Energy Savings from Paving Asphalt at Reduced Temperature – WMA (Warm Mix Asphalt)

There are various approaches for determining the savings in energy when paving warm mix asphalt. The calculation used on www.bgbau.de was based on the following.

1. The typical temperature for hot asphalt mixture preparation in France is around 160 °C (320 °F) for a 35/50 penetration grade bitumen. Even a reduction of the process temperature to 120 °C (248 °F) would result in a saving of 25 % of the expended energy. For a typical hot mix production plant, running at about 100 t/h, this savings would translate in a saving of about 130 m^3 of natural gas (or about 130 kg of fuel oil) per hour. A reduction in temperature will also result in a substantial reduction of gas emissions to the atmosphere during the production.

Emission Measurements of Hot Mix Asphalt and WMA (Warm Mix Asphalt)

	Hot Mix Asphalt T_{mix} = 160 – 175 °C	Warm Mix Asphalt T_{mix} = 110 – 120 °C
CO_2 (mg/m^3)	-25 %	
CO (mg/m^3)	-30 %	
NO_x (mg/m^3 eq. NO_2)	-25 %	
Dust (mg/m^3)	-88 %	

Source: L. Grampre, J.A. Gonzales Leon, G. Barreto: Warm asphalt mixtures by chemical additivation: field tests and laboratory studies; 4th Congress Eurasphalt & Eurobitume, 21 – 23 May 2008, Copenhagen.

2. CO_2 emissions at 180 °C 3.4 t/h, at 125 – 130 °C 2.1 t/h; for a temperature reduction of 50 – 55 °C and thus 28 % less CO_2

Source: Emission and occupational exposure at lower asphalt production and paving temperatures. M. Lecomte; F. Deygour; A. Menetti; 4th Congress Eurasphalt & Eurobitume, 21 – 23 May 2008, Copenhagen

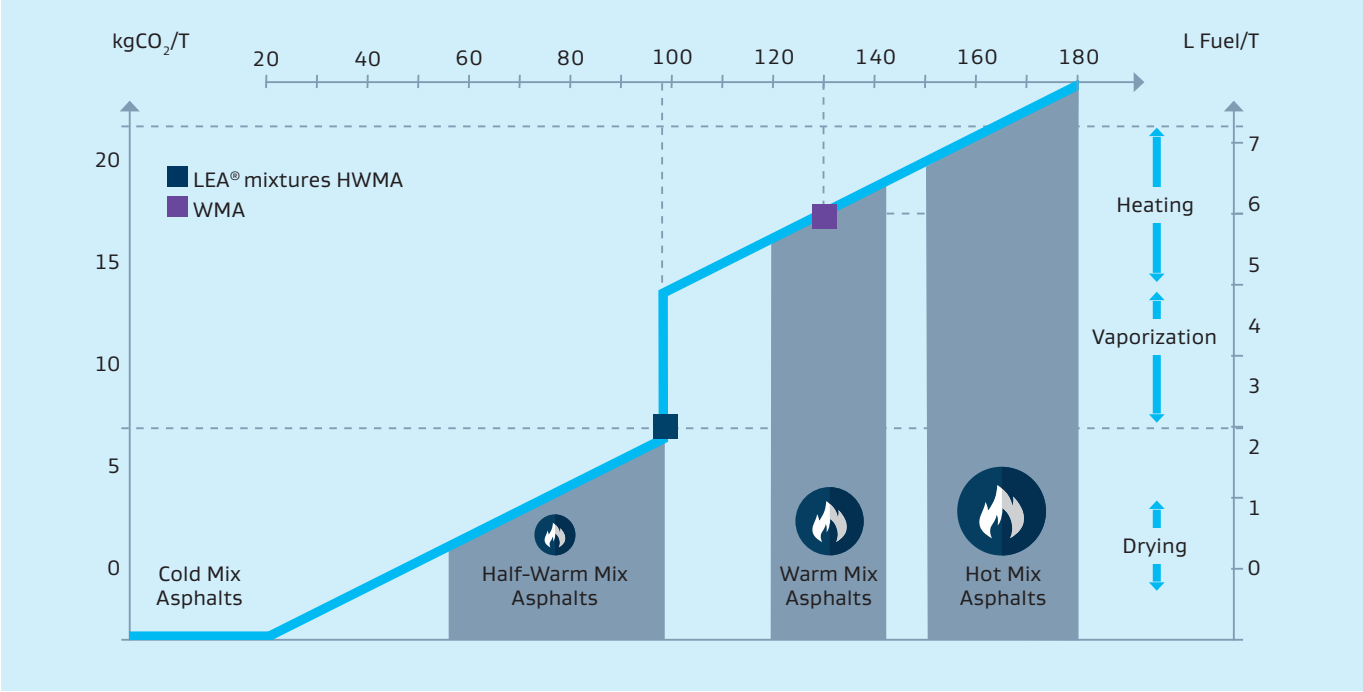
3. In the case of a gas-fired dryer, with a temperature reduction of 30 °C the average energy consumption was 5.4 m^3/h for the control mix and 4.5 m^3/h for the energy saving mix, with measurement durations in excess of 2 hours and the same production rate of 180 t/hour. This clearly shows a reduction in gas consumption of 0.9 m^3/t, i.e. 16.5 %.

Source: Environmentally friendly energy saving mixes. X. Carbonneau, J.P. Henrat, F. Létaudin; 4th Congress Eurasphalt & Eurobitume, 21 – 23 May 2008, Copenhagen

4. A temperature reduction of 25 °C means savings in energy and CO_2 of 15 %.
   (Sasol Wax GmbH, construction site at Ljubljana (Slovenia), October 2005)

5. Figure 1 illustrates the different types of asphalt mixes in relation to their paving temperature and corresponding consumed heating energy, as described in the literature:
   - cold mix asphalt (CMA), usually manufactured at ambient temperature from asphalt emulsions or foams,
   - half-warm mix asphalt (HWMA), produced at temperatures below water vaporization,
   - warm mix asphalt (WMA), manufactured at approximately 130 °C,
   - hot mix asphalt (HMA), usually produced at 150 – 180 °C depending on the used binders.

Figure 1:
Energy savings depending on the mixing temperature



Source: Olard. E&E Congress Kopenhagen 2008

From the graph prepared by Olard et al., it can be seen there is an energy fuel consumption of 7.27 l/t at 160 °C versus an energy fuel consumption of 6.07 l/t at 130 °C. For a temperature reduction of 30 °C, there results a fuel difference of 1.2 l/t (16.5 %).
At a 'normal temperature' for conventional asphalt of 150 – 180 °C, taking the average of 165 °C, the graph shows a fuel demand of 7.43 l/t and a CO_2 emission of 21.4 kg/t.

Source: Low energy asphalts for sustainable road construction. F. Olard, C. Le Noan, E. Beduneau, A. Romier.

6. A temperature reduction of 30 °C results in 19.4 % less CO_2. (Ammann company)

7. Evaluation of the measurements showed that, by lowering the mixing temperature by 30 – 35 °C, the energy demand was cut by 30 %. For the case described, it was possible to lower the specific energy demand by 14 kWh per tonne of asphalt. For an asphalt mixing plant that during normal operation needs 8 ltr. of fuel oil per tonne of asphalt, this means a saving of 2.4 l/t. By extrapolating from this model to Germany's annual asphalt production of around 64 million t, this would save the huge quantity of approximately 400,000 t of carbon dioxide from being emitted to the atmosphere.

   Source: Barthel, W.: Energy savings and emission reductions during production and paving of high-temperature asphalt (in German); Tiefbau 12/2001, pp. 831-833.

Summary of the Energy Savings Shown

Temperature reduction	Reduction of energy and CO_2	Reduction of energy and CO_2 per 10 °C	Source
40.0 °C	25.0 %	6.2 %	Gramprecht et al.
52.5 °C	28.0 %	5.3 %	Lecomt et al.
30.0 °C	16.5 %	5.5 %	Olard et al.
25.0 °C	15.0 %	6.0 %	Sasol
30.0 °C	16.5 %	5.5 %	Carbonneau et al.
30.0 °C	19.4 %	6.5 %	Ammann
32.5 °C	30.0 %	9.2 %	Barthel
		Average 5.9 %*	

*Average without considering the two extreme values

Based on the above, it can be deduced that energy savings of 5.9 % may be attained by reducing the mixing temperature by 10 °C.

For the Further Considerations, the Following Assumptions Are Made:

- There is a linear relationship between the reduction of the required energy and the reduction of the mixing temperature.
- A reduction of the paving temperature results in a corresponding reduction of the mixing temperature.

Determination of 'Normal' Conventional Paving Temperatures

When stipulating a normal paving temperature, the values actually used in practice must be taken as a guide and not standard temperatures. The following data on practice-related paving temperatures for conventional asphalt are used until a sufficient number of independent examples becomes available.

At a construction site in Slovenia (October 2005), the paving temperature of conventional rolled asphalt was 168 °C, while for temperature-lowered asphalt it was 143 °C.

In 1997, on the B7 at Lenröden-Ifta, the MHI company laid conventional and temperature-lowered rolled asphalt at 164 to 168 °C and 114 to 145 °C respectively.

From a graphic published by Olard et al. in 2008, a 'normal temperature' for conventional asphalt of 165 °C can be read off.

In 1999, Shell reported on paving of conventional (260 °C) and manual paving of temperature-lowered (230 °C) mastic asphalt. It is noted that there is an 'appreciable energy saving' and 'reduced equipment wear', specifically of the drying drum.

Until a representative number of citations of 'normal' paving temperature become available, reference will be made to the 75th percentiles of paving temperature at construction sites at which exposure was measured during paving of conventional asphalt.

Rolled Asphalt

Asphalt temperatures during exposure measurements when paving conventional rolled asphalt

168 °C (75th percentile of 413 measurements)						
min.	25 %	average	50 %	75 %	95 %	max.
135 °C	157 °C	162 °C	161 °C	168 °C	180 °C	180 °C

Mastic Asphalt, Manual

Paving temperatures during exposure measurements for conventional manual mastic asphalt

260 °C (75th percentile of 587 measurements)						
min.	25 %	average	50 %	75 %	95 %	max.
208 °C	244 °C	252 °C	250 °C	260 °C	275 °C	280 °C

Mastic Asphalt, Mechanical

Paving temperatures during exposure measurements for conventional machine layed mastic asphalt

250 °C (75th percentile of 290 measurements)						
min.	25 %	average	50 %	75 %	95 %	max.
215 °C	235 °C	242 °C	245 °C	250 °C	256 °C	270 °C

Determination of the Consumption of Fuel Oil per Tonne of Asphalt

Various energy sources are used in the asphalt mixing plants. For the sake of clarity, on www.bgbau.de the energy savings are always quoted in liters of fuel oil. According to the standard DIN 51603, 1 liter of fuel oil corresponds to a weight of 0.860 kg.

The energy values are estimated by Barthel (8 ltr. fuel oil/t asphalt), Grampre et al. (5.2 kg fuel oil/t asphalt = 6.0 ltr. fuel oil/t asphalt) and Olard et al. (7.4 ltr. fuel oil/t asphalt) as those typically used for mixing conventional rolled asphalt. Of course, these energy figures depend on many factors, among others the humidity and the initial temperature of the material to be mixed, etc. An energy figure of 7.1 ltr. fuel oil/t asphalt taken as the average of the papers cited, though, may be considered to be a representative value.

According to the Shell company, an empirical value is quoted of 10 ltr. fuel oil/t of asphalt for manufacturing mastic asphalt.

Source: Sasol Wax GmbH

Determination of the Reduction of CO_2 Emissions

Under www.umweltpakt.bayern.de/suchen/index.htm?q=berechnung+co2 it is noted that 1 ltr. of fuel oil gives rise to 2.62 kg of CO_2. Apart from the CO_2, under consideration of other climate-relevant gases, like methane, nitrous oxide, etc., burning 1 ltr. of fuel oil produces 3.12 kg of CO_2 equivalent.

The result of the calculation of the energy saved during the construction measures is:

Manual mastic asphalt:	((260 °C – paving temperature) / 10) x 0.59 ltr/t = X ltr/t X ltr/t x quantity laid in t = ltr. per construction measure
Mechanical mastic asphalt:	((250 °C – paving temperature) / 10) x 0.59 ltr/t = X ltr/t X ltr/t x quantity laid in t = ltr per construction measure
Rolled asphalt:	((168 °C – paving temperature) / 10) x 0.42 ltr/t = X ltr/t X ltr/t x quantity laid in t = ltr per construction measure

Calculation of Savings in Fuel Oil and Reduction of CO_2 Emissions

With the temperature lowered by 10 °C with resulting energy savings of 5.9 %:

- for each tonne of rolled asphalt, the saving in fuel oil is 0.42 ltr. and 1.31 kg less CO_2 is emitted and
- for each tonne of mastic asphalt, the saving in fuel oil is 0.59 ltr. and 1.84 kg less CO_2 is emitted.

Fuel Oil Consumption of a Family of Four

Based on 2007 heating costs: A building with an average energy consumption and with a heated area of 100 to 250 m^2 consumes an average of 120 kWh heating energy per m^2 and year. For buildings with multiple dwelling units, this average value is even lower.

1 liter of fuel oil has an energy content of 10 kWh.

100 m^2 living area x 120 kWh per year = 12,000 kWh per year

12,000 kWh corresponds to 1200 liter fuel oil per year

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