

Optimized road noise asphalt pavements - The types of noise-reducing road surfaces

Kerim Hrapović^a

^aGESTRATA - Society for the Maintenance of Road Construction Technology with Asphalt, Vienna, Austria

ARTICLE INFO

DOI: 10.31075/PIS.70.03.04

Professional paper

Received: 03.08.2024.

Accepted: 18.08.2024.

Corresponding author:

kerimhrapovic046@gmail.com

ORCID ID

Kerim Hrapović: 0000-0002-7720-0508

Keywords:

Asphalt

Bitumen

Noise

ABSTRACT

The noise has long been recognized as a stress factor for humans. A high level of noise has many negative influences on health such as: difficulty to concentrate, stress, health issues for the ears, and also has a damaging effect on the cardiovascular and endocrine systems. Road traffic is main source of total noise, especially in conurbations. In order to effectively reduce noise emissions, surface courses can be installed as road surfaces that generate particularly little noise in interaction with the vehicle tire. This paper delas with different types of noise-reducing road surfaces.

1. Introduction

Noise is any kind of sound that can disturb, annoy or even harm people's health (B. Mihaylova, 2008). Passing cars, the drone of an aeroplane in the air, conversations in an open-plan office - noise is manifold and is one of the greatest health risks, especially in cities. According to a WHO study, traffic noise is the environmental problem with the second strongest impact on our health after air pollution. High noise levels make it difficult to concentrate, cause stress and health problems for the ears, and also have a harmful effect on the cardiovascular and endocrine systems.

From today's perspective, about one in three young people will therefore need hearing aids by the age of 50," says Anna Streissler, education expert and head of the "Learning without Noise" project at the Umweltdachverband (Austrian environmental umbrella organization) (STANDARD Verlagsgesellschaft m.b.H., 2019).

The reduction of traffic noise has gained in importance in recent years. Active noise protection in the form of walls or embankments is reaching its limits or can even only be guaranteed through the use of enclosures (O. Ripke, 2011).

Especially in the area of noise emission, which is dominated by the rolling noise of the tyres in the speed range of motorways and motorways, a differentiated picture emerges here with the types of surface course used. Here, depending on the traffic volume and composition, a compromise must be found between the acoustic properties and the load-bearing capacity of the road surface. While open-pored asphalt wearing courses have very good acoustic properties, they can only be used to a limited extent on highly loaded or stressed routes due to the associated reduction in service life.

Road pavements such as asphalt concretes or washed concrete pavements have a good durability even with high proportions of heavy traffic, but this structural durability comes at the price of increased noise emissions. In order to guarantee high quality of all parameters, noise-reducing dense or semi-dense asphalt wearing courses are of great importance. At the time of their installation, these exhibit good acoustic properties and a long service life, even on highly loaded stretches of road. However, a reduction in their noise-reducing effect is evident, which can assume an extent of 3-5 dB(A) within 5 years (BMVI, 2017).

2. The types of noise-reducing road surfaces

2.1. Stone Mastic Asphalt SMA 8 S Noise-Optimized

Stone mastic asphalt is in most cases a dense wearing course construction type with a high filler and chippings content. This results in a particularly high stability and thus the primary area of application on highly loaded roads. Compared to asphalt concrete, where a continuous grading curve is responsible for the transmission of forces between the aggregates of different grain sizes, in Stone Mastic Asphalt the force is transmitted primarily by the decisive (largest) grain, i.e. the macadam principle is basically applied here. In the meantime, there are also corresponding adaptations to semi-dense Stone Mastic Asphalt, which was developed against the background of optimized sound absorption and has been a standard construction method for noise-reducing wearing courses in the 3 DACH countries (Germany, Austria, Switzerland) for many years (BMVI, 2017). The Stone Mastic Asphalt SMA 8 S serves as the reference pavement in the comparative analysis. This pavement is currently used as a standard surface course in urban road construction in Berlin. In the construction method according to ZTV Asphalt-StB 07/13 (FGSV, 2013) with chipped surface, the noise assessment leads to a DStrO value of 0 dB(A). If no spreading is applied and the surface is blunted with 0.5 - 1.0 kg/m² aggregate of the 1/3 delivery grain size, a correction value of -2 dB(A) may be applied, as for the non-spread Stone Mastic Asphalt. The layer thickness is 3.5 - 4 cm. Surface courses of Stone Mastic Asphalt SMA 8 S are deformation-resistant and intended for high traffic loads. In residential areas or in areas with low traffic loads, asphalt concrete wearing courses are more suitable (ASPHALTA Prüf- und Forschungslaboratorium GmbH, 2018).

2.2. Stone Mastic Asphalt SMA 5 S Noise-Optimized

Thin hot mix asphalt wearing courses made of Stone Mastic Asphalt SMA 5 S are suitable for use in roads with high and normal traffic loads, depending on the choice of binder. As a standard construction method, this pavement is used for the structural maintenance of traffic areas in asphalt construction according to the ZTV BEA-StB (FGSV, 2011). The asphalt mix, like the variants with 8 and 11 mm maximum aggregate size, is standardized in Europe and introduced and documented in Germany as a standard construction method in TL Asphalt-StB 07/13 (FGSV, 2013). Due to the smaller maximum aggregate size, the pavement has a higher noise reduction potential compared to the SMA 8 S. The pavement can be installed in thicknesses from 2.0 cm to 2.5 cm. The requirements for noise-optimized asphalt wearing courses made of SMA 5 S LO are shown in Table 1 (ASPHALTA Prüf- und Forschungslaboratorium GmbH, 2018).

Table 1. Requirements for noise-optimised asphalt wearing courses made of SMA 5 S LO (edited by author), Source: ASPHALTA Prüf- und Forschungslaboratorium GmbH, 2018

Designation	Unit	SMA 5 S LO
Material		
Aggregates (delivery aggregate)		
Percent of crushed surfaces of particles		$C_{1000}; C_{90/11}; C_{90/1}$
Resistance to fragmentation		SZ ₁₆ /LA ₂₀
Resistance to fragmentation		PSV _{specified} (51)
Flakiness index		F ₁₅
Min. percentage of delivery granul. composition 0/2 with E _{cs} 35	%	95
Binder, type and sort		25/55-55 A; 50/70 + 1,5 % TE)
Composition of mixture		
Mineral aggregate		
Grading (passing)		
	8,0 mm M.-%	100
	5,6 mm M.-%	90 to 100
	2,0 mm M.-%	30 to 40
	0,063 mm M.-%	7 to 12
Minimum binder content		B _{min} 7,4
Asphalt mixture		
Filler / Bitumen ratio		< 1,8
Minimum void content MPK		V _{min} 3,5
Maximum void content MPK		V _{max} 5,5
Binder volumen	Air Vol.-%	is to be indicated
voids content	Proportional rut depth	is to be indicated
	Predicted value for skid resistance	PRD _{Air1,0,0}
	Mean surface texture depth	≥ 0,42 ¹⁾
MTD	mm	0,4 to 0,8
Shape factor g	%	≥ 80

1) Polishing value according to level 3 of the traffic simulation in accordance with the test instruction of the TU Berlin, status 2004

The installation of the top layer of SMA 5 S LO may only be carried out with a completely dry substrate. When installing SMA 5 S LO, the air temperature must be at least +10 °C and the temperature of the dry substrate must be at least +8 °C. Do not apply the material if there is strong wind. When placing the asphalt surface course, fully thermally insulated transport vehicles with push-off technology must be used. Before placing the surface course, the base should be sprayed with 250 g/m² to 350 g/m² of an unstable cationic polymer-modified bitumen emulsion C60BP4-S. Paving the asphalt surface course with an asphalt paver with integrated spraying equipment is possible and is considered technically equivalent. Dulling of the asphalt surface course must be avoided at all costs for reasons of noise optimization (ASPHALTA Prüf- und Forschungslaboratorium GmbH, 2018).

2.3. Thin hot mix asphalt overlays on the road seal DSH-V

The new edition of the ZTV BEA-StB (FGSV, 2013) (Additional technical terms of contract and guidelines for the structural maintenance of traffic bearing structures - asphalt pavements) contains information on corresponding maintenance construction methods. Thin hot mix asphalt overlays on the road seal (DSH-V) can ensure high-quality surface properties such as skid resistance and noise reduction and provide long-lasting protection for the road seal.

This is why they have been included in the new edition of the ZTV BEA-StB. To this end, the latest developments in this area are outlined. These include in particular the way the construction method works, new developments in equipment technology and the asphalt mixture composition, regulations in the ZTV BEA-StB that are relevant for the execution of works, and experience regarding noise effects. This construction method has been in use for approximately 20 years now. When properly used, it can safeguard the substance of the road pavement structure at an acceptable cost, while at the same time considerably reducing noise in comparison with conventional surface courses (FGSV, 2013). A special type of thin asphalt surface course is thin hot mix asphalt overlays on the road seal (DSH-V). This is characterized by an asphalt mix composition specially designed for the intended use and the sealing of the base by a polymer-modified bitumen emulsion. However, mix compositions with a maximum grain size of 5 mm (DSH-V 5) are predominant, as the noise-reducing effect of a DSH-V 8 (maximum grain size 8 mm) is not as high. The bitumen emulsion is applied and the mix is placed in one operation. A layer of bitumen emulsion is first applied by a road paver equipped with a spraying device, which is immediately overlaid with the hot mix. The fine-grained and concave pavement texture leads to a noise reduction potential of -4 to -5 db(A) (BMVI, 2017). Table 2 shows the guide values for DSH-V 8 and DSH-V 5 asphalt mixes.

The top layer of DSH-V 5 LO may only be installed when the substrate is completely dry. When installing DSH-V 5 LO, the air temperature must be at least +10 °C and the temperature of the dry underlayment at least +8 °C. Do not apply the material if there is strong wind. When laying the asphalt surface course, only fully thermally insulated transport vehicles with push-off technology should be used. The asphalt surface course made of DSH-V 5 LO is to be laid using an asphalt paver with integrated spraying equipment. When placing the surface course, spray the base with 250 g/m² to 350 g/m² of an unstable cationic polymer modified bitumen emulsion C67BP4-DSH-V.



Figure 2. Thin hot mix asphalt overlays on the road seal (DSH-V) uncompacted 18 mm thick, Source: M. Schellenberger, 2010

Table 2. Guide values for asphalt mixes DSH-V 8 and DSH-V 5 (FGSV 798, 2013) (edited by author), Source: BMVI, 2017

Designation	Unit	DSH-V 8	DSH-V 5
Material			
Aggregates (delivery aggregate)			
Percent of crushed surfaces of particles		C ₁₀₀₀ ; C _{95/1} ; C _{90/1}	C ₁₀₀₀ ; C _{95/1} ; C _{90/1}
Resistance to fragmentation		SZ ₁₈ ; LA ₂₀	SZ ₁₈ ; LA ₂₀
Resistance to polishing		PSV _{specified} (51)	PSV _{specified} (51)
Loading class Bk100 to Bk3,2		PSV _{specified} (48)	PSV _{specified} (48)
Shape index / Flakiness index		SI ₁₅ / FI ₁₅	SI ₁₅ / FI ₁₅
Min. percentage of delivery granul. composition 0/2 with E _s 35	%	50	50
Binder, type and sort			
Loading class Bk100 to Bk3,2		45/80-50 A;	45/80-50 A;
Loading class Bk1,8 to Bk0,3		70/100	70/100
Composition of mixture			
Mineral aggregate			
Grading (passing)			
	11,2 mm M.-%	100	
	8,0 mm M.-%	90 to 100	100
	5,6 mm M.-%	60 to 65	90 to 100
	2,0 mm M.-%	35 to 45	40 to 50
	0,125 mm M.-%	9 to 13	8 to 12
	0,063 mm M.-%	6 to 10	7 to 11
Minimum binder content		B _{min} 6,0	B _{min} 7,2
Asphalt mixture			
Marshall specimen	Vol.-%		
Minimum void content MPK	Vol.-%	V _{min} 3,5	V _{min} 3,5
Maximum void content MPK	Vol.-%	V _{max} 5,5	V _{max} 5,5
Air voids content		17 to 21	17 to 21

Note: Applies when paving over a newly produced asphalt binder course. When paving on a milled base, increase the quantity of binder as required. For reasons of noise optimization, the asphalt surface course must not be dulled (ASPHALTA Prüf- und Forschungslaboratorium GmbH, 2018). Table 3 shows the requirements for noise-optimized thin hot mix asphalt overlays on the road seal (DSH-V 5 LO). Fig. 1 shows a DSH-V SMA 0/5; 1.2 cm thick.

Table 3. Requirements for noise-optimised thin hot mix asphalt overlays on the road seal (DSH-V 5 LO) (edited by author), Source: ASPHALTA Prüf- und Forschungslaboratorium GmbH, 2018

Designation	Unit	DSH-V 5 LO
Material		
Aggregates (delivery aggregate)		
Percent of crushed surfaces of particles		C ₁₀₀₀ ; C _{95/1} ; C _{90/1}
Resistance to fragmentation		SZ ₁₈ ; LA ₂₀
Resistance to polishing		PSV _{specified} (51)
Flakiness index		FI ₁₅
Min. percentage of delivery granul. composition 0/2 with E _s 35	%	75
Binder, type and sort		25/55-55 A; 50/70 + 1,5 % TE; (45/80-50 A)
Composition of mixture		
Mineral aggregate Grading (passing)		
	8,0 mm M.-%	100
	5,6 mm M.-%	90 to 100
	2,0 mm M.-%	40 to 50
	0,125 mm M.-%	8 to 12
	0,063 mm M.-%	7 to 11
Minimum binder content		B _{min} 6,2
Asphalt mixture		
Filler / Bitumen ratio		< 1,8
Minimum void content MPK		V _{min} 3,5
Maximum void content MPK		V _{max} 5,5
Air voids content	Vol.-%	17 to 21
Binder volumen	Vol.-%	is to be indicated ¹⁾
Wheel tracking		
Predicted value for skid resistance		PRD _{Air10,0}
Mean surface texture depth MTD	mm	≥ 0,42 ²⁾
Shape factor g	%	0,4 to 0,8 ≥ 80

1) Experience values are greater than 12% by volume
2) Polishing value according to level 3 of the traffic simulation in accordance with the test instruction of the TU Berlin, status 2004

2.4. Noise-optimized asphalt concrete surface course AC D LOA

Noise-optimized asphalt concrete AC D LOA 5 has to date been used practically without exception on inner-city routes. Through the use of modified binders, a high stability or resistance of the asphalt surface layer is achieved with a simultaneous low void content. An asphalt surface course made of AC D LOA 5 has a void content of 4.0 to 9.0% by volume. The noise-optimized effect of the pavement is based on its concave ("plateau with ravines") surface texture.

Guideline values for AC 5 D LOA asphalt mix are compiled in the recommendations for the planning and execution of noise-optimized asphalt wearing courses made of AC D LOA and SMA LA. When paving an AC 5 D LOA, the air temperature must be at least +10 °C, and that of the base +8 °C. In contrast to "classic" asphalt wearing courses, the noise-optimized variant does not need to be blunted (BMVI, 2017).

During constructional implementation, it should be noted that small-scale installation of the surface course leads to an increased risk of errors. The acoustic effectiveness of all low-noise road surfaces is linked to a homogeneous formation of the texture and void content characteristics. Note: Therefore, the construction sections for the surface course should be as large as possible; a continuous paving over all construction sections is optimal. Specifications in this regard cannot be made without detailed knowledge of the construction processes and scheduling constraints.

The surface course of AC 5 D LOA may only be laid when the substrate is completely dry. When installing AC 5 D LOA, the air temperature must be at least +10 °C and the temperature of the dry base must be at least +8 °C. Do not install in strong winds. Before placing the surface course, the base should be sprayed with 250 g/m² to 350 g/m² of an unstable cationic polymer-modified bitumen emulsion C60BP4-S.

Paving the asphalt surface course with an asphalt paver with integrated spraying equipment is possible and is considered technically equivalent. The requirements for noise-optimized thin asphalt concrete wearing courses in hot construction from AC 5 D LOA are shown in Tab.4. The asphalt concrete surface course made of AC 5 D LOA is to be laid in a thickness of 2.5 cm. Exceeding the paving thickness is only permissible by a maximum of 10 % for reasons of deformation resistance. An installation in greater thickness is considered a defect (ASPHALTA Prüf- und Forschungslaboratorium GmbH, 2018).

Table 4. Requirements for noise-optimised thin asphalt wearing courses in hot asphalt construction from AC 5 D LOA (edited by author), Source: ASPHALTA Prüf- und Forschungslaboratorium GmbH, 2018

Designation	Unit	AC 5 D LOA	
Material			
Aggregates (delivery aggregate)		$C_{1000}; C_{95/11}; C_{90/1}$	
Percent of crushed surfaces of particles		$SZ_{10}; LA_{20}$	
Resistance to fragmentation		$PSV_{specified} (51)$	
Resistance to polishing		FI_{15}	
Flakiness index			
Binder, type and sort		25/55-55 A; (40/100-65 A)	
Composition of mixture			
Mineral aggregate			
Grading (passing)			
	8,0 mm	M.-%	100
	5,6 mm	M.-%	90 to 100
	2,0 mm	M.-%	30 to 40
	0,125 mm	M.-%	12 to 18
	0,063 mm	M.-%	10 to 13
Minimum binder content			$B_{min 5,8}$
Asphalt mixture			
Filler / Bitumen ratio			< 1,8
Minimum void content MPK			$V_{min 4,0}$
Maximum void content MPK	Vol.-%		$V_{max 6,0}$
Binder volumen	Air	Vol.-%	is to be indicated ¹⁾
voids content	Proportional rut		is to be indicated ²⁾
depth	Predicted value for skid		$PRD_{Air 10,0}$
resistance	Mean surface texture depth		$\geq 0,42$ ³⁾
MTD		mm	0,4 to 0,8
Shape factor <i>g</i>		%	≥ 80

- 1) Experience values are greater than 12.5 % by volume
- 2) Experience values lie between 65 and 75 %
- 3) Polishing value according to level 3 of the traffic simulation in accordance with the test instruction of the TU Berlin, status 2004

Figure 3 shows the road surface with a LOA D: a) fresh after paving, b) after 10 months, c) after 19 months.



Figure 3. The road surface with a LOA D: a) fresh after paving, b) after 10 months, c) after 19 months, Source: M. Schünemann, 2011

Figure 4 shows the installation of noise-optimized asphalt wearing course AC 5 D LOA on Rheinbrückenstrasse, Karlsruhe, Germany.



Figure 4. Installation of noise-optimised asphalt wearing course AC 5 D LOA on Rheinbrückenstrasse, Karlsruhe, Germany, Source: M. Schellenberger, 2010

2.5. Mastic asphalt with improved noise properties (MA LA)

Mastic asphalt with improved noise properties (DStro value of -2 dB(A)) is to be produced in accordance with ZTV Asphalt-StB 07 in procedure B. Additional technical instructions for the construction of mastic asphalt layers for traffic area pavements, in particular with regard to noise properties, are set out in R2 - Recommendations for the construction of mastic asphalt layers, abbreviated E GA, (FGSV 740 (FGSV, 2022)) (BMVI, 2017). For the production of mastic asphalt with improved noise properties, two essential prerequisites must be fulfilled. The mastic asphalt must be laid in such a way that the surface is as smooth as possible, with hardly any macrotexture. The subsequent spreading must be extremely homogeneous and not in excess. The largest grain size of the aggregate used should not exceed 4 mm in diameter; a blunting material of the special grain size 2/3 has proven to be most favourable (ASPHALTA Prüf- und Forschungslaboratorium GmbH, 2018).

Mastic asphalt may only be installed when the substrate is completely dry. The temperature of the dry base must be at least +10 °C. The mastic asphalt must be laid by machine. Manual installation is possible in the pre- or post-laid strips. Only paving machines equipped with an automatic levelling device are to be used. For the asphalt surface course made of mastic asphalt, a scattering grain consisting of a bitumen-coated delivery grain 2/3 with a scattering quantity of 11 to 13 kg/m² is to be applied mechanically and evenly to the hot surface in accordance with the ZTV Asphalt-StB, procedure B. The scattering grain is to be applied by hand. The delivery of the scattering granulation has to take place immediately before the start of installation in thermal vehicles with a temperature of at least +170 °C. The scattering granulation has to be applied evenly by machine.

The scattering granulate must sink into the asphalt mortar of the mastic asphalt surface by its own mass and thus be firmly bound. As a rule, the scattering granulation is not to be pressed on or in with rollers (ASPHALTA Prüf- und Forschungslaboratorium GmbH, 2018).

2.6. Mastic asphalt with a surface rich in voids (open-pored) PMA

Working Paper W2 - Texture Influence on the Acoustic Properties of Pavements (FGSV, 2013) - also contains information (experiences) on the noise-reducing pavement made of MA 5 S (Tab.5). In contrast to traditional mastic asphalt (MA), a mastic asphalt with an open porous surface (PMA) can be developed by adapting the asphalt recipe. The focus here is on the mix, which now has a higher proportion of coarse aggregate. The result is that the mastic asphalt is open-pored in the upper area, but remains dense in the lower area. The open-pored surface or concave texture ("plateau with ravines") forms after the mortar has settled into the lower layer. The dense layer makes extra protection of the binder and base course against water unnecessary, as the lower layer is already impermeable to water. A noise reduction of 4 dB(A) can be expected with this asphalt wearing course. The mastic asphalt surface course with an open-pored surface is used for all speed ranges (BMVI, 2017).

Table 5. Guide values for asphalt mix MA (FGSV 797, 2013) (edited by author), Source: BMVI, 2017

Designation	Unit	MA 8 S	MA 5 S
Material			
Aggregates (delivery aggregate)			
Percent of crushed surfaces of particles		C _{10/1}	C _{10/1}
Resistance to fragmentation		SZ _{10/1} :LA ₁₀	SZ _{10/1} :LA ₁₀
Resistance to polishing		PSV _{applied} (48)	PSV _{applied} (48)
Min. percentage of delivery granul. composition 0/2 with E _s 35	%	35	35
Binder, type and sort			
Composition of mixture			
Mineral aggregate			
Grading (passing)			
11.2 mm	M.-%	100	100
8.0 mm	M.-%	90 to 100	90 to 100
5.6 mm	M.-%	75 to 90	55 to 65
2.0 mm	M.-%	50 to 60	24 to 32
0.063 mm	M.-%	22 to 30	24 to 32
Minimum binder content	M.-%	B _{min} 7.0	B _{min} 7.0
Asphalt mixture			
Minimum static penetration depth cube		I _{min} 1.0	I _{min} 1.0
Maximum static penetration depth cube		I _{max} 3.0	I _{max} 3.0
Increase penetration depth cube		I _{inc} 0.4	I _{inc} 0.4
Dynamic penetration depth	mm	is to be indicated	is to be indicated

For the production and the finished layer of PMA 5, the ZTV Asphalt-StB or the TL Asphalt-StB as well as the special regulations described below apply accordingly. The surface course of PMA 5 may only be laid when the base is completely dry. When laying PMA 5, the air temperature must be at least +10 °C and the temperature of the dry base must be at least +8 °C. When placing the asphalt wearing course, fully thermally insulated transport vehicles with push-off technology must be used. Before placing the surface course, the base shall be sprayed with 250 g/m² of an unstable cationic polymer-modified bitumen emulsion C60BP4-S. The asphalt mix shall not exceed a temperature of +200 °C during production. The time from loading the mix lorry to placing the asphalt mix (including transport time) must not exceed 45 min.

The required laying temperature of the asphalt mix is at least +180 °C. Cooled mix and/or mix that has fallen onto the base during transfer to the paving process must be removed and may no longer be fed into the paving process. For the production of a flat surface, smooth rollers without vibration are to be used. The rolling process should only start at core temperatures below +130 °C. Rubber wheel and combi rollers must not be used. The requirements for noise-optimized asphalt wearing courses made of PMA 5 are shown in Tab.6 (ASPHALTA Prüf- und Forschungslaboratorium GmbH, 2018). Figure 5. shows the surface of the installed PMA asphalts.

Table 6. Requirements for noise-optimised asphalt surface courses made of PMA 5 (edited by author), *Source: ASPHALTA Prüf- und Forschungslaboratorium GmbH, 2018*

Designation	Unit	PMA 5	
Material			
Aggregates (delivered aggregate)		$C_{100/0}$	
Percent of crushed surfaces of particles		$SZ_{16}; LA_{20}$	
Resistance to fragmentation		$PSV_{specified} (54)$	
Resistance to polishing		F_{15}	
Flakiness index		< 30	
Flow coefficient E_{cs} specified		30/45;	
Binder, type and sort		25/55-55 A	
Additives		Type and quantity must be indicated	
Composition of mixture			
Mineral aggregate			
Grading (passing)			
	8,0 mm	M.-%	100
	5,6 mm	M.-%	90 to 100
	2,0 mm	M.-%	25 to 40
	1,0 mm	M.-%	25 to 40
	0,063 mm	M.-%	16 to 20
Minimum binder content			$B_{min} 6,9$
Asphalt mixture			
Minimum void content MPK	Vol.-%		$V_{min} 3,0$
Void content of test specimens from an asphalt sample plate	Vol.-%		$V_{max} 7,0$
penetration depth on mod. MPK	Static mm		is to be indicated
Wheel tracking	mm		is to be indicated
Predicted value for skid resistance	%		is to be indicated
Mean surface texture depth MTD or estimated texture depth ETD	mm		is to be indicated

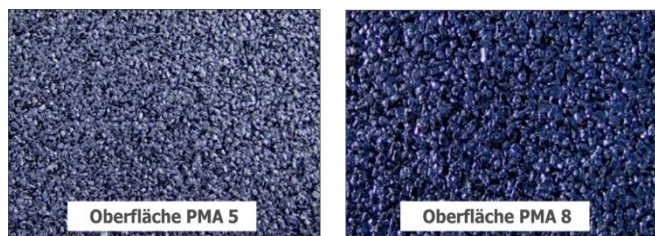


Figure 5. Surfaces of PMA 5 (left) and PMA 8 (right), *Source: B. Jannicke, 2010*

2.7. Stone Mastic Asphalt optimized for noise SMA LA

The SMA LA emerged as an alternative to porous asphalt and as a further developed form of the classic Stone Mastic Asphalt. SMA LA differs from SMA in that it has a different grading curve. Essentially, this means the reduction of fine-grained aggregates. The new favourable macrotexture with a higher void content of 9.0 to 14.0% by volume in combination with a polymer-modified binder is characteristic of this road surface. On average, a noise reduction potential of 3 to 4 dB(A) can be expected, depending on the use in urban or extra-urban areas (BMVI, 2017). Table 7 shows the guide values for asphalt mix SMA LA according to FGSV 739 (FGSV, 2015).

Table 7. Guide values for asphalt mix SMA LA according to FGSV 739 (edited by author), *Sources: BMVI, 2017; F. Garthe, 2014*

Designation	Unit	SMA 8 LA	SMA 5 LA
Material			
Aggregates (delivered aggregate)			
Percent of crushed surfaces of particles		$C_{100/0}; C_{95/1}; C_{90/1}$	$C_{100/0}; C_{95/1}; C_{90/1}$
Resistance to fragmentation		$SZ_{16}; LA_{20}$	$SZ_{16}; LA_{20}$
Resistance to polishing		$PSV_{specified} (51)$	$PSV_{specified} (51)$
Min. percentage of delivered granul. composition 0/2 with E_{cs} 35	%	100	100
Binder, type and sort		40/100-65; 45/80-50; (25/55-55)	40/100-65; 45/80-50; (25/55-55)
Composition of mixture			
Mineral aggregate			
Grading (passing)			
	11,2 mm	M.-%	100
	8,0 mm	M.-%	90 to 100
	5,6 mm	M.-%	20 to 30
	2,0 mm	M.-%	15 to 20
	0,063 mm	M.-%	6 to 8
Minimum binder content	M.-%	$B_{min} 6,6$	$B_{min} 7,0$
Binder volumen	M.-%	is to be indicated	is to be indicated
Binder support	M.-%	≥ 0,3	≥ 0,15
Asphalt mixture			
Marshall specimen	Vol.-%	$V_{min} 9,0$	$V_{min} 9,0$
Minimum void content MPK	Vol.-%	$V_{max} 11,0$	$V_{max} 11,0$
Maximum void content MPK	Vol.-%	is to be indicated	is to be indicated
Air voids content	%	is to be indicated	is to be indicated
Wheel tracking	%	is to be indicated	is to be indicated

When laying SMA LA, the air temperature must be at least +10 °C and the temperature of the dry base at least +8 °C. When laying the asphalt surface course, fully thermally insulated transport vehicles with push-off technology must be used. Due to the high void content of the surface course, the base is not protected against water ingress. Therefore, before placing the surface course, the underlay should be sprayed with 350 g/m² to 450 g/m² of an unstable cationic polymer-modified bitumen emulsion C60BP4-S. In case of high temperatures (air and base), measures may have to be taken to prevent the binder from being drawn up by site traffic. Paving the asphalt surface course with an asphalt paver with integrated spraying equipment is possible and is considered technically equivalent. Dulling of the asphalt surface course must be avoided at all costs for reasons of noise optimization (ASPHALTA Prüf- und Forschungslaboratorium GmbH, 2018).

Table 8 gives the requirements for noise-optimized asphalt wearing courses made of Stone Mastic Asphalt (SMA 5 LA) (ASPHALTA Prüf- und Forschungslaboratorium GmbH, 2018). Figure 6 shows the texture of a SMA LA asphalt pavement.

Table 8. Requirements for noise-optimised asphalt wearing courses made of stone mastic asphalt (SMA 5 LA) (edited by author), Source: ASPHALTA Prüf- und Forschungslaboratorium GmbH, 2018

Designation	Unit	SMA 5 LA
Material		
Aggregates (delivered aggregate)		$C_{100/0}; C_{95/1}; C_{90/1}$
Percent of crushed surfaces of particles		$SZ_{18}; LA_{20}$
Resistance to fragmentation		$PSV_{specified} (51)$
Resistance to polishing		Fl_{15}
Flakiness index		
Min. percentage of delivered granul. composition 0/2 with $E_{cs} 35$	%	100
Binder, type and sort		40/100-65 A; 45/80-50 A; (25/55-55 A)
Composition of mixture		
Mineral aggregate		
Grading (passing)		
	8,0 mm M.-%	100
	5,6 mm M.-%	85 to 100
	2,0 mm M.-%	20 to 30
	0,063 mm M.-%	7 to 10
Minimum binder content		$B_{min 7,0}$
Asphalt mixture		
Filler / Bitumen ratio		< 1,8
Minimum void content MPK	Vol.-%	$V_{min 9,0}$
Maximum void content MPK	Vol.-%	$V_{max 11,0}$
Binder volumen	Vol.-%	is to be indicated
Air voids content	%	is to be indicated
Wheel tracking		
Predicted value for skid resistance		$\geq 0,38$



Figure 7. Installation of SMA 5 LA in Baden-Baden, Germany, Source: F. Garthe, 2014

Figure 8 shows the surface of SMA LA 0/8 and SMA 0/8 S: a) fresh after installation, b) and c) after approx. two years in service. Figure 9 shows the installation of noise-reducing SMA LA asphalt on the A10 Tauern motorway in Austria in May 2003.

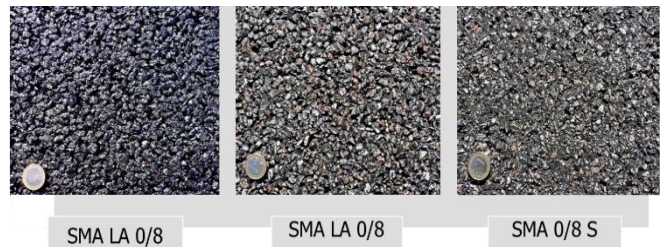


Figure 8. Surfaces of SMA LA 0/8 and SMA 0/8 S: a) fresh after installation, b) and c) after approx. two years in service, Source: K. Graf, M. Schellenberger, 2009

Figure 6. shows the texture and Fig.7 the installation of an SMA 5 LA in Baden-Baden, Germany.



Figure 6. Texture of an SMA 5 LA in Baden-Baden, Germany, Source: F. Garthe, 2014



Figure 9. Installation of noise-reducing SMA LA asphalt on the A10 Tauern motorway in Austria in May 2003, Source: K. Graf, M. Schellenberger, 2009

2.8. Open-pore asphalt (OPA / ZWOPA)

In addition to dense and semi-dense wearing courses, "open-pored asphalt" (OPA) (Fig.10) or "drain asphalt" (sometimes also referred to as "whisper asphalt" in older literature) plays an important role in the field of noise-reducing wearing courses. Basically, its grading curve is characterized by an extremely high proportion of chippings of a certain grain size and a very low proportion of sand or filler.

The main advantages of drain asphalt compared to dense and semi-dense wearing courses are on the one hand the noise reduction due to the high sound absorption and the shift of the frequency range, so that up to -6 dB(A) noise reduction can be achieved. Another advantage is the drainage effect and the avoidance of spray plumes, which benefits road safety. A significant disadvantage can be observed in winter road maintenance, as due to the run-off of the salt-water mixture during salt spreading, significantly more de-icing agent has to be applied to the road and the "freezing over" (enclosing the grains on the surface with a layer of ice) also brings significant disadvantages (BMVI, 2017).

Fig. 10 shows possible construction methods for drainage asphalt wearing courses (porous asphalt). They can be laid in one layer (OPA) from one type of mix or in two layers (ZWOPA or 2OPA) from two different types of mix (B. Mihaylova, 2008).

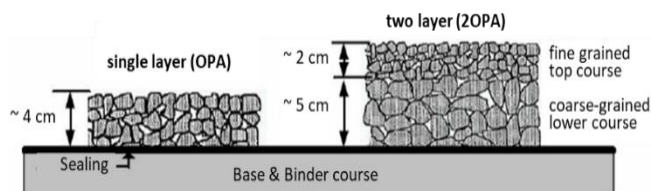


Figure 10. Structure types of drainage asphalt (OPA = porous asphalt) (edited by author), Source: B. Mihaylova, 2008

The examples of drainage asphalts (OPA asphalts): a) Grain size lower layer 11/16 mm, grain size upper layer 5/8 mm are shown in Figures 11, 12. and 13. shows the section through the installed two-layer porous asphalt (2OPA).

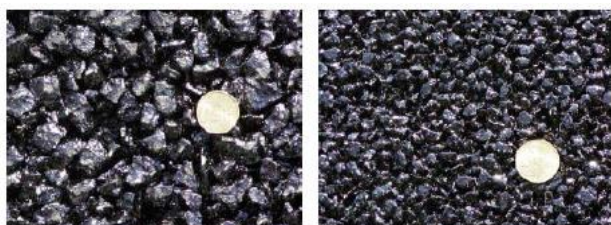


Figure 11. . Examples for drainage asphalts (OPA asphalts): a) Grain size lower layer 11/16 mm, grain size upper layer 5/8 mm, Source: B. Mihaylova, 2008



Figure 12. Section through the installed two-layer porous asphalt (2OPA), Source: M. Schellenberger, 2010

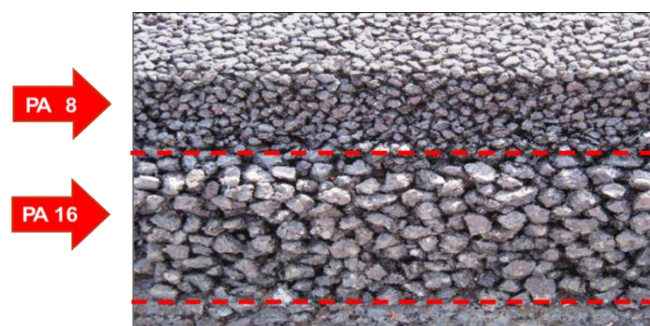


Figure 13. Two-layer porous asphalt (2OPA), Source D. Gogolin, 2015

3. Conclusion

59 % of Germans feel disturbed or annoyed by road traffic; approx. 16 % of the population are exposed to noise levels that are hazardous to health due to road traffic. Since tyre-road noise is the dominant source in road traffic noise from speeds of approx. 30 to 40 km/h, the use of noise-reducing road surfaces can contribute to reducing noise pollution and its consequences. With regard to the durability of asphalt road surfaces, the requirements of the relevant surface course parameters, such as skid resistance, longitudinal and transverse evenness, as well as the acoustic properties of the road surfaces, are increasing. In order to guarantee a high quality of all parameters, noise-reducing dense or semi-dense asphalt wearing courses are of great importance. At the time of paving, these exhibit good acoustic properties and a long service life even on highly loaded road sections, but a reduction in their noise-reducing effect is evident, which can reach 3-5 dB(A) within 5 years. The noise measurements show that open-pore asphalt wearing courses (OPA) of the third generation with void contents above 22% initially show high noise reduction values of -8 dB(A) and higher and only slightly decrease in the following years. Currently, DStrO values of -5 dB(A) can already be assumed as safe for a period of 6 years. There are no deformation problems if all constructional specifications are met. Due to their low deformation tendency, open-pored ceilings do not lead to rutting and are comfortable for the user, i.e. quiet, no spray plume formation in wet conditions and no risk of aquaplaning.

References

- [1] B. Mihaylova, Technische Universität Wien, Institut für Straßenbau und Straßenerhaltung, Diplom Arbeit, Bautechnische Maßnahmen zur Reduktion des Straßenverkehrslärms, Wien, 2008
- [2] STANDARD Verlagsgesellschaft m.b.H., Wenn Lärm krank macht, <https://www.derstandard.at/story/2000101896587/wenn-laerm-krank-macht>, 24. April 2019
- [3] O. Ripke, Bast, Berichte der Bundesanstalt für Straßenwesen, Straßenbau, Heft S 68, Lärmindernder Splittmastixasphalt, Bergisch Gladbach, März 2011
- [4] BMVI - Bundesministerium für Verkehr und digitale Infrastruktur, Akustische Dauerhaftigkeit lärmindernder dichter oder semidichter Asphaltdeckschichten – ADURA- Ein Projekt finanziert im Rahmen der D-A-CH Kooperation Verkehrsinfrastrukturforschung 2017, DACH 2017, Berlin, 2017
- [5] ASPHALTA Prüf- und Forschungslaboratorium GmbH, Leitfaden für die Planung, den Bau und die Bauliche Erhaltung von lärmtechnisch optimierten Asphaltdeckschichten in Berlin, Ausgabe 2018, Senatsverwaltung für Umwelt, Verkehr und Klimaschutz, Berlin, 2018
- [6] J. Haberl, Technische Universität Wien, Institut für Straßenbau und Straßenerhaltung, Dissertation, Akustische Bewertung von Fahrbahndeckschichten, Wien, 2011
- [7] Rasmussen R.O., Bernhard R.J., Sandberg U., Mun E.P., The little book of quieter pavements, Federal Highway Administration, 2007 (PIARC – The World Road Association, Quiet Pavement Technologies, France, 2013)
- [8] FSV – Forschungsgesellschaft Straße - Schiene – Verkehr, Richtlinien und Vorschriften für das Straßenwesen RVS 01.02.12 Asphalttechnik, Wien, 2011
- [9] FSV – Forschungsgesellschaft Straße - Schiene – Verkehr, Richtlinien und Vorschriften für das Straßenwesen, RVS 08.97.05 Anforderungen an Asphaltmischgut, Wien, 2010
- [10] CORDIS - The Community Research and Development Information Service, Publications Office of the European Union - European Commission's research and innovation, Final Report Summary - SILENCE (Quieter surface transport), <https://cordis.europa.eu/project/id/516288/reporting> 2008
- [11] DIN Deutsches Institut für Normung e.V. Schweizer Norm SN 640 431-1-NA, Asphaltmischgut - Mischgutanforderungen - Teil 1: Asphaltbeton, Berlin, 2013
- [12] Prüflabor AG, Handbuch 2020 – Bituminöser Strassenbau, Schweiz, Mörschwil, 2020
- [13] Schweizer Norm SNR 640 436, Semidichtes Mischgut und Deckschichten Festlegungen, Anforderungen, Konzeption und Ausführung, 2015
- [14] Kanton Aargau, Department Bau, Verkehr und Umwelt, Lärmarme Strassenbeläge – Chancen und Risiken, Schweiz
- [15] FGSV - Forschungsgesellschaft für Straßen- und Verkehrswesen e.V., FGSV-Nr.: 799 - ZTV Asphalt-StB 07/13, Zusätzliche Technische Vertragsbedingungen und Richtlinien für den Bau von Verkehrsflächenbefestigungen aus Asphalt, Köln, 2013
- [16] FGSV - Forschungsgesellschaft für Straßen- und Verkehrswesen e.V., FGSV 798 - Zusätzliche Technische Vertragsbedingungen und Richtlinien für die Bauliche Erhaltung von Verkehrsflächen – Asphaltbauweisen (ZTV BEA-StB 09) mit Änderungen und Ergänzungen gemäß BMV ARS 03/2011, Köln, 2011
- [17] FGSV - Forschungsgesellschaft für Straßen- und Verkehrswesen e.V., FGSV-Nr. 797: TL Asphalt-StB 07/13 Technische Lieferbedingungen für Asphaltmischgut für den Bau von Verkehrsflächenbefestigungen: Köln, 2013
- [18] FGSV - Forschungsgesellschaft für Straßen- und Verkehrswesen e.V., ZTV BEA-StB 09/13 Zusätzliche Technische Vertragsbedingungen und Richtlinien für die Bauliche Erhaltung von Verkehrsflächenbefestigungen – Asphaltbauweisen, Köln, 2013
- [19] M. Schünemann, VSVI Mecklenburg-Vorpommern, Offener Asphalt - Aktuelles aus dem Asphaltstraßenbau-Spiegelbilder des Alltags, 2011
- [20] M. Schellenberger, VSVI Hessen e.V. Dünne Asphaltdeckschichten in Heibauweise auf Versiegelung (DSH-V), Friedberg, Hessen, 2010
- [21] F. Garthe, Lärmindernde Asphaltdeckschichten AC D LOA und SMA LA, SWA Südwest Asphalt GmbH & Co.KG, KIT Karlsruher Institut für Technologie, Karlsruhe, 17. Dezember 2014
- [22] FGSV - Forschungsgesellschaft für Straßen- und Verkehrswesen e.V., FGSV-Nr.: 740 M MA - Merkblatt für den Bau von Asphaltmischgut aus Gussasphalt, Köln, 2022
- [23] FGSV - Forschungsgesellschaft für Straßen- und Verkehrswesen e.V., FGSV 442 – Arbeitspapier Textureinfluss auf die akustischen Eigenschaften von Fahrbahndecken, Köln, 2013
- [24] B. Jannicke, Gussasphalt mit offener Oberfläche PMA – Erste Maßnahmen, Landesbetrieb Straßenbau NRW, Friedberg, Hessen, Januar 2010
- [25] FGSV - Forschungsgesellschaft für Straßen- und Verkehrswesen e.V., FGSV-Nr.: 739, E LA D Empfehlungen für die Planung und Ausführung von lärmtechnisch optimierten Asphaltdeckschichten aus AC D LOA und SMA LA, Technische Regelwerke, Köln, 2015
- [26] K. Graf, M. Schellenberger, 35. Gestrata Bauseminar 2009, Lärmtechnisch optimierte Splittmastixasphalte, Linz, Oberösterreich, 2009
- [27] D. Gogolin, DAV Informationsveranstaltung, Lärmreduzierung auf kommunalen Straßen mit Asphalt, Lehrstuhl für Verkehrswegebau Ruhr-Universität Bochum.