Innovative gussasphalt for noise reduction

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ABSTRACT

The initial research focus to reduce traffic noise in Germany had been placed on porous asphalt and was subsequently switched to dense pavements. An innovative approach to optimise these surfaces is the so called Porous Mastic Asphalt (PMA). The basic idea behind this construction method is the forming of a dense bottom zone of the surface layer, i.e. similar to Gussasphalt (mastic asphalt), whereas the upper smaller zone of the layer has a porous structure with good acoustic properties. First test sections on motorways and some bridges were carried out in combined research activities of the state road administration, research facilities and industry. An in depth investigation was carried out in the interdisciplinary research project "Quiet Road Traffic 3" which included the optimisation of the mix design and visualisation of the homogeneity with the help of X-Ray computer tomography. The measurement of the skid resistance and acoustic emission were further points of interest. The analysis of the data indicates that the concept is very promising, but a few problems have to be solved. This includes the procedures in the laboratory and how to control precisely the different zones of the layer (dense on the bottom, porous on top).

Keywords: Mastic Asphalt, Noise reduction

1. INTRODUCTION

Large areas in Europe especially in the central and western parts have a rather high population densities and have numerous metropolitan areas where the need to protect the population against traffic noise is particularly high. The use of noise barriers is often not sufficient and the heights which are required can be problematic. It therefore seems obvious that the road surface should also make a contribution to the reduction of traffic noise.
Noise-reducing road surfaces lower tyre/road noise very effectively, as prevention takes place where the noise is generated. Porous asphalt layers were found to be very effective because they ensure the absorption of the noise as well as the ventilation of the tyre profile, the so-called “Airpumping-Noise”. Effective on one side, porous asphalt layers have some disadvantages on the other side. Clogging, costs, winter service and the susceptibility to mechanical damages are to be mentioned. In the last few years some developments started to have sufficient noise reduction without the disadvantages of porous asphalt. These newly designed wearing courses produce less tyre vibration due to their fine texture (small maximum size of the aggregates used) and allow a ventilation of the tyre profile, although to a lesser extent.

2. USE OF GUSSASPHALT IN GERMANY

Gussasphalt (German for Mastic Asphalt) is one of the two possible methods to construct an asphalt layer. Compared to the conventional and widespread rolled asphalt, it shows some basic differences. Some of them have a positive effect on the durability of the pavement which is not to be underestimated:

- The resulting layer is free of voids and therefore watertight. It prevents water from entering the binder layer.
- The hot mix behaves as a liquid at construction temperatures (up to 230 °C) and needs no compaction.
- The special paver only acts as a screed to distribute the material.
- Chippings are applied on the hot surface to ensure the skid resistance of the trafficked layer. Caused by the high amount of material used, skid resistance values are rather high.

Taking these advantages into account, Gussasphalt was a standard surface layer on German motorways up to the 1980’s. In some German states it is still used, but lost ground to Stone Mastic Asphalt (SMA). The overall result is a very durable road pavement.

3. ACOUSTIC OPTIMISATION OF CONVENTIONAL GUSSASPHALT

For the understanding of the properties of a Gussasphalt surface, it is helpful to look more closely at the production process. The hot mixture is distributed by the paver/screed and because it reacts as a liquid at the high construction temperatures the coarse aggregates sink to the bottom and the mortar (binder + filler + fine sand) enriches on the top. When cooled down this would lead to a very smooth but slippery surface which is unsafe for traffic use. Chippings have to be applied on the road surface to provide good skid resistance for road traffic. This is carried out directly during the paving process on the still hot Gussasphalt surface. The paver/screed applies up to 15 kg/m^2 coarse aggregates 2/5 mm, in earlier times even up to 18 kg/m^2 of course aggregates 5/8 mm. Rollers (rubber wheeled + tandem roller) were used to incorporate this high amount of aggregates into the still hot and workable Gussasphalt surface. The use of relatively coarse aggregates as chipping material and the influence of the rollers on the surface lead to a rather high noise emission of conventional Gussasphalt surface layers compared to SMA.
The acoustic optimization of conventional Gussasphalt layers started in the 1990’s to improve the situation. Three technical changes of the process were carried out:

- Reduction of the maximum aggregate size of the mixture from 11 mm to 8 mm, or even 5 mm.
- Change of the chipping material: Up to 13 kg/m^2 of 2/4 mm, or 2/3 mm instead of 5/8 mm.
- The use of rollers has to be avoided. The chippings have to integrate into the surface by their own weight.

Several test section were constructed following the new concept. In the year 2010, after gathering experience and proving its durability, the new method was granted a noise bonus of 2 dB(A) compared to the German reference surface which is conventional Gussasphalt.
Despite this success a basic problem of Gussasphalt surface layers was still unsolved. The application of chippings on the surface leads to a texture type which could be described as positive according to ISO 13473-2 [1] (Figure 1). This type of texture generates more tyre/road noise compared to a negative texture [2].

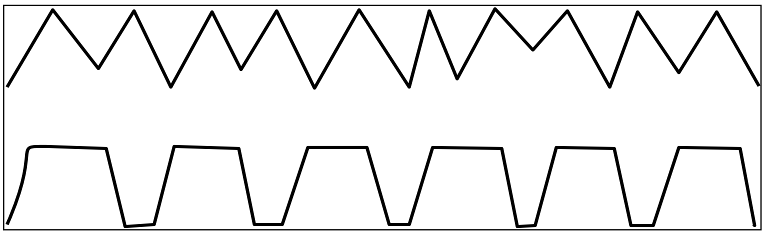

Figure 1: Basic types of a road surface texture, top: Positive texture, e.g. Gussasphalt, below: Negative texture, e.g. hot mix asphalt compacted with rollers (SMA etc.)

With this in mind it seemed nearly impossible to achieve a further reduction in tyre/road noise of Gussasphalt surfaces and a completely new concept was necessary.

4. POROUS MASTIC ASPHALT AS A NEW CONCEPT

Road research is marked by empiricism and sometimes random events help to achieve progress. In 2009 the road authority of the German state of North Rhine-Westphalia initiated a trial installation of a Gussasphalt layer deliberately without chipped surface. During construction the normal enrichment of mortar on the surface did not occur and the resulting surface could be compared with rolled asphalt, or even porous asphalt and showed the desired negative texture (compare Figure 1). Having the basic texture problem of Gussasphalt in mind, it was decided to look more closely at the effects which occurred at the trial and to start the development of a new construction method. The new design had the working title "Porous Mastic Asphalt (PMA)" and is characterized by the following properties:

- Small maximum aggregate size of the mixture, i.e. 5mm.
- The grading curve has a gap between 1 mm and 2 mm. This results in a fine mortar which can easily fill the skeleton of the coarse aggregates. The latter have a share of over 60 % on the total aggregate mix. Table 1 and Figure 2 illustrate a PMA grading curve and typical mixture properties in comparison to a standard Gussasphalt MA 5 S according to German technical delivery terms for bituminous mixtures [3].
- Due to the precise adjustment of the mortar, the resulting layer is a dense and therefore watertight Gussasphalt at the bottom and porous in a zone of approx. 1 cm at the top.
- Use of additives to modify the binder viscosity similar to warm mix asphalt.
- Mixing temperature approx. 200 °C. Construction temperature 180 to 190 °C.
- Use of normal construction equipment (dump trucks, paver, light tandem rollers).
- Use of rollers not for compaction but for smoothening of the surface.

Laboratory procedures for mixture design and quality control are an important topic in asphalt pavements in general. In the case of PMA there is the need to define new boundary conditions for the production of laboratory specimen and the test procedures.

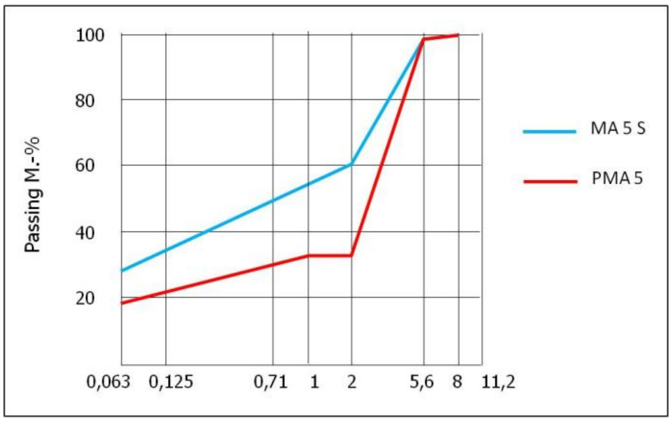

Figure 2: Grading curve of PMA 5 compared to Gussasphalt MA 5 S

Table 1: Typical mixture properties, PMA and Gussasphalt (MA) according to German technical delivery terms for bituminous mixtures

Properties of the mixture		**PMA 5**	**MA 5 S**
Grading:			
above 2 mm	[M.-%]	71.8	35 to 45
0.063 mm to 2 mm	[M.-%]	8.7	23 to 41
Filler	[M.-%]	19.5	24 to 32
Binder content	[M.-%]	6.8	min. 7.0*
Binder		30/45**	20/30; 30/45; 10/40-65; 25/55-55
Softening point ring and ball	[°C]	91.5	---
Max. indentation 30 minutes at 40 °C	[mm]	1.8	max. 3.0
Max. indentation 60 minutes at 40 °C	[mm]	2.0	---
Max. increase of indentation after 30 minutes at 40 °C	[mm]	0.2	max. 0.4
Max. dynamic indentation at 50 °C	[mm]	1.8	to be declared

* based on a particle density of the aggregates of 2,65 g/cm^3
** viscosity reduced binder (amid wax)

Prior to the initial incident in Germany a development of a similar concept was carried out in Japan. During a Danish/Dutch study tour in 2005 the Japanese hosts presented a so called "Hybrid Pavement"[4]. The aim here is to use this surface layer as alternative to porous asphalt with improved mechanical stability and reduced damages due to winter service in the snowy north of Japan.

5. RESULTS OF TEST SECTIONS

5.1 Overview

Starting in 2009 a larger number of test sections were constructed in Germany mostly on motorways, some with a high traffic volume, e.g. the A4 near the city of *Köln/Cologne*. In most cases the mix design followed the example described in Table 1 and the basic principles of this construction method were applied. Normal transportation vehicles and a standard asphalt paver were used, completed with a small roller exclusively to produce a homogenous surface. After two years and some good empirical results, more systematic research was carried out. From 2011 to 2014 a consortium involving industry, universities and other research organisations worked on the collaborative project *Quiet road traffic – LEISTRA 3*. The project partners were subsidised by the German Federal Ministry of the Economy Affairs and Energy and supported by the Federal Ministry of Transport and Digital Infrastructure. Besides other topics, the optimization of PMA was one the tasks to improve non-porous asphalt layers. Within the project the test sections A5 *Friedberg* and A553 *Brühl* were constructed and further investigated.
The German state of North Rhine-Westphalia has constructed 500,000 m^2 of test sections in the last few years on motorways alone.

5.2 Distribution of voids

Following the PMA principle most of the voids should be concentrated in the upper zone of the layer. In reality a dividing line between porous and dense is not fixed. Ideally the lower zone of the layer is similar to Gussasphalt. Figure 3 illustrates the distribution of the voids in a cut section of a core specimen. In this example the voids are concentrated in the upper half of the layer, which means the dense and watertight part is below this zone.

Figure 3: Typical distribution of voids in a PMA layer (cut of core specimen)

A perfect distribution of the voids, high content at the top and zero at the bottom, is not always the case and irregularities could occur. To get further clarification X-ray Computer Tomography (CT) scans of core specimen of the motorway A4 *Köln* were carried out by the Federal Institute for Materials Research and Testing (BAM) in Berlin. The technology detects differences in the density of a scanned specimen and after analysis a 3-dimensional structure of the voids could be produced. Figure 4 shows the void distribution over layer height of three core samples of the A4. The mean values of the void content in the upper and lower zone are also illustrated. The sample on the right shows a very high void content at the bottom of the layer and a void system which is connected from bottom to top. This means the layer is not watertight anymore and has to be seen as a failure. Contrary to this the sample on the left has a void content of 2.0 % by volume at the bottom and therefore the function as a dense layer is secured.

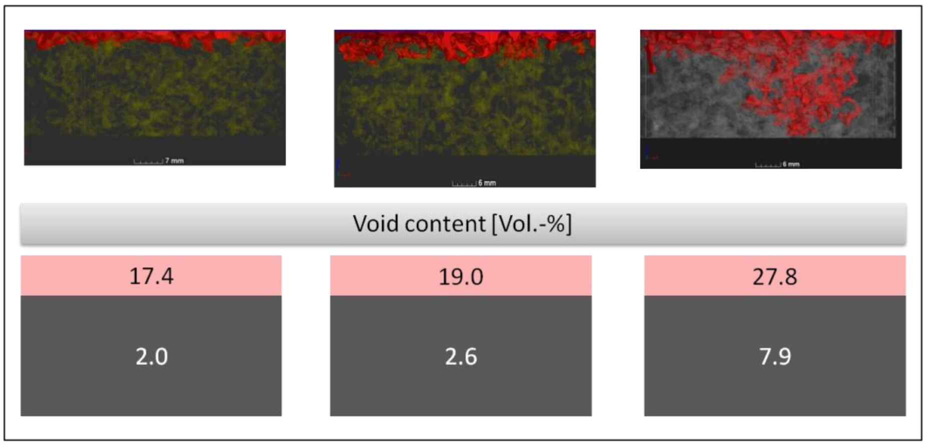

Figure 4: Distribution of voids over the layer height, CT-scans of three specimen, test section A4 *Köln*, red: void content upper zone, dark grey: void content lower zone (CT-scans: Federal Institute for Materials Research and Testing (BAM), Berlin)

5.3 Temperature homogeneity during construction

On the test section A5 *Friedberg* a closer look at the construction temperatures was carried out. The mean temperatures of the mix at the screed of the paver were 163 °C to 167 °C measured on three different days. To measure the temperature distribution after the screed, a thermographic camera was used. Figure 5 shows three thermographs with a comparable measuring range of around 50 °K. After the screed there is a temperature range of the surface of approximately 20 °K, which is a normal value also with conventional rolled asphalt. More interesting are some relatively cold areas of about 130 °C occurred (Figure 5, middle thermograph). Due to a reduced viscosity of the mastic the desired filling of the skeleton of the coarse aggregates could be hindered in these areas which lead to an inhomogeneous distribution of the voids.

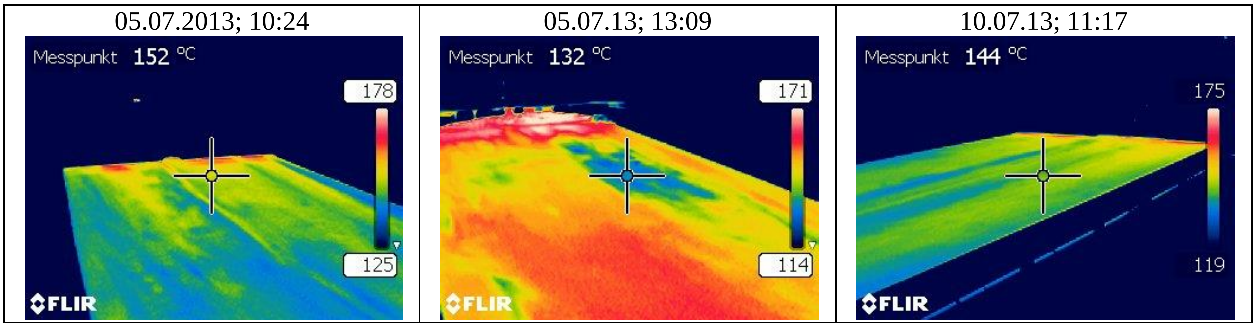

Figure 5: Thermographs of the surface layer behind the paver screed

5.4 Noise measurements: Close Proximity Method (CPX)

Noise measurements in the near-field with the measuring trailer (CPX method) were performed by the Federal Highway Research Institute (BASt) after laying on most of the test sections (Table 2). CPX measurements according to ISO/DIS 11819-2 are a good instrument to show the acoustic homogeneity of a test section and to compare different segments within one test section. The comparison of surfaces in different locations is possible under certain conditions, i.e. use of same trailer, same test tyres and extensive data base.

Table 2: CPX measurements on test sections (after laying, BASt trailer)

Test section	**CPX 80 km/h [dB(A)]**	
	Tyre P1	**Tyre H1**
A24 *Neuruppin*	94.0	95.0
A4 *Köln*	96.3	97.0
A30 *Lotte* (direction west)	95.5	96.8
A30 *Lotte* (direction east)	95.6	96.8
A5 *Friedberg*	94.8	96.0
A 553 *Brühl* (segment with lowest values)	94.0	95.7
A 553 *Brühl* (segment with highest values)	94.7	96.9

The PMA test sections have a value range of around 2 dB(A), both for the tyre P1 and tyre H1. The mean value for the seven test sections is 95.0 dB(A) for tyre P1 and 96.3 dB(A) for tyre H1. For comparison normal SMA 8 surfaces have a mean P1 value of approximately 97.5 dB(A), which means 2.5 dB(A) reduction for new PMA surfaces.

5.5 Noise measurements: Statistical pass-by method (SPB)

Noise measurements by means of the Statistical pass by method were carried out on two selected test sections (Table 3). This type of measurement is time consuming (recording of 100 vehicles at least) but gives an absolute value which could be easily compared to a reference value, which is 85.2 dB(A) for cars at 120 km/h in the case of the German noise classification system. For the two PMA test sections measured, the reduction compared to the reference value would be 3 – 4 dB(A). Compared to SMA it is lower, only 1 – 2 dB(A), because SMA has a granted noise reduction in the classification system of 2 dB(A).

Table 3: SPB measurements on test sections (after laying)

Test section	SPB [dB(A)]	
	Cars 120 km/h	Heavy trucks 80 km/h
A24 *Neuruppin*	81.2	85.4
A4 *Köln*	82.2	87.8

6. PROBLEMS TO BE SOLVED

6.1 Homogeneity in the distribution of voids

It is of vital importance for PMA to achieve homogeneity in the distribution of the voids. This means a concentration of the voids in the upper zone of the finished layer and this requires a correct viscosity and amount of the mortar to fill the stone skeleton. Problems arose here in a few test sections. Besides an inhomogeneous surface texture, connected voids could develop and a watertight layer is not guaranteed. At this stage of the development only some recommendations could be given to solve this problem. The use of a proven binder or binder system, the correct temperature of the mix and the use of a material feeder in addition to the paver seemed to have a positive influence on the results and provide a process secure construction.

6.2 Laboratory procedures

Besides the construction of test sections, the project *LEISTRA 3* also focussed on the laboratory procedures for PMA. It seemed clear from the very beginning of the development, that the standard Marshall-procedures for rolled asphalt could not directly be used to produce test samples for PMA. The central problem is how to simulate the drainage of the mastic in the lab as it occurs during production/paving of the layer on the road. After an extensive lab test programme, a provisional test procedure was developed [4]:

- Compaction temperature 180 °C.
- Reduced number of compaction blows of 1 x 20. This value was chosen after testing a series of different number of blows and a stabilization of the bulk density could be recognized between 1 x 20 and 1 x 25 blows (Table 4).
- After compaction the specimen is immediately turned upside down.
- Remove mould after specimen has cooled down to 20 °C.

Table 4: Properties of Marshall-specimen after different number of compaction blows [5]

Number of compaction blows [-]	Bulk density [g/cm^3]	Void content [Vol.-%]
1 x 5	2.199	13.0
1 x 10	2.302	8.9
1 x 12	2.346	7.2
1 x 15	2.377	6.0
1 x 20	2.383	5.7
1 x 22	2.386	5.6
1 x 25	2.391	5.4
1 x 30	2.425	4.0
1 x 50	2.431	3.8
1 x 75	2.432	3.7

In the case of the “Hybrid Asphalt” in Japan, the Marshall-Procedure was changed as well. A reduction of compaction blows in the mix design could effectively reduce binder run off problems during construction [6].

7. CONCLUSIONS AND OUTLOOK

Porous Mastic Asphalt as a new concept promises two important properties of an asphalt surface layer: noise reduction and a watertight construction. At this moment it is possible to draw first conclusions from the test sections which started in 2009:

- The noise reduction potential of PMA in new condition is at a better level than that of standard asphalt wearing courses such as a SMA 8.
- The homogeneity of the finished layer is not always satisfactory. It requires the correct viscosity and amount of the mortar to fill the stone skeleton to reach the distribution of voids wanted: open structured surface texture on top and void free watertight at the bottom.
- The use of a proven binder or binder system, the correct temperature of the mix and the use of a material feeder in addition to the paver seem to have a positive influence on the results and provide a process secure construction to a certain extent.
- New laboratory procedures are necessary for PMA. The provisional new procedures have to be further investigated and optimized.

The testing and optimization of the method will continue and new test sections were built. A first guideline will be published in late 2015 and will give contractors and road authorities a hand to carry out this promising and to a certain point demanding construction exercise. Questions concerning the durability of PMA must be answered in the near future. This includes the resistance to deformation (rutting) and the stability of the surface texture to provide a good skid resistance and noise reduction over the years.

REFERENCES

[1] ISO 13473-2: Characterization of pavement texture by use of surface profiles - Part 2: Terminology and basic requirements related to pavement texture profile analysis (ISO 13473-2:2002).
[2] Sandberg, U.; Ejsmont, J.A.: Tyre/Road Noise Reference Book. Published by INFORMEX, Kisa/Sweden, 2002.
[3] Technische Lieferbedingungen für Asphaltmischgut für den Bau von Verkehrsflächenbefestigungen, Ausgabe 2007/Fassung 2013 (TL Asphalt-StB 07/13) (Technical delivery terms for bituminous mixtures for traffic area pavements). Published by the Road and Transportation Research Association (FGSV), Köln, 2013.
[4] Bredahl Nielsen, C. et al.: Noise reducing pavements in Japan – study tour report. Danish Road Institute, Technical Note 31, ISBN electronic 87-91177-77-4, December 2005.
[5] Root, V.: Optimierung der lärmtechnischen und bautechnischen Wirksamkeit und Nutzungsdauer dichter Asphaltdeckschichten (Optimization of the acoustic and constructional effectiveness and durability of dense asphalt surface layers). Project Leiser Straßenverkehr 3, second interim report 2011 (in German, unpublished).
[6] Kamiya, K. et al.: Long lasting durable mix as alternative of porous asphalt. Paper 0580, proceedings 24th World Road Congress, Mexico City, September 2011, World Road Association (PIARC), Paris, 2011.