WARM ASPHALT MIXES BY ADDING A SYNTHETIC ZEOLITE

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ABSTRACT

All around the globe efforts are being put forward to protect the environment. Currently main emphasis is on reducing CO_2 emissions in view of reducing the greenhouse effect. The European Union target has been defined to reduce the CO_2 emissions between 1990 and 2010 with 15 %.
In Germany the Mitteldeutsche Hartstein-Industrie AG and EUROVIA have developed a method to produce hot mix asphalt for road construction at lower temperatures. At the same time it was an objective that this asphalt should be able to be applied and compacted at the lower temperatures without any loss in workability and quality. The concept has been further developed and introduced also in France and the US.
The reduction of production and application temperatures of hot mix asphalt means a significant environmental contribution in reducing energy consumption. And by reducing the fumes a significant improvement of the working environment is obtained. The principle of the process is based on the special structure of aspha-min®. This creates the ability to store crystalline water into the pores of the molecules. By adding aspha-min® in the pre-heated mixture of sand and stone at the same time as the bitumen is being introduced, a water based vapour is created. This creates a controlled foaming effect, which then creates an increased volume of the binder in the mix. The extremely fine foam is creating micro pores, which again are creating a higher workability of the mix. Doing so the mix is obtaining a higher ability to be compacted, which was previously only possible at higher temperatures. A successful application is obtained after a homogeneous addition of the aspha-min®. Mixing takes places between 130° and 140°C. It is important that the aspha-min® particles are loosing its water content in several steps and not all at once. Until cooling down to approximately 100 °C (212 °F) the possibility to compact the mix was observed. The workability of the mix is increased without changing the temperature. Furthermore no separation of the binder takes place in the mixing process which means that good adhesion between binder and aggregates is obtained.
All test sections, which have been constructed so far, demonstrate that the asphalt mix produced with aspha-min® does not perform differently from regular asphalt mixes produced without aspha-min®.
The paper describes results of test sections and reports on the results of laboratory investigations.

KEY WORDS:
ENVIRONMENTAL ASPECTS / WARM ASPHALT MIX / ZEOLITE / PRODUCTION / CHARACTERISTICS OF ZEOLITE / REDUCTION OF EMISSIONS / WORKABILITY AND PERFORMANCE / USER CHARACTERISTICS

1. ENVIRONMENTAL ASPECTS

All around the globe efforts are being put forward to protect the environment. Currently main emphasis is on reducing CO_2 emissions in view of reducing the greenhouse effect. CO_2 is part of our natural environment but as it is also created in the burning of coal, oil and gas, mankind causes more than half of the current quantity of CO_2. In 1995 approximately 23 billion tons of CO_2 were emitted worldwide, of which approximately 900 million tons of CO_2 in Germany. To avoid significant impact of CO_2 emissions in future on our environment worldwide, efforts are being made to reduce these emissions significantly.

A result is the European Union target, which has been defined to reduce the CO_2 emissions between 1990 and 2010 with 15 %. Target of the government in Germany is to obtain a reduction of 25 % compared to 1990 and already in the year 2005.

To reach this target the asphalt industry in Germany is trying to play its part in this reduction. To be successful the German Asphalt Association DAV has started a program in 1998 called "low temperature asphalt", which has as main objective to develop and investigate several production methods in which hot mix asphalt [1)] can be produced at lower temperatures. The German road research association FGSV who is now chairing the working groups, which are active in further developing and testing these methods, has adopted the DAV initiative.

2. WARM ASPHALT MIX (Niedrigtemperaturasphalt - NTA)

In collaboration with several industrial partners the Mitteldeutsche Hartstein-Industrie AG has developed a method to produce hot mix asphalt for road construction at lower temperatures. At the same time it was an objective that this asphalt should be able to be applied and compacted at the lower temperatures without any loss in workability and quality (Figure 1). Since 2001 collaboration between MHI and EUROVIA has been created to develop the method further and to introduce it also internationally.

The reduction of production and application temperatures of hot mix asphalt means a significant environmental contribution in reducing energy consumption. Furthermore at lower temperatures the amount of fumes is significantly lower. Normally in Germany for the production of several types of hot mix asphalt production temperatures of 150 to 250 °C (302 to 482 °F) are required.
The 250 °C temperature range is used for gussasphalt. Furthermore an overheating of mix, during production happens occasionally to prolong the time that mix can be applied and compacted, as the workability of asphalt is higher at higher production

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[1)] Note: In Europe „asphalt" refers to „asphalt concrete" or „asphalt mix".

The term „bitumen" is equivalent to the US term „asphalt cement".

temperatures. Especially harder bitumen as well as certain modified binders require higher production temperatures, to blend in well with the stone mix.

The principal of the method hereafter described is to add 0.3 % of additive to the mix, which enables to reduce production and laying temperatures with approximately 30 °C (54 °F).

3. ZEOLITE

Zeolites are crystalline hydrated aluminium silicates. Zeolites exist in the natural environment and are also produced artificially.

Synthetic zeolites are being characterized by a very homogeneous structure and quality in which the granularity is of main importance. Natural and synthetic zeolites have the ability to hold different quantities of water, and also the behaviour to release this water is different. For the purpose of lowering asphalt-mixing temperatures, this special zeolite has been developed. It is being added to the hot mix asphalt in the temperature range of 100 to 200 °C (212 to 392 °F) during which it is loosing its crystalline water. The developed zeolite has been called "aspha-min®".

4. PRODUCTION OF WARM ASPHALT MIX (NTA)

All known bitumen as well as polymer modified bitumen is usable in this process. Furthermore all normal mineral aggregates as well as fillers can be used in this process. This means that in the mix conception and in existing recipes no modifications are required. Also in the type testing procedures no modifications are required. The added aspha-min® is to be considered as an additional support by the increase of workability at low temperatures. Depending on the type of asphalt mixing plant (batch plant or drum mixer) mixing temperature of between 130 °C and 145 °C (266-293 °F) can be obtained. This means in general that a reduction of mixing temperature of approximately 30 °C (54 °F) is possible.

aspha-min® is being stored at the mixing plant in a big bag or in a special silo. The addition into the mixing process is done through special devices. Here a similar procedure as adding certain types of fibres can be used. Extremely important is that the addition of zeolite is not prolonging the mixing process. This means that adding the zeolites does not influence the performance of the mixing plant.

5. CHARACTERISTICS OF ZEOLITE AND HOW IT WORKS

The special structure of aspha-min® creates the ability to store crystalline water into the pores of the molecules. By adding aspha-min® in the pre-heated mixture of sand and stone at the same time as the bitumen is being introduced, a water based vapour is created (Figure 2). This creates a controlled foaming effect, which then creates an increased volume of the binder in the mix. The extremely fine foam is creating micro pores, which again are creating a higher workability of the mix. Doing so the mix is obtaining a higher ability to be compacted, which was previously only possible at higher temperatures. A successful application is obtained after a homogeneous addition of the aspha-min®. It is important that the aspha-min® particles are loosing its water content in several steps and not all at once. Until cooling down to approximately 100 °C (212 °F) the possibility to compact the mix was observed. The workability of the mix is increased without changing the temperature. Furthermore no separation of the binder takes place in the mixing process which means that good adhesion between binder and aggregates is obtained.

All test sections, which have been constructed so far, demonstrate that the asphalt mix produced with aspha-min® is not performing or behaving differently from regular asphalt mixes produced without aspha-min® (Figure 3).

6. REDUCTION OF EMISSIONS

As it was important to determine the influence of the lower mixing temperature on emissions and energy consumption a specific test programme was designed. The evaluation of the measurements indicated that by the reduction of mix temperatures of 30 – 35 °C (about 55 °F) the energy consumption was reduced by 30 % (Figure 4). In the several tests a reduction of energy equivalent of approximately 14 kWh per ton of asphalt mix could be obtained. If one would take an asphalt mixing plant, which uses 8 litres of oil per ton of asphalt mix, then this reduction would mean 2.4 litres per ton. If one calculates the reduction in Germany, where annually 65 million tons of hot mix asphalt are produced, then this would mean a reduction of 400,000 tons of CO_2, which would not be emitted into the atmosphere (Figure 5).

Lower temperatures in the production process also mean the reduction of emission of fumes and total particulate matter. Measurements have demonstrated the reduction of these emissions. So next to the energy reduction a significant reduction in emissions of fumes and odour can be obtained. In measurement on bitumen B 65 in Germany at a temperature of 168 °C (340 °F) an emission of 350,7 mg fumes and aerosols per cubic meter was determined. At a production temperature of 142 °C (285 °F) where zeolite had been added only 90.4 mg per m^3 was determined. In conclusion: a reduction of 26 °C (47 °F) created a reduction in fume emissions of 75 %.

Measurements at the application site have even demonstrated larger reductions (Figure 6). In praxis reductions of over 90 % were measured as the mix temperature was reduced from 175 °C (347 °F) to 140 °C (285 °F). So a 35 °C reduction resulted in as low as 1/10 of the equivalent fume level.

Significant changes were also found in the odour evaluation. Evaluation of measurements has indicated that in all cases where zeolite had been added and temperatures have been reduced, that the number of odour units (GE’s) was significantly reduced. Most significant were the statements of truck drivers and members of the asphalt crew who have confirmed significantly improved working conditions when the asphalt was produced at lower temperatures.

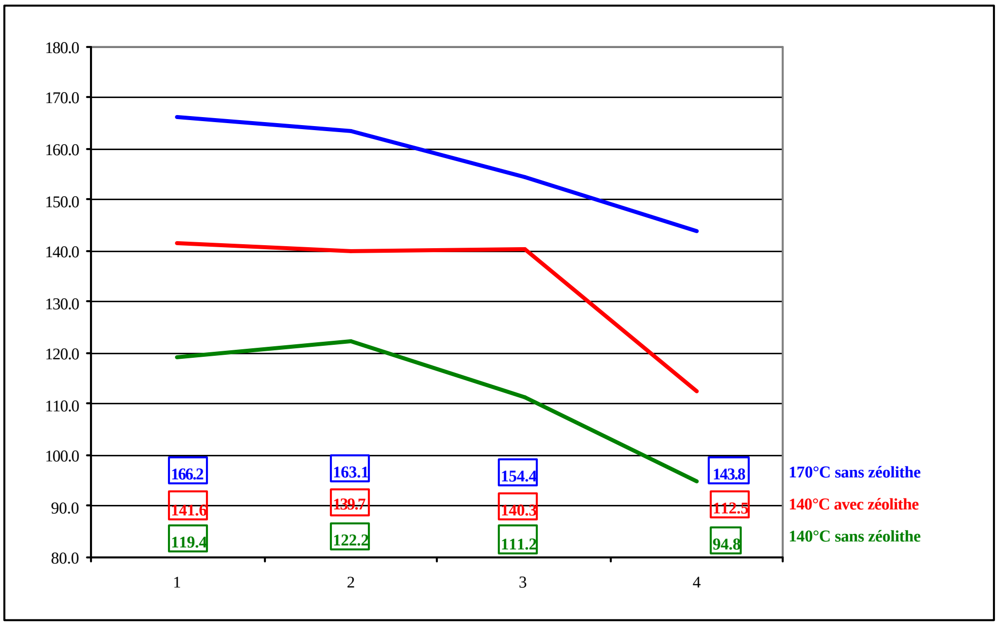
7. WORKABILITY AND PERFORMANCE

In general all asphalt mixes, which were produced at lower temperatures with the

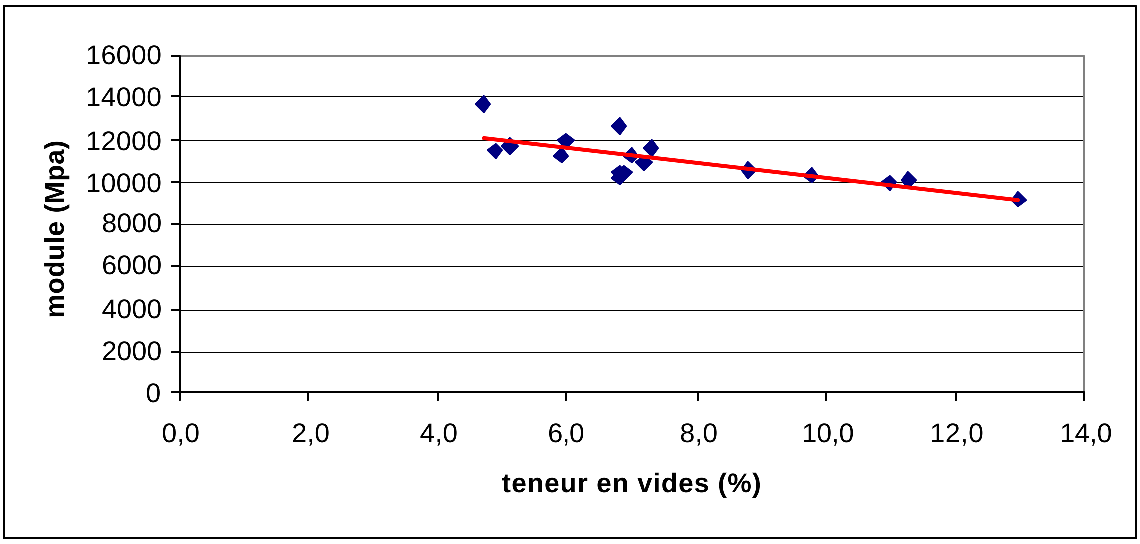
application of zeolite, could be handled in the same way as traditional asphalt mixes which were produced at (previously) normal temperatures. Comparative testing was done by the same asphalt crews on similar stretches with similar types of asphalt mix. Only the variation of the temperature took place. In order to show the effectiveness of the aspha-min® at a reduced mixing temperature a site with a standard bituminous mix was realized with (0.3 ppc) and without aspha-min® (French mixtype : (BBSG) 0/10). The mix was laid in a layer of 5 cm bituminous mix BBSG 0/10 with bitumen 35/50 (5.6 ppc) in binder course. Production was done at two temperatures (170°C and 140°C) and with two modes of compaction (immediate and differed).
Following testsections were constructed:
BBSG without zeolite at mixing temperature of 170°C:
BBSG with zeolite at mixing temperature of 140°C:
BBSG without zeolite at mixing temperature of 140°C

The used mixing plant is a batch plant. The temperatures of the bituminous mix were taken in the trucks at the mix plant, on their arrival on job site (after approximately 1hour of transport), in the hopper of the finisher, in the screw of the finisher and on the level of the screed of the finisher. They are recalled in the table and the graph hereafter.

Mode of manufacture	Type of compaction	Samples			
		e (cm)	Voids (%)	Voids corrected for 5 cm (%)	Modulus (MPa)
170°C without zeolith	Immediate compaction	6.1	6.7	6.0	11000
	differed compaction	4.9	8.5	8.4	10630
140°C with zeolith	Compaction without rain	4.8	5.3	6.6	12400
	Compaction with rain	5.4	6.2	5.5	11800
	differed compaction	4.5	11.8	11.3	9700
140°C without zeolith	Immediate compaction	6.0	8.5	9.2	10400



The manufacture of bituminous mix BBSG 0/10 with Zeolith was without any special problem. One realizes the bituminous mix, containing zeolithe with 140°C, allows to obtain voids contents within the specs (5.3 %); whereas the reference without zeolithe is about 6.7%. Moreover, after analysis of the change of the temperature throughout advance of the bituminous mix, it seems that zeolite allows the maintenance of those as long as the bituminous mix remains in mass in the truck. The mechanical characteristics measured with the modulus are not changed as the graph shown hereafter (void content versus Modulus).



8. USER CHARACTERISTICS

Everyone expects that roads are providing a comfortable and safe surface, independent on whether the asphalt has been applied hot, warm or cold. Characteristics as stability, skid resistance and durability should be guaranteed. Since the first applications in test sections of zeolite, three years have passed by. Measurements on the first stretches have indicated no significant changes in the surface characteristics, neither deformations were found. All test sections were built in comparison to traditional asphalt. So far it can be stated that NTA or Warm Asphalt Mix with the addition of a zeolite is absolutely comparable to the traditional hot mix asphalt. Furthermore as the heating in the production process of the bitumen is not taking place to the same extend as in the traditional process, less oxidation of the bitumen is to be expected. This should provide a longer durability of the binder and therefore of the entire mix, which again results in a longer durability of the entire road surface. Also in those situations where cores were taken from the road surface and the connection between the several layers was tested no changes were found compared to traditionally constructed road layers. At this moment the evaluation of field test sections is continued.

SYNOPSIS

Looking at the mineral composition of the mix, the addition of recycled asphalt, the type and amount of binder, and the addition of other possible additives, no effect has been identified, neither on the mixing time nor on the performance and the characteristics of warm asphalt mix prepared with zeolites. The addition of aspha-min® into the mixing process did not create any special problem or limitation from a storage (or handling) point of view. The special purpose designed equipment for adding the zeolite didn't show any limitations and performed well.

As adding of zeolite did not prolong mixing times, production effort was similar as with traditional hot mix asphalt.

By reduction of the mixing temperature with approximately 30 °C (54°F) a lower energy consumption was achieved. This lower energy consumption relates similar to a reduction of CO_2 emissions into the atmosphere. Combined with a lower level of emissions of fumes and odour, a significant contribution to a better environmental performance can be achieved by warm asphalt mix. Additional advantages are that at lower temperatures the wear and tear of the asphalt mixing plant is lower, and lower mixing temperatures relate to a lower oxidising process of the used bitumen, which again results in a longer durability of the mix. Since 1998 several tests both in laboratory and on building sites were performed. Tests were also performed during several weather conditions as well as in using several types of binders, and several amounts of added recycled asphalt.

During mix application temperature differences ranged from above 30 °C until nearly freezing point. In all theses circumstances no significant differences were obtained compared with traditionally mixed and produced asphalt. Although the addition of zeolite is increasing the cost of a tonne of mix, savings can be obtained in energy reduction, and wear and tear of the plant. Additional cost benefits, which are more difficult to calculate, are related to fume, odour and CO_2 reduction as well as improved working environment. All these factors are significantly adding to the image of the asphalt industry and will contribute to continued use of asphalt in road construction. All tests carried out so far have demontrated that zeolite is the way forward.

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Figure 1
Construction site with AC 0/11 + aspha-min®

Figure 2
Adding the aspha-min®

Figure 3
The final product

	B 65 Standard	B 65 NTA
Application Temperature	168° C	142° C
Aerosols	172,1 mg/m³	7,3 mg/m³
Total fume + Aerosols	350,7 mg/m³	90,4 mg/m³

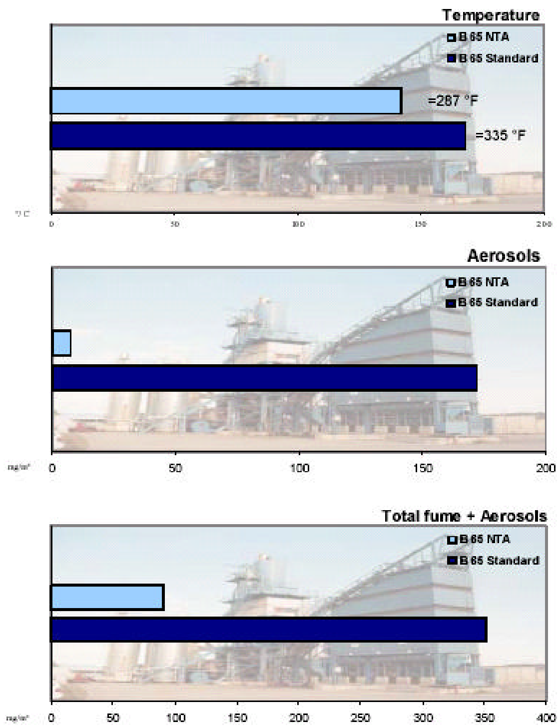

Figure 4
Testing at Mixing Plant
B 65 versus B 65 with aspha-min®

Figure 5
CO_2 Measurement at the plant

Figure 6
Fume exposure measurement in September 2001 on a paver

Figure 7
Construction of standard mix in France at 150 °C.

Figure 8
Application and compaction of AC with aspha-min® at 120 °C in France