Comparison between Lime, Cement & Wetfix I

from a life cycle perspective

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Karin Löfnertz
Environmental Development
Akzo Nobel Surface Chemistry

1. Introduction

In this study a comparison is made between the environmental load from the use of Wetfix I, lime and cement in hot mix for asphalt pavement. All comparisons are made between the used amount of each product in the hot mix (see 2. Basis for calculations).

Wetfix I is representative of the adhesion promoters used in the asphalt called “hot mix” used as a pavement on roads. Wetfix I is a surface-active material that concentrates at the interface between bitumen and the aggregate’s surface. This product extend the life of asphalt pavements. Wetfix I is manufactured by Akzo Nobel Surface Chemistry in Stockvik (Sweden).

An alternative to using Wetfix I as an adhesion promoter, is to add lime or cement to the hot mix. This study is therefore based on a comparison between these products.

In contrast to treatment with lime or cement, adhesion promoters in general are required at low use levels (see 2. Basis for calculations). The amount of each additive is chosen provided that the pavements have the same lifetime and maintenance needed [5,6].

All steps prior to production have been included like natural resource extraction, raw material production and transports. The main energy resources and air emissions for hotmix and the three different additives are given in the table in the Appendix. The figures are based on the amount of hotmix and additive used in the pavement.

2. Basis for calculations

Asphalt layer of a road 1km x 13m	→	13 000 m^2 asphalt road
95 kg hot mix / m^2 road	→	1235 ton hot mix

1235 ton hot mix contains:
- 74 ton bitumen (6,0%)
- 1161 ton aggregate

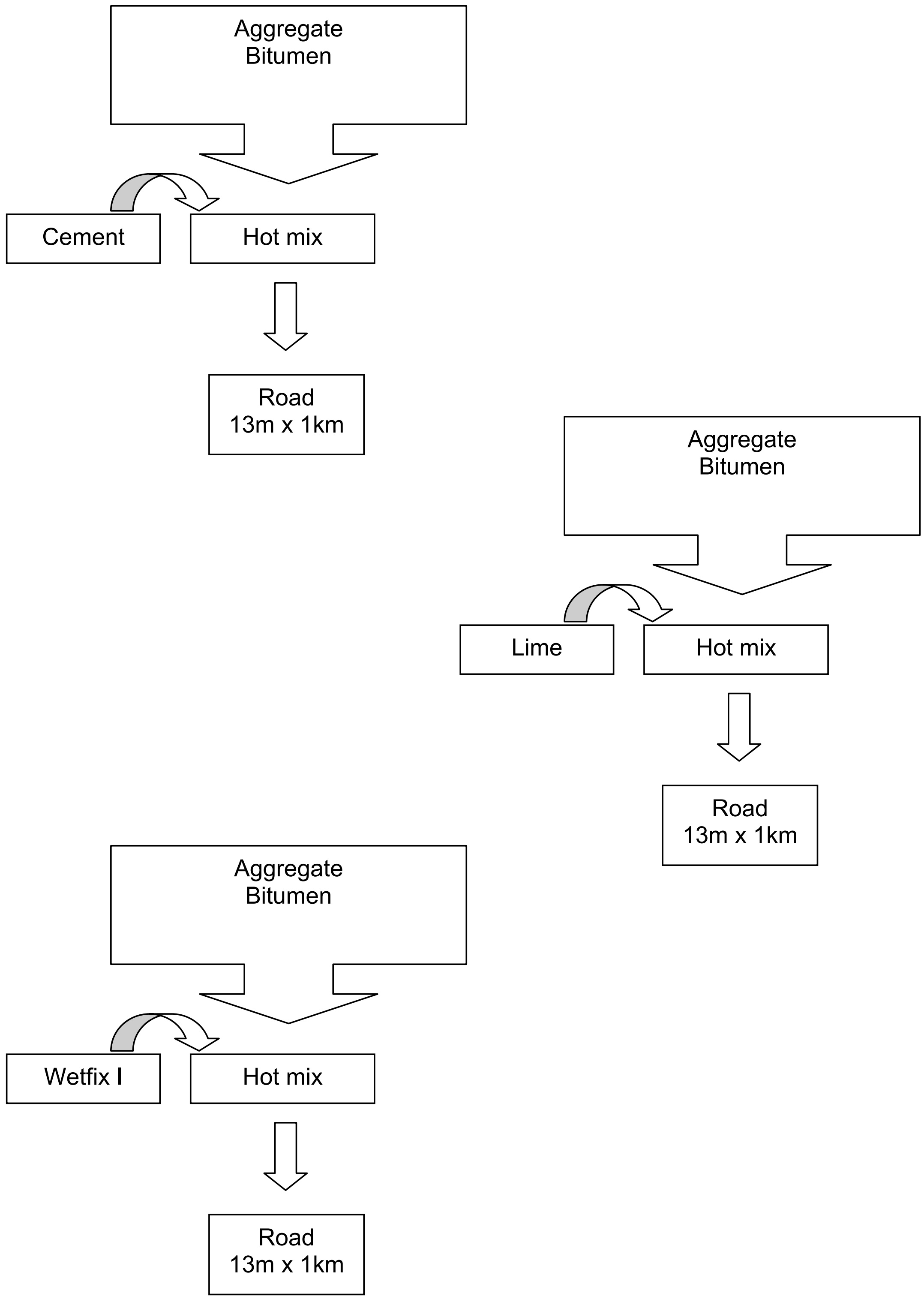
  in addition
- ~17 ton cement (1,5% of the aggregate)
  or
- ~17 ton lime (1,5% of the aggregate
  or
- ~0,2 ton Wetfix I (0,30% of bitumen)

The basis for the calculations is one asphalt layer of a road of dimension 1km x 13m. The dimensions of the road and the amount and composition of the hot mix is according to the report by Håkan Stripple – Life Cycle Assessment of Roads – A Pilot Study for Inventory Analysis [1].

“Vägverket” has given the indication of the added amount of cement or lime. Usually 1,5-2,0% of the aggregate is added as cement or lime [4]. 1,5% was chosen in this example.

The amount of added Wetfix I is normally 0,2-0,4%. In this study 0,3% is used which is an average value [5].

Figure 2.1 Description of basis for calculations



3. Data sources

Hot mix
LCI-data for hot mix is from the report by Adeline Ries – Life Cycle Assessment of an adhesion promoter used in hot mix for asphalt pavement [2]. Data includes crushing of aggregate, extraction of bitumen and energy resources used at the asphalt mixing plant. Transport of aggregate and bitumen to the mixing plant is also included.

Cement
In principal, cement consists of Calcium oxide, Silicone oxide, Aluminium oxide and Iron oxide.

LCI-data for cement from three different references have been compared. In this study, data for Portland Cement from Norcem has been used [3]. The data from Norcem was compared to average production of cement in the Nordic countries (Finncement, Cementa, Norcem) [4] and cement produced in Sweden (Cementa) [1].

Data from the three different sources corresponded very well. LCI-data from Norcem [3] was chosen in this study because this data is detailed and very well documented.

Lime (slaked)
Slaked lime is produced when water is added to quicklime (CaO). Calciumoxide reacts with water and Calciumhydroxide ($Ca(OH)_2$) and slaked lime is obtained. Heat and steam are released during the reaction. Because heat and steam are not utilised, LCI-data for quicklime is also representative for slaked lime [7].

LCI-data for slaked lime (produced by Nordkalk) from the report by Håkan Stripple – Life Cycle Assessment of Roads – A Pilot Study for Inventory Analysis [1] has been used in this study. LCI-data for slaked lime has also been retrieved directly from Nordkalk [7]. The data given from Nordkalk compares well with the data from Stripple's report.

Wetfix I
LCI-data for Wetfix I is from the report by Adeline Ries – Life Cycle Assessment of an adhesion promoter used in hot mix for asphalt pavement [2].

4. Results

All comparisons are made between the amount of lime, cement and Wetfix I which are added to the hot mix used for the reference asphalt layer of a road (see 2. Basis for calculations). Note that even if an increase of environmental load often is discussed here, the additives will increase the lifetime of the road. Therefore the total environmental load will decrease when additives are used.

4.1 Energy consumption

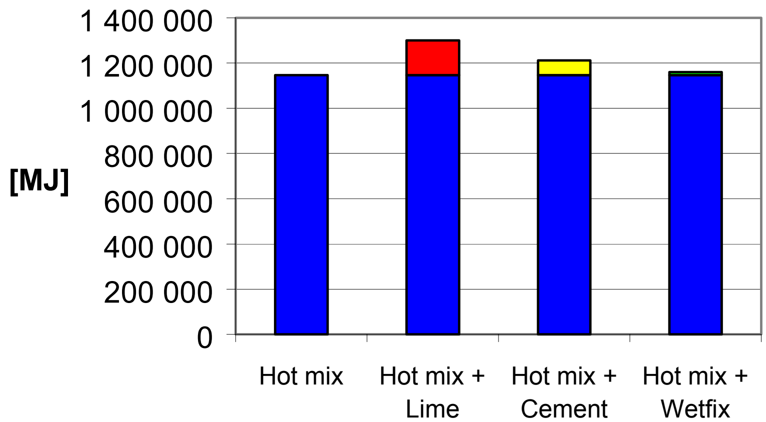


Figure 4.1.1 Total energy resources (crude oil, natural gas, coal, renewable energy etc.) [MJ]

About 95% of the energy resources used for hot mix consist of crude oil (40%) and natural gas (55%). Hot mix also use 2 654 GJ bitumen as raw material. This is not accounted in figure 4.1.1.

The addition of Wetfix I increase the total use of energy resources with 1%. Lime gives an increase with more than 10% and cement gives an increase with 5%.

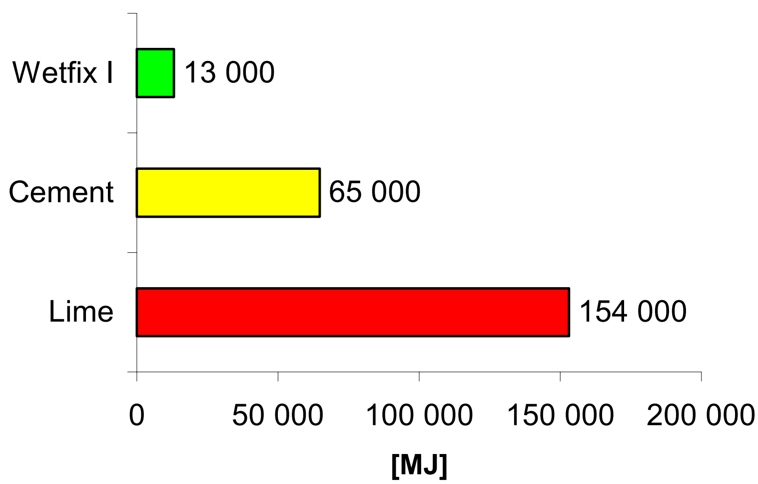
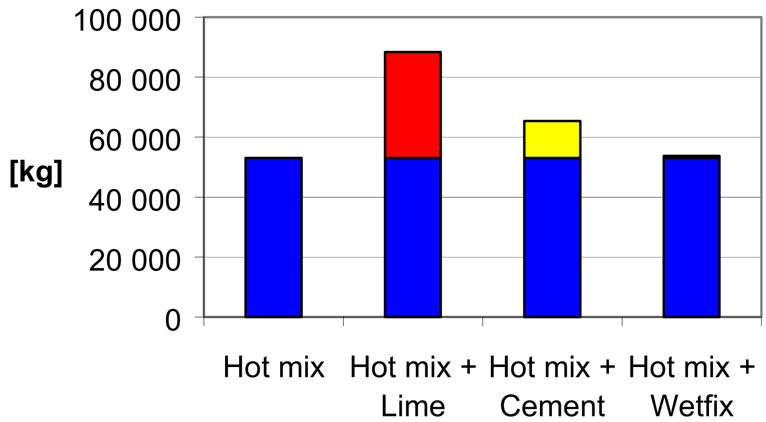


Figure 4.1.2 Total energy consumption [MJ] related to the additives

4.2 Emissions to air



4.2.1 CO_2 emissions [kg]

The addition of Wetfix I increase the total emission of CO_2 with 1%. If lime is used, the total amount of released CO_2 will increase with about 65%. Cement will give an increase of 20%. In the production of lime (and cement), CO_2 is released both from the production process (heating) and from the material itself when limestone is converted to Calciumoxide. Lime has a theoretical uptake of CO_2 according to the reaction $Ca(OH)_2$+$CO_2$$CaCO_3$(s) +$H_2O$. The uptake of CO_2 is normally very slow or negligable, especially in this application [1].

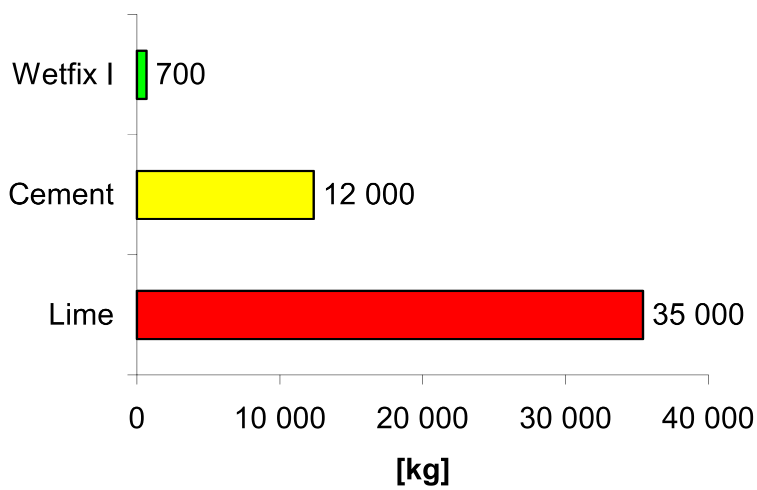


Figure 4.2.2 CO2 emissions [kg] related to the additive

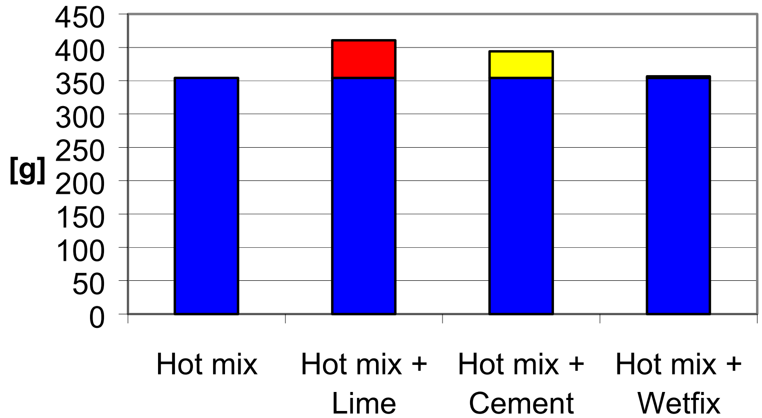


Figure 4.2.3 NO_x emissions [g]

The addition of Wetfix I increase the total emission of NO_x with 1%. NO_x emissions from lime and cement are about 10% of the emissions from Hot mix.

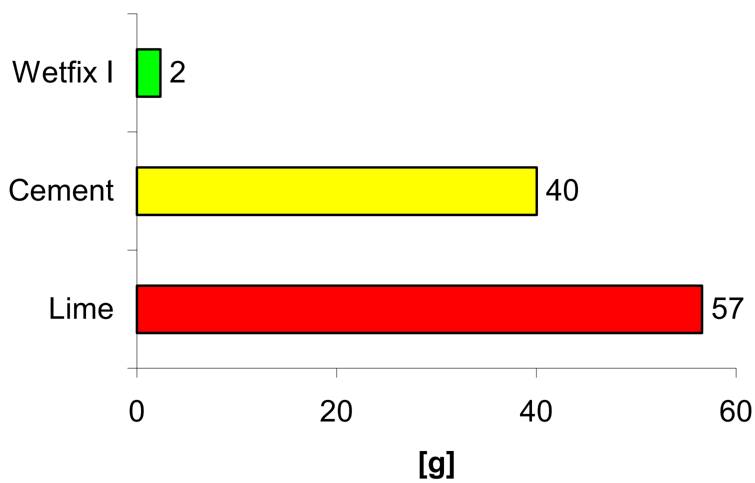


Figure 4.2.4 NO_x emissions [g] related to the additive

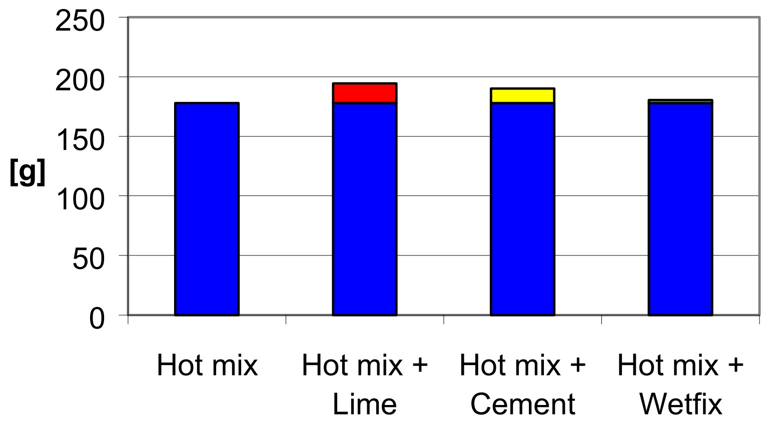


Figure 4.2.5 SO_2 emissions [g]

The addition of Wetfix I increase the total emission of SO_2 with 1%. SO_2 emissions from lime and cement are almost 10% of the emissions from Hot mix.

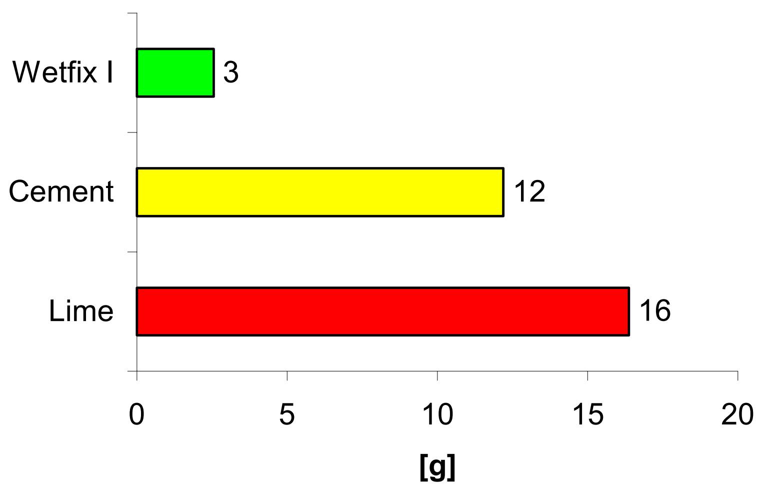


Figure 4.2.6 SO_2 emissions [g] related to the additive

5. Discussion

The environmental impact, based on emissions to air (CO_2, NO_x, SO_2) and use of natural resources (crude oil, natural gas) is much bigger from hot mix used for asphalt pavement than from the additives.

The environmental impact from Wetfix I represent about 1% of the one from the hot mix used for asphalt pavement.

The environmental impact from the two other additives in this study, lime and cement, is bigger than the impact from Wetfix I. The emissions of CO_2 is most noticable, and the addition of lime represent 65% of the emissions from hot mix. This can be compared with the emissions of NO_x that represent about 10% of the emissions from hot mix. In most cases the increased amount of emissions of CO_2 and NO_x are in the similar range. The reason why it is different for lime (and cement) is that in the production of lime (and cement), CO_2 is released both from the production process (heating) and from the material itself when limestone is converted to Calciumoxide.

The possible inherent properties from Wetfix I has not been discussed. Wetfix I is a surface-active material that concentrates at the interface between bitumen and the aggregate's surface. The extraction of Wetfix I from the asphalt layer is not in any significant extent. Wetfix I will biodegrade after long time to carbon dioxide and water. The amount of carbon dioxide emitted then will be in very small quantity [6].

6. References

1. Stripple Håkan – Life Cycle Assessment of Roads – A Pilot Study for Inventory Analysis, IVL report, Second Revised Edition, March 2001
2. Ries Adeline – Life Cycle Assessment of an adhesion promoter used in hot mix for asphalt pavement – Thesis report, February 2001
3. Norcem AS, Norsk Miljøvaredeklarasjon (MVD) för Portland Sement, gyldig til 31.des.2001
4. STØ, LCA of Cement and Concrete; Fredrikstad, November 1995
5. Simonsson Bo; Vägverket
6. Thorstensson Bengt-Arne; Akzo Nobel Surface Chemistry AB
7. Partek Nordkalk AB, Malmö, Sweden

Appendix

Energy resources and emissions for the amount of each product used in this study (see 2. Basis for calculations). If there is no value given it only means that there is no value available.

Energy consumption

	1235 ton Hot mix	**17 ton Lime**	**17 ton Cement**	**0,2 ton Wetfix I**
Crude oil [MJ]	435 000	15 500	14 700	3 700
Natural gas [MJ]	650 000	20	700	8 300
Coal [MJ]	3 300	140 000	42 600	700
Biomass [MJ]	8000	100	42	150
Peat [MJ]	0	10	0	7
Nuclear energy [MJ]	112 300	4000	0	510
Hydro energy [MJ]	50 600	1180	6 720	125

Emissions to air

	1235 ton Hot mix	**17 ton Lime**	**17 ton Cement**	**0,2 ton Wetfix I**
CO_2 [kg]	53 000	35 400	12 400	680
SO_2 [kg]	178	16	12	3
NO_x [kg]	354	57	40	2
CO [kg]	16	6	49	0,3
VOC [g]	13 338	370	1,2	0,9
CH_4 [g]	8 077	0,3	16	1290
HC [kg]	127			0,4