmental impacts of products. The National Asphalt Pavement Association has started an EPD program, but as of this writing the program has not released any publically available results. EPDs are most accurate way to measure GHG reductions associated with different asphalt mix designs and should be used as the primary means of calculating reductions.

Until EPD reporting becomes common for asphalt mixes the following resources and tools are available.

- EPA's *Analysis of Recycling of Asphalt Shingles in Pavement Mixes from a Life Cycle Perspective*[1]: This report provides a detailed analysis of GHG reductions from WMAC, RAP and RAS. The analysis considers a number of different mix designs and calculates the carbon intensity for each (lbs. CO2e / short ton). A summary of these findings are shown in Figure 1 and Figure 2.

- **Tools**
    - **EPA's Waste Reduction Model (WARM):** WARM provides a GHG accounting tool and background documentation for reclaimed asphalt pavement and reclaimed asphalt shingles. WARM is available in two forms – an Excel spreadsheet and a web-based calculator. The tool allows the user to calculate net emissions for various waste management scenarios for RAP and RAS.
    - **National Asphalt Pavement Association's GHG Calculator:** NAPA developed a greenhouse gas (GHG) calculator for asphalt plant energy use and the carbon intensity of products including the GHG effects of incorporating RAP into the mix and using warm mix.
    - **Pavia System's Roadprint:** Roadprint Online is an online life cycle assessment (LCA) tool for use with new or rehabilitated pavements. Given basic design and construction input parameters Roadprint will calculate the quantitative environmental impact of a pavement including energy use and greenhouse gas emissions associated with the pavement over its lifecycle.

Purchasing Resources

- **Example specifications:**
    - City of Eugene, www.eugene-or.gov/standardspecs, see Part 00700, Section 00744, for paving specifications.
    - Oregon Department of Transportation, http://www.oregon.gov/ODOT/HWY/SPECS/Pages/index.aspx
- **Industry recommendations:**
    - Asphalt Pavement Association of Oregon, www.apao.org
    - Warmmixasphalt.com
    - National Asphalt Pavement Association, www.asphaltpavement.org

Case Study: City of Eugene

Working with the Asphalt Pavement Association of Oregon (APAO) and resources at the Texas Department of Transportation, the City of Eugene developed a special specification for use of

[1] Prepared for EPA by Booz | Allen | Hamilton. Available for download online at http://www3.epa.gov/warm/pdfs/WARM_Documentation.pdf.

warm mix asphalt concrete (WMAC) on City projects in 2008. In order to test WMAC on a City project, the City worked with a local asphalt concrete producer, Eugene Sand and Gravel, to place approximately 8,000 tons of WMAC on an existing multi-year paving project on Roosevelt Blvd. This would be the largest WMAC project in Oregon at the time. Eugene Sand and Gravel retrofitted their asphalt plant to produce WMAC using a plant foaming process, which foams the asphalt oil through an injection of steam as it is mixed with the aggregate to create asphalt concrete. This process reduces mix temperatures by approximately 50 degrees Fahrenheit. The City worked closely with Eugene Sand and Gravel, and Lane County testing staff who provided mix design review and field testing to assure that the WMAC product was successful. The required compaction densities were easily achieved.

The foaming process increases the volume of the binder in the mix which results in better coating of the aggregate in the mix. Eugene found that this better coated material acted as if there was more asphalt cement in the mix and was easier to compact than conventional hot mix asphalt pavement. Compaction is a primary factor in the longevity of asphalt pavements, so ensuring better compaction would also ensure a longer life. Preliminary measurements by Eugene Sand and Gravel showed energy savings of approximately 15% during WMAC production.

After the success of the pilot project, the City chose to require the use of WMAC on six pavement preservation projects under two separate contracts, amounting to an additional 20,000 tons of WMAC to be produced. In addition to this, the City allowed the use of WMAC on other paving projects in 2009 at the option of the Contractor. The use of WMAC in Eugene has generated interest across the state for use of this technology and has given municipalities as well as asphalt concrete production and paving companies an example of how this product can be successfully implemented in Oregon. The City has provided specifications and related construction experiences to multiple jurisdictions interested in using WMAC in Oregon including Federal Highways, ODOT, City of Roseburg, City of McMinnville, Douglas County, and Washington County. Between 2009 and 2014, the City of Eugene specified the placement of approximately 361,000 tons of WMAC, reducing greenhouse gas emissions by approximately 8,700 Metric Tons CO_2e. 1 The use of WMAC in Eugene is now the standard practice for all City paving projects.

Even though the use of WMAC can allow longer hauling distances, Eugene specifies a haul distance limitation to ensure that the GHG benefits realized during material production are not negated by the longer travel distances.

The use of reclaimed asphalt pavement, or “RAP”, has been used for more than 30 years in Eugene. For many years, it has been standard practice to specify up to 30% RAP in asphalt pavements. Using typical materials properties, the 30% by weight RAP content replaces approximately 25 - 30% of the virgin binder content of a typical asphalt pavement.

In 2013, Eugene began to move beyond 30% RAP content by increasing the overall asphalt binder replacement in the pavement on a test project. After reviewing materials from various agencies studying this concept, staff met with the three asphalt pavement producers in the Eugene area to discuss the possibilities and plant capabilities. Because each producer had different plant capabilities, the City decided to revise the percentage of RAP content specification to call for 35% binder replacement with reclaimed asphalt materials. A benefit to using a specification based on binder replacement is that the mix design is based on the asphalt content of the specific reclaimed materials rather than industry averages that may not be accurate for the specific stockpile.

The contractors were allowed to use a combination of reclaimed shingles or reclaimed asphalt pavement to meet this 35% binder replacement requirement, up to 5% shingles. Adjustments were made to the grade of virgin asphalt cement used to compensate for the stiffer mix, a result of higher RAP content. Not only did this mix design decrease the use of virgin asphalt binder and increase the use of reclaimed materials in the pavement mix, but there is a potential cost savings to the City. In 2013, two streets were repaved using increased reclaimed binder content asphalt pavement.

Based on positive test results from the 2013 projects, in 2014 and 2015, Eugene continued the practice of using the increased the reclaimed binder in asphalt pavements, using the 35% binder replacement mixes on nearly a dozen streets. With over 13,700 tons of RAP used on 2014 projects, the City reduced the need for nearly 800 tons of asphalt cement and 12,900 tons of aggregate to be mined, refined, processed and subsequently shipped to the pavement producers. In 2016, the City will let a project with 40% reclaimed asphalt materials.

Selection of mix design properties is critical for any asphalt pavement material. Considerations include the environmental conditions, traffic loading and local materials that go into the mix design. For example, while RAP may be more resistant to rutting due to a stiffer mix, many local agency roadways do not experience traffic loading such that rutting is a concern. Instead, local agency roadways are typically more susceptible to cracking and a stiffer mix will increase this susceptibility. Eugene balanced this stiffer material by working with APAO to select an asphalt cement grade that would compensate for this characteristic.

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