INNOVATIVE NOISE OPTIMISED POROUS MASTIX ASPHALT (PMA) FOR HEAVY DUTY HIGHWAYS

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ABSTRACT

This study deals with newly developed Porous Mastic Asphalt (PMA) with porous surface for highly loaded highways. For this new asphalt mix no verified experiences are available for mix design, for production asphalt specimen for laboratory tests and asphalt paving. Hence, new production method to produce adequate samples in laboratory has been develop and by means of test mixing and test field adequate paving method has been determined. The gained test results of performance oriented laboratory tests show that the pavement with PMA will have high resistance against rutting, significant noise reduction and is still impermeable as conventional mastic asphalt. These multi properties are induced by untypical asphalt layer structure of 3 cm thickness: the upper-third one as porous asphalt, middle-third one as stone mastic asphalt and the bottom-third one as mastic asphalt. By means of test mixing and test field, it could be found out that porous mastix asphalt is self-compactable, can be delivered via conventional trucks and placed by means of a conventional paver. An additional compaction by roller and the sprinkle for grip are not necessary. Because of these advantages, this asphalt mix has been selected to place 100.000 m² on the most trafficked highway in Germany (BAB A4, Highwayring Cologne). In addition, to determine the quality of surface-texture immediately after paving, an innovative test method by means of laser apparatus has been applied.

Keywords: Porous Mastic Asphalt, Open porous surface, Noise mitigation, Heavy duty highways, Noise absorption, Texture measurement

1. INTRODUCTION

The protection of noise pollution caused by transportation becomes more attention by the European Union, as consequence the European Union passed the Directive 2002/49/EC to mitigate noise pollution. A study of Federal Government of Germany reveals, it is to suspect that around 12 million inhabitants are suffering by health disease caused by noise pollution only in Germany [1]. As consequence, in the context of the economic stimulus package, the Federal government of Germany has given financial support to construct noise reduced asphalt pavement in last three years. It results in developing of noise optimised asphalt pavement for urban area and heavy duty highways.

It is well known that the open graded, porous asphalt pavement with air voids >20 Vol.-% in situ promotes significantly the noise mitigation. But, on the one hand the use of open graded porous asphalt shows still decreasing effectiveness of noise mitigation with increasing lifetime and the other hand it causes high maintenance cost. It is also well known, that the porous asphalt does not show high resistance against shear forces, trends rapidly to fretting and ageing. Thus, the porous asphalt is not always the most economic variant over the lifetime. The noise mitigation can be also reached by means of dense graded asphalt with small size of aggregates (≤ 5 mm) in thin surface layer. In common this type of asphalt is suited for the low volume roads, but it is not adequate for heavy duty high ways. Thus, a new type of asphalt with a high effectiveness of noise mitigation and long lifetime had to be developed.

This study deals with the development of mastic asphalt with porous surface PMA (Porous Mastic Asphalt) for heavy loaded high ways. Further more the construction experience of this asphalt on one of heaviest loaded highway in Germany (A4) will be reported.

2. ASPHALT PAVEMENT FOR HEAVY DUTY HIGH WAYS

According to German Standard only stone mastic asphalt (SMA 11 S, SMA 8 S), mastic asphalt (MA 11 S, MA 8 S, MA 5 S) and porous asphalt (PA 11, PA 8) are recommended as asphalt wearing course for highways. Stone mastic asphalt and mastic asphalt are dense graded asphalt with very low or without air voids in situ. It is well known, that these asphalt variants have long lifetime and cause low maintenance cost compared to the porous asphalt. In addition high amount of experiences are availabe for these mixtures. But, the noise mitigation of these asphalt wearing courses are not satisfying. Thus in this study a new type of innovative asphalt wearing course was developed for a long lifetime and a durable noise mitigation.

2.1 Asphalt Mix Design

The objective was to develop an asphalt wearing course with multi properties of all of the above mentioned advantages of three asphalts variants. It means development of an asphalt wearing course with a surface texture of porous asphalt, aggregates skeleton of stone mastic asphalt and dense graded like mastic asphalt. Taking into account this requirement porous mastic asphalt with a maximum grain size of 5 mm (PMA 5) has been developed. Thereby, upper third one as porous asphalt, middle-third one as stone mastic asphalt and bottom-third one as mastic asphalt structure were targeted.

In addition, to keep the construction cost as low as possible, the new developed PMA should be self-compactable, transported by means of conventional trucks and paved by conventional pavers.

The grading and mix design has been developed on the basis of the grading of mastic asphalt and stone mastic asphalt with respect to German Standard. For this new asphalt mix no verified experiences or any Specifications are available for mix design, to establish initial type test or to produce asphalt specimen for laboratory tests. Hence, in this study initial type test and respective Job Mix Design for this new type of porous mastic asphalt has been established. In the Figure 1 the grading of asphalt wearing course mixtures considered in this study has been displayed. The volumetric characteristics of these wearing course mixtures can be taken in Table 1. The grading and volumetric properties of the mastics asphalt and porous asphalt PA 8 has been presented only for information and this variant has not been considered for further investigation.

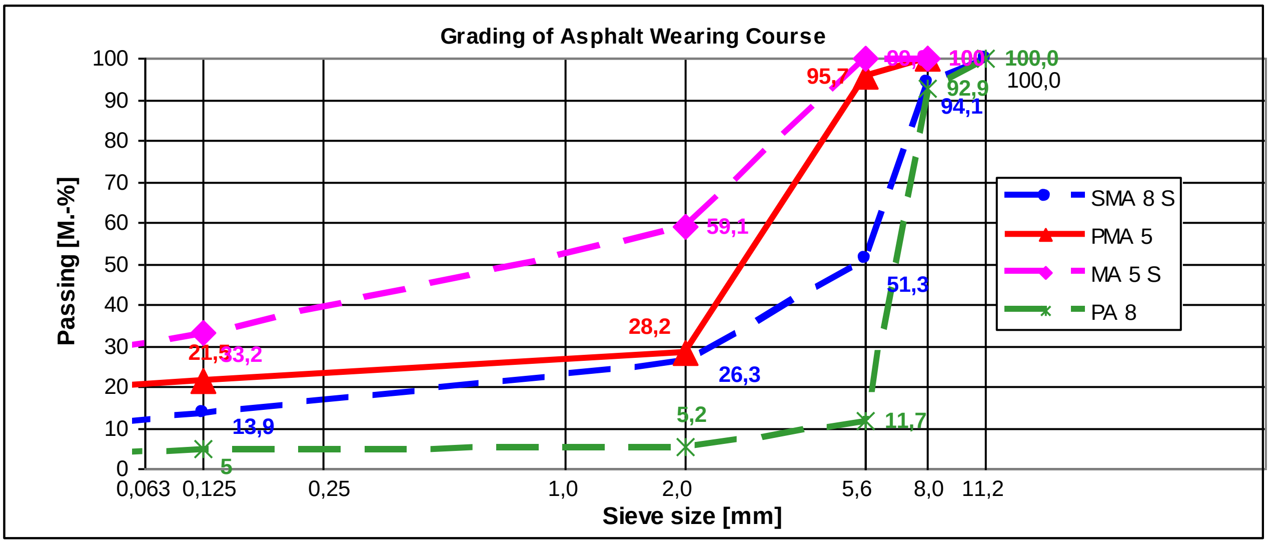

Figure 1. Grading of Typical Asphalt Wearing Course Mixtures accordingly German Standard

Tabelle 1: Volumetric characteristics of wearing course mixtures

	MA 5 S	SMA 8 S	PMA 5	PA 8
Binder Content [%]	6.8	7.0	7.1	6.6
Fines ≤ 0.063 mm [%]	24.5	10.5	19.5	3.8
Fine aggregates 0,063/2.0 mm [%]	35.2	15.8	8.7	1.4
Coarse aggregate > 2.0 mm [%]	40.3	73.7	71.8	94.8
Air voids in Marhall Specimenn [vol.-%]	[-]	2.8	3.5	24.2
Voids in Mineral Aggregates VMA [vol.-%]	[-]	20.2	26.6	36.7
Voids filled with binder VFA [vol.-%]	[-]	86	55.8	34.0

It is well known that the surface characteristics contribute extremely the noise development. The texture characteristics of surface can be influence by aggregate type used, binder content and volumetric properties. The texture characteristics can be divided into concave surface (plateau with canyons) and convex surface (mountain with valleys), Figure 2. According to the experience, a concave surface design of asphalt pavement has a very high sound mitigation [2]. Due to, the selected grading and composition of porous mastics asphalt should provide a concave surface in situ associated with an awesome eveness like a horizontally planed area., Figure 2.

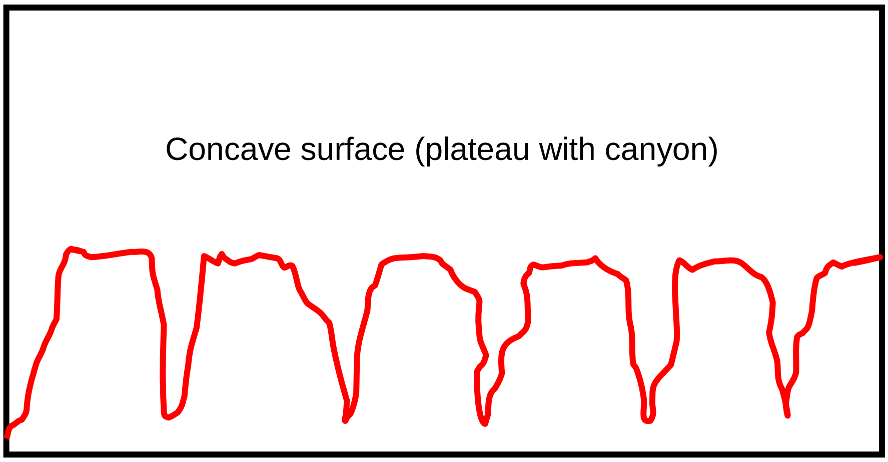

Figure 2: Concave surface (plateau with canyons)

As binder for stone mastic asphalt polymer modified bitumen 25/55-55 A has been applied. For the PMA temperature reduced bitumen SueBit VR 35 (low viscosity bitumen) has been selected. Accordingly German Standard temperature reduced bitumen has to be applied for the mastic asphalt. Based on a technical study, the Federal Highway Research Institute (BASt) recommended the bitumen SueBit VR 35 as the temperature reduced bitumen. The properties of binder used can be taken from the Table 2.

Tabelle 2: Properties of Bitumen used

Binder	Virgin Bitumen SP R&B [°C]	Virgin Bitumen Penetration [1/10 mm]	Virgin Bitumen Elastic recovery [%]	Extracted Bitumen SP R&B [°C]	Extracted Bitumen Penetration [1/10 mm]	Extracted Bitumen Elastic recovery [%]
25/55-55 A	61,7	46,9	65	65,0	33,1	67,8
SueBit VR35	88,3	36,4	[-]	92,2	24,6	[-]

3 LABORATORY TESTS

It is very important to find out the adequate laboratory tests for forecasting the behaviour of asphalt. In addition, to gain reliable laboratory test results it is also necessary to produce adequate asphalt specimen. It is well known, a lot of asphalt tests are available to describe the behaviour of asphalt as a function of traffic load and climate. In this study following asphalt tests have been applied:

- Wheel Tracking Test on stone mastic asphalt and porous mastic asphalt [EN 12697-22]
- Indentation using cube on porous mastic asphalt [EN 12697-20],
- Dynamic Indentation using cylindrical specimen on porous mastic asphalt [EN 12697-25],
- Determination of Sound Absorption [ISO 10534] and
- Mean profile deth (MPD) and estimated texture depth (ETD) by means of static T3D- Measuring system [ISO 13473 – 1]

The properties of PMA accordingly the resistance against rutting and noise mitigation have been compared with the properties of stone mastic asphalt SMA 8 S. Stone mastics asphalt SMA 8 S is a polymer modified asphalt variants. In most case of asphalt pavement for heavy duty highways this asphalt will be preferred and in this study SMA 8 S will be considered as reference variants.

3.1. Production of Asphalt Specimen

For this new asphalt mix PMA 5 any verified experiences or any Specifications are available to produce asphalt specimen for laboratory tests. Therefore new production method to produce asphalt samples in laboratory has been developed.

Rutting is mostly formed within surface and binder courses. Thus, permanent deformation tests were done on composite slabs made of asphalt wearing course material and asphalt binder course material. Therefore, adequate the asphalt slabs with asphalt binder course material (6 cm thickness) have been produced by means of roller compactor (EN 12697-33, 2007) as first. After applying bitumen emulsion, the wearing course material (4 cm thickness for material with aggregates size ≤ 8 mm; 2.5 cm thickness for material with aggregates size ≤ 5 mm) has been placed on the binder course slab and compacted [Figure 2]. The production of slabs for PMA takes place on the basis of EN 12697-33 with modified compaction method. To achieve the above mentioned multi properties the production of porous mastics asphalt specimen take place in different methods. Thereby the conditions of asphalt mixture production and compaction method have been verified. The sound absorption and texture measurement have been determined on the drill cores (ø 100 mm) gained from composite slabs. The cubes for static indentation tests have been produce with respect to EN 12697-20.

The cylindrical Specimen for dynamic indentation test have been produced by means of both methods: tamper with a spatula based on EN 12697-20 and drill cores gained from slabs based on EN 12697-33.

3.2 Resistance against Permanent Deformation

For the asphalt mix PMA no experiences are available. Due to, in this investigation the rutting resistance of porous mastic asphalt has been determined with respect to EN 12697-22 and compared to the rutting resistance of stone mastic asphalt SMA 8 S.

The gained test results of composite slabs are displayed in Figure 3. In common a proportional rut depth PRD of 4% will be required for noise optimised asphalt layer. The test results determined meet this requirement and can be considered as rutting resistant asphalt. The determined rut depth of variant PMA has been resulted in by means of not adequate distribution of coarse aggregates in binder slabs [Figure 2]. By means of indentation using cube a depth of 0.7 mm after 30 minutes and 0.8 mm after 60 minutes has been determined for PMA. An indentation of 0.2 mm has been determined by means of dynamic Indentation. These indentations denotes on high resistance against rutting.

Figure 3: Composite slabs made of asphalt wearing course and asphalt binder course material (PMA und SMA)

3.3 Texture Measurement

The texture of asphalt pavement surface has significant influence on sound initiation, emission and expansion. In the range of micro texture a high amount of roughness of the aggregate should be aimed to mitigate the noise caused by tyre-pavement contact [2]**.** But the range of wave length 0.5 mm $< \lambda <$ 10 mm is decisive responsible for the development of noise caused by air pumping at high frequency (> 1000 Hz).

The surface design factor (g) can be calculated by means of texture measurement [2]. Surface design factors (g) between 20 % and 60 % has a convex surface and surface design between 60 % and 90 % has a concave surface. But a asphalt pavement with a surface design factor of > 75 % will show high sound mitigation [3].

In this study, the texture of asphalt surface has been determined by means of static T3D- Measuring system. It is an automated surface inspection with 3D measurement system based on laser inspection technology and can be used to determine micro- and macro texture of surface. As samples drill cores with 100 mm-diameter has been applied.

3.4 Estimated Texture Depth

By means of measured mean profile depth (MPD) the estimated texture depth (ETD = 0.2 mm + 0.8 MPD) has been determined. Sufficient skid resistance will be available at ETD of 0.4 mm [2]. The estimated ETD is displayed in Figure

4. The determined test results meet the recommendation for skid resistance. The estimated texture depths for variant PMA indicates on high texture depths also after sand blasting. It means that the variant PMA will show durable texture during the service time.

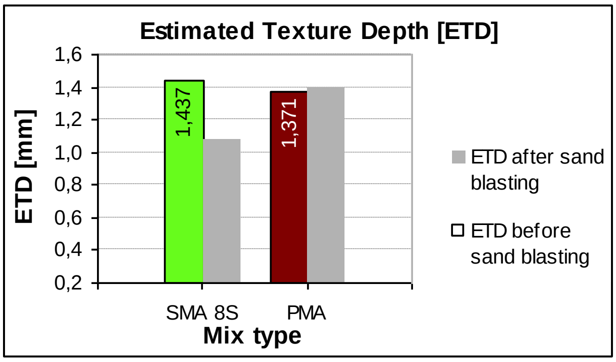

Figure 4: Estimated Texture Depth

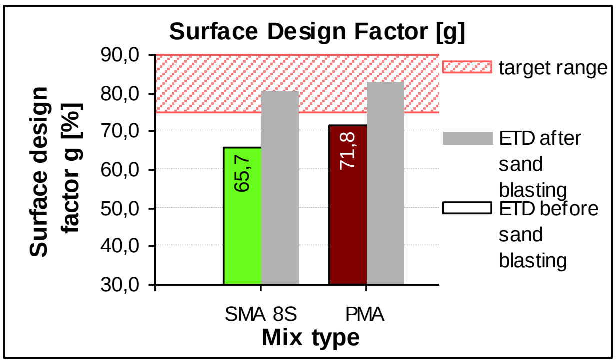

Figure 5: Surface Design Factor [g]

3.5 Surface Design Factor (g)

The calculated surface design factors [g] are by means of measured texture depth will be displayed in Figure 5. The determined surface design factor range between 65.7 % and 71.8 %. Due to, the surface of the both asphalts variants used can be designated as concave surface texture, in particular after abrasion by traffic, which was simulated by sand blasting.

By means of gained test results in laboratory, the both asphalt variants show high resistance against rutting. The variant PMA meets much more the target values on surface texture compared to the variant stone mastic asphalt. Thus, the PMA will show better noise mitigation compared to stone mastic asphalt in situ.

4. CONSTRUCTION OF POROUS MASTIX ASPHALT PMA 5

The State Enterprise Landesbetrieb Strassen NRW tendered a noise optimised asphalt wearing course with high rutting resistance for a Highwayring Road in Cologne (BAB A 4 between Cologne-South and Cologne-West). Thereby the asphalt wearing course and asphalt binder course had been renewed in the beginning of the year 2010. This section is one of the heaviest loaded highways in Germany.

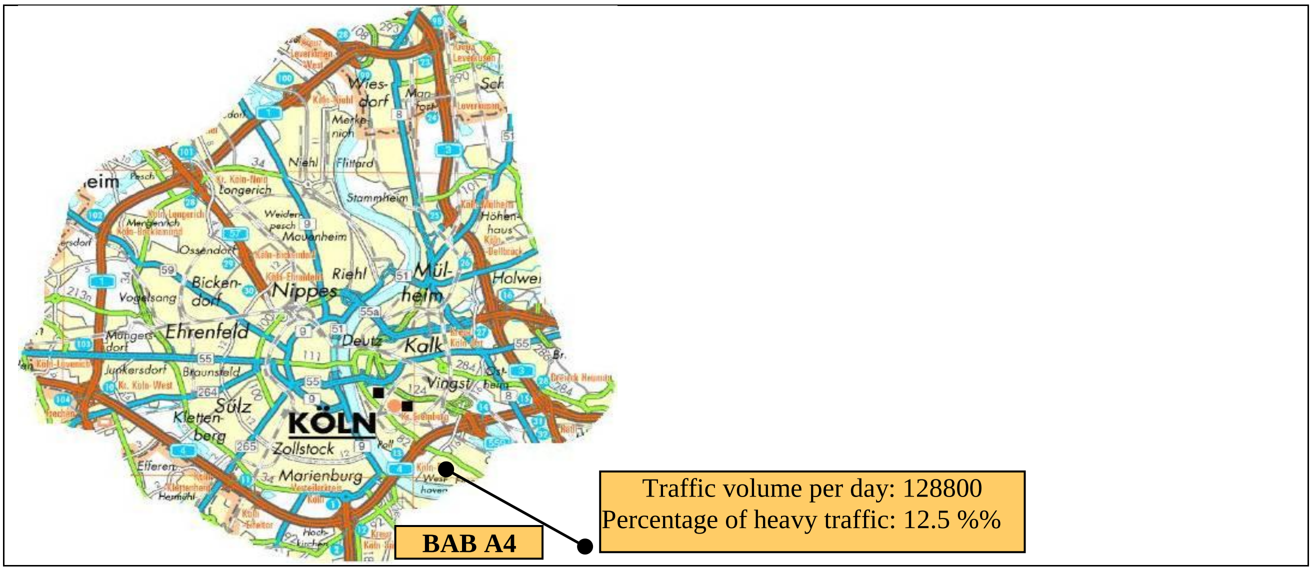

Figure 6: Highwayring Road in Cologne (BAB A 4 between Cologne-South and Cologne-West

4.1 Optimise of Asphalt Mix Production and Paving Method

Accordingly this announcement with respect to requirement on rutting resistance and noise mitigation, the newly developed porous mastic asphalt PMA 5 with multi properties has been considered suitable. For this new asphalt mix only few experiences of asphalt mix production at the plant, transportation to the site and paving were available. But, a concept for the design of this asphalt PMA were vaialable by Strassen NRW. The initial type test and job mix design has been established by means of experience collected in the above mentioned study. Several trial mixes at the mixing plant in combination with laboratory tests has been carried out to optimise the mix design with respect to aggregates used and mixing process. In addition a test field has been placed to find out the optimised paving condition for gaining a PMA structure as shown in Figure 7.

By means of test field evaluation in combination with the experiences gained in the laboratory tests for diverse variants of PMA the following result for mix design, production method and preparation of asphalt specimen have been gained:

- The production temperature should be between 190 – 200 °C
- Transportation with conventional trucks is possible
- Able for paving with conventional asphalt paver
- Asphalt paving temperature about 180 – 190 °C
- Paving with very low precompaction dependly of paver used about 25 % of tamper adjustment
- Multi properties of unconventional layer is reached straight behind the screed
- Self compacting, an additional compaction is not necessary
- Application of lightweight roller for even the surface, heavy weight roller 100 m behind of the paver
- Sprinkle to increase the skid resistance not essential
- Water proving of the layer below is not necessary
- Rapidly take in service is possible
- Thickness can be varied between 3 – 8 cm ion one layer to compensate of unevenness in under layer
- In the case of shut down, the paving has to be go out and restart the placing

Figure 7: Optimal PMA Structure

4.2 Construction of PMA (Porous "surface" mastic asphalt)

With respect to gained experience, the above mentioned construction has been carried out by means of conventional paver, Figure 8. During the construction several laboratory tests have been carried out. The gained test results confirm the findings of this study. In addition, a rapid cooling of PMA surface has been determined, so that a quickly beginning of operation is possible. The paving quality has been determined by means of texture measurement immediately behind the paver with automated texture measurement apparatus, Figure 9. This is an innovative test method by means of laser method. The ETD-value range from 1.0 to 1.2 mm and correspond to the test results gained in laboratory. Accordingly gained test results of texture measurement the paving quality can be obviously determined. But to find out a correlation between laboratories measured texture and in site measured texture more experience has to be collected.

Figure 8: Paving of porous mastic asphalt

Figure 9: Texture measurement in situ

4.3 Measurement of Noise and Skid Resistance

The road traffic noise measurement has been carried out by means of Close-Proximity method (CPX-Method) according to ISO/CD 11819-2. The CPX method can be applied to record the noise properties of a road surface caused by rolling noise. Thereby the rolling noise will be measured by means of two microphones near the accurately specific reference tyres, Figure 10. The rolling noise has been determined for the section paved with PMA and the section before and after PMA. As asphalt wearing course of the section before and after PMA is build up of SMA.

Figure 10: Close-Proximity Method (CPX-Method)

The determined rolling noise measured by CPX-Method is displayed in Figure 11. At the speed of 80 km/h a mean value of 92.6 dB(A) on PMA and 97.1 dB(A) on SMA have been determined. A significance noise mitigation of -4.5 dB(A) have been achieved by PMA. Because of limited speed of 80 km/h on this section with PMA (construction period) it was not possible to determine the rolling noise at a speed of 100 km/h. That's why the noise mitigation for 100 km/h has been extrapolated based on test results measured at speed 80 km/h. Due to, the test result of 100 km/h is given only for information.

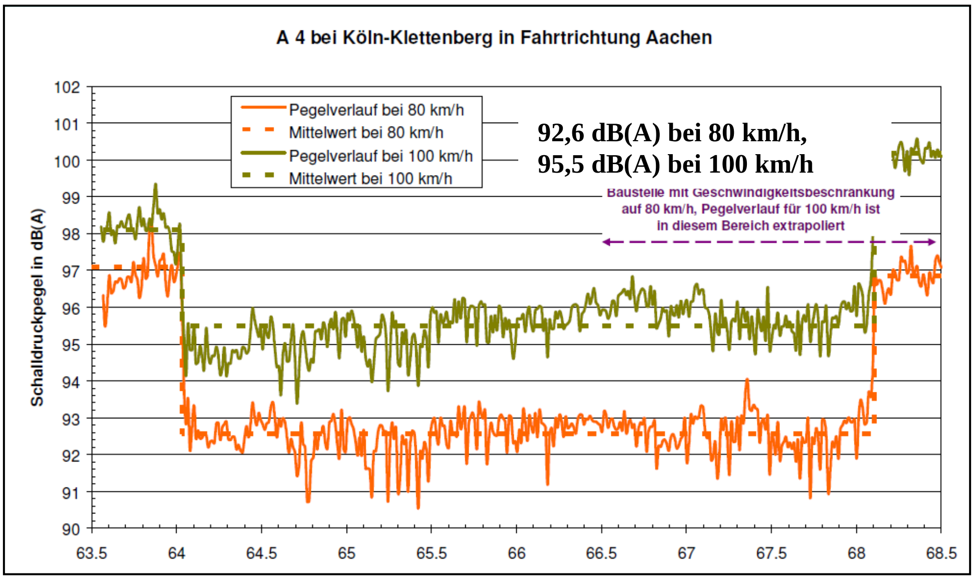

Figure 11: Test result of CPX-Method

In addition the noise has been measured by means of Statistical Pass By method accordingly the Standard ISO 11819-1. The measured value in mean is 81.5 dB (A). Reference value for noise reduced pavement construction in Germany is 85.2 dB (A). Thus, the measured value on PMA surface shows a significantly reduction of noise compared to the reference value.

The skid resistance has been determined by means of sideway-force measurement method (SKM Method) with respect to German Standard TP Griff-StB (SKM) 07 [4]. The determined test result is displayed in Figure 12. With respect to German Standard an acceptance parameter ≥ 0.46 has to be achieved on new construction. The gained test results meet this requirement.

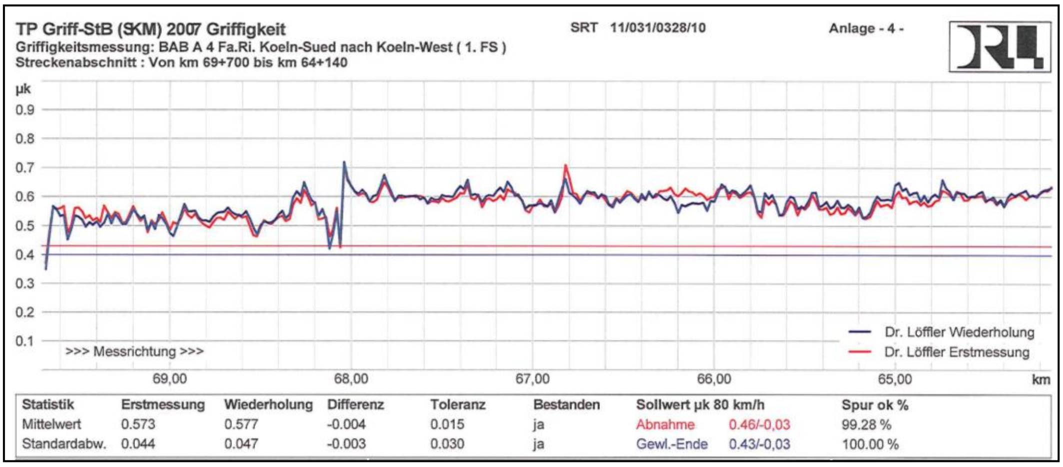

Figure 12: Test result of sideway-force measurement method for skid resistance.

5 CONCLUSION

In this study porous “surface” mastic asphalt PMA has been developed and constructed on a one of the heavy duty highway, Kölner Ring, during the maintenance of asphalt wearing and asphalt binder course. The initial type test and job mix design have been established by means of dynamical performance tests in laboratory. Test production on asphalt mixing plant and placing of test section contribute to verify the job mix design and to optimise the production method on mixing plant as well as construction process on site. Accordingly gained findings in the laboratory and on the test field, the porous mastic asphalt can be tranported by means of conventional trucks, placed by conventional paver and an addition compaction by roller is not necessary. A construction of 100 000 m² asphalt wearing course on above mentioned highway section has been placed with porous mastic asphalt. Finally the noise mitigation and skid resistance has been determined. The gained test results show, that the porous mastic asphalt has a high resistance against rutting. In addition, it has significantly noise mitigation compared to stone mastic asphalt in site compared to in laboratory. Further more PMA can be produced with 30°C lower than mastic asphalt. This contributes for significantly CO_2 mitigation.

It is to note that currently sufficient experience with respect to preparation of Specimen, production of mixes and paving available gained from several projects in Germany within last two years..

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