Friction of different surface courses

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ABSTRACT

Friction is one of the most important facts for drivers, because they think allways to have a road with good friction values. To get experience with german asphalt surfaces 21 sites from Bavaria to Schleswig-Holstein examined. Friction after polishing was examined in three stages on samples drilled out of plates (produced with the roller compactor) and cores from the sites). The plates were made with asphalt mixtures mixed in the lab and in the asphalt plant. With this different samples a comparison between laboratory samples and real layed samples is possible and you can get a decission with which sample a prognosis of the friction can be made. In addition the texture depth was messured in different stages of polishing. The tests were made on 16 SMA -, 4 AC - and 1 MA –surface. The statistical calculations show that there is no difference between the three methods of gaining samples. With this it will be possible to make a prognosis with asphaltmixtures and moulds produced in the laboratory. It is shown that the categories given in the EN 13108 don't fit tot he asphalt surfaces used in Germany.

Keywords: Asphalt, Friction, Performance testing, Safety, Skid Resistance

1. INTRODUCTION

Every road user expects – unspoken – a useful roadway surface, which also offers a sufficiently short breaking distance under wet circumstances. In dry conditions, the pavement grips of roadway covers are mostly high enough. With wet, humid surfaces the pavement grip is decisively influenced by the texture of the street surface. Therefore, the street surface needs to provide roughness, adequate to the intended purpose, even under wet conditions.

With the European harmonized asphalt specification EN 12697-49 „Bituminous mixtures. Test methods for hot mix asphalt. Determination of friction after polishing“ [1] a method is introduced which allows an assessment of the pavement grip of asphalt in the lab. The test method was developed approx. 50 years ago by Wehner/Schulze.

To gain experience with German asphalt surfaces, pavement grip was examined in 21 construction sites from Bavaria to Schleswig-Holstein in course of the research project „Representative Determination of Performance-relevant Asphalt Properties that Provide the Basis for New Conditions of Contract "R&D Project 07.0253/2011/ERB On Behalf of the Federal Ministry of Transport, Building and Urban Development [16].

In 16 of 21 cases, tests were performed on a bituminous mixture of stone mastic asphalt, five of which were built with SMA 11 S., two with SMA 8 LA and the remaining nine sites with SMA 8 S. In four construction projects an Asphalt concrete was utilized for overlayers (three times AC 11 D S, once AC 11 D N) while a Mastic Asphalt MA 5 was used once.

2. EXAMINATION METHOD

Testing of „Determination of friction after polishing“ can be carried out using laboratory-manufactured specimens or specimens obtained from drill cores.

There is a lack of knowledge regarding possible differences and changes in the behaviour in use of laboratory-manufactured asphalts or of the in-situ installed asphalt layers.

Therefore, asphalt mixture design was tested in three stages. The first stage (EP) represents the asphalt mixture design, which was "reconstruction" by bitumen and mineral. The second stage (MW) investigates industrial-scale asphalt mixture production by examining the asphalt mixture produced at the asphalt mixing plant. Thirdly, respective samples taken during paving stage (MW) represent the installed asphalt layer. Drill cores with different diameters were sampled at the installation site for tests within stage (BK).

2.1 Pavement grip measurement

With the testing method according to Wehner/Schulz or EN 12697-49 we are able to gain knowledge about the pavement grip developement of an asphalt surface up to the end of its duration of usage. The procedure according to Wehner/Schulz consists of the polishing unit and friction-measuring unit. The specimen is carried out in drilling cores (stage BK) or prepared by using a roller compactor (EN 12697-33 [8]). Subsequently, cylindrical test samples (stage EP and MW) with a diameter of 225 mm are drilled out.

The surface of the specimen was made in the lab or taken in situ by drilling cores (original state – no traffic demand). The surface was seperated as much as possible from the binder and filler by sandblasting, so that the roughened surface corresponds to the state after installation and weathering of the binding film.

The specimens are fixed in the polishing unit (figure 1) and are polished by three polishing rollers running under slip with across and longitudinal profile (figure 2). Through the polishing procedure the surfaces gets a water quartz flour mixture.

In EN 12697-49, the polishing process is finished after 90.000 passes. Additionly, the surface of the drilling core / test body was polished with a total of 270.000 passes in the present investigations. Furthermore, pavement grip of the asphalt surface was determined after 4.500, 7.500, 15.000, 22.500, 30.000, 45.000, 90.000, 135.000, 180.000, 225.000 and at the test end after 270.000 passes .

For the pavement grip measurement the measuring head (figure 3) is first accelerated to a rotation speed of 100 km/h. Afterwards the surface of the sample continuously gets a water film (thickness: 1 mm) moistened and the impulse switched off. The measuring head with three rotary sliding blocks is lowered with a contact pressure of 2 bar on the watered test surface. Three sliding blocks fastened to a ring of a circle (measuring rubber) glide on the 565-mm-long circular path above the examining surface and are slowed down by the appearing friction up to the point of cessation.

The ascertained force of friction is reported about the whole speed area up to the shutdown. The frictional coefficient measured with 60 km/h is documented for evaluation.

Figure 1: Testing set to EN 12697-49 for the procedure to Wehner/Schulz (polishing unit and friction measuring unit)

Figure 2: Testing set to EN 12697-49 polishing head

Figure 3: Testing set to EN 12697-49 measuring head

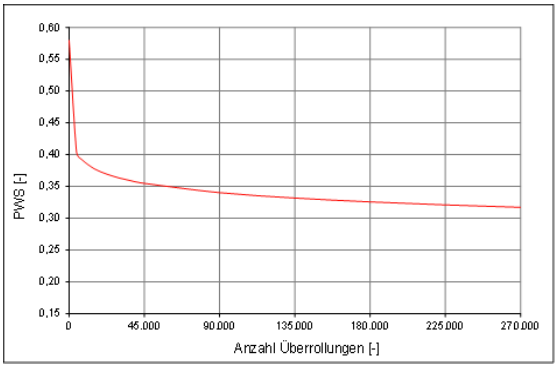

Figure 4: Exemplary representation of the pavement grip development (According to evaluation [2])

The pavement grip value μ_{PWS} results following equation 1 of the friction coefficient at μ_m 60 km/h, a control surface with a grip value of μ_{ref} and the averaged measuring result of the controlling record μ_{km} before and after the pavement grip measurement.

$$\mu_{PWS} = \mu_m - \mu_{km} + \mu_{ref} \qquad \text{[Equation 1]}$$

The pavement grip measurement under respective loads returns in a few points the pavement grip with different demand duration (rising number in passes).

The continuous pavement grip course becomes as a function of the number of the passes (demand duration) up to the achievement of the final pavement grip after 270.000 passes (PWS_{270}) according to the draught of the technical test regulation „a regulation of the pavement grip development of surfaces with the testing method to Wehner/Schulze (PWS), draught issue in 2009“ [2] with a logarithm function.

$$PWS = a \cdot \ln(x) + b \qquad \text{[Equation 2]}$$

PWS is described in dependence of the number of the passes x, the coefficients a and b are determined by correlation (figure 4). According to previous research results [6] the main evaluations are carried out and reported for the final pavement grip after 270.000 passes.

The texture of a roadway surface describes its geometrical shape in the wavelength area of few micrometres to maximum 0,5 m [3] as the divergence of the level surface. The concept of surface texture in asphalt road construction is synonymous to the one of roughness [7].

In this research project, the ELAtextur ® measuring instrument was used to examine surface texture (figure 5). This testing set uses a laser-triangulation sensor, which is widely free of operator's influence, and is more time efficient than the usually applied procedures of combined pavement grip and roughness measurement (outflow knife after moors, SRT pendulum [7]) as well as sandy spot procedure [4].

The used measuring instrument ELAtextur ® was modified on a measuring circle with a diameter of 180 mm and corresponds therefore to the diameter of the measuring head with three rotary sliding blocks which is lowered during the pavement grip measurement (PWS) on the to be examined, watered surface.

The laser sensor of the ELAtextur ® explores the roadway surface rotary with high resolution (vertical resolution: 0,01 mm; horizontal resolution: 0,2 mm; measuring spot diameter: < 1 mm according to DIN EN ISO 13473-1 [5])..

Figure 5: Modified ELAtextur ® measuring instrument

The so determined surface curve allows the calculation of the MPD (Mean Profile Depth) on the base of a semicircle segment of the texture according to DIN EN ISO 13473-1. The average profile depth is the average of the profile depth in relation to the circumference (base line of the instrument).

The MPD value can be converted by use of a transformation equation in the respected texture depth ETD (Estimated Texture Depth, comparably with MTD/sand spot according to DIN EN ISO 13473-1).

2.2 Results of the investigations of pavement grip behaviour

The pavement grip development was not determined according to EN 12697-49 definitions in which 90.000 passes are given up to the achievement of the final pavement grip. Instead of this 270.000 passes were used for the asphalt overlayer variations in each case for the stages EP, MW and BK.

Stone Mastic Asphalt SMA 8 S.

The average values of the final pavement grips PWS_{270} (figure 6) of nine examined split mastic asphalts SMA 8 S in the stages EP, MW and BK lie regardless of the used binding agent with 0,281, 0,263 and 0,274 at a nearly identical level (pulled through line)

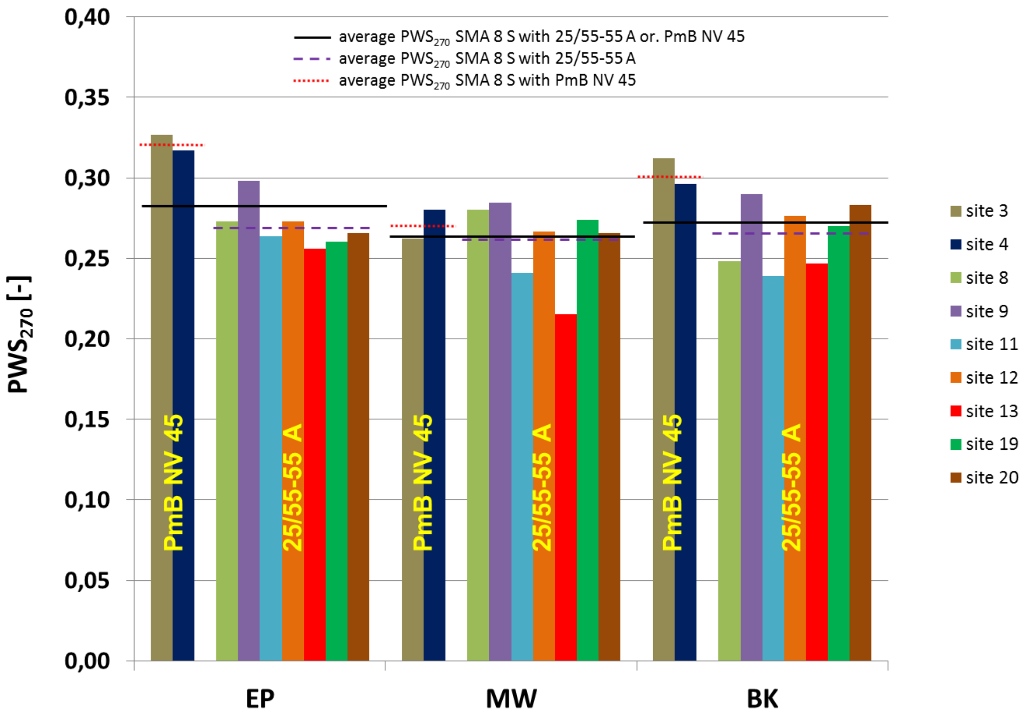

Figure 6: Final pavement grips PWS_{270} for SMA 8 S

The spread between maximum and minimum final pavement grip within the stages EP, MW or BK lies with 0,071, 0,069 or 0,073. The SMA 8 S with polymer-modified binding agent 25/55-55 A (sketched black line) shows average values between 0,261 and 0,270 for final pavement grips PWS_{270} in the stages EP, MW and BK. The SMA 8 S with the PmB 45 NV shows final pavement grips (spotted with red line) between 0,271 and 0,322

For interpretation of the test results after 270.000 passes the determined pavement grip values μ_{PWS} are evaluated statistically. Statistical analysis was performed according to previously described procedures [15]. In order to be able to detect potentially significant differences between the examined stages (EP, MW, BK), one-way analysis of variance was performed and possible group differences analyzed by LSD test (Leases Significant Difference test). In the statistical evaluation (table 1) is recognizable that the stages EP, MW and BK are one homogeneous group except of the sites 3, 8 and 20. A steady array in the homogeneous groups in the results of the stages is not recognizable.

The three stages (EP, MW, BK) do not influence the result of the final pavement grips, which is also reflected in the results of the multiple variance analysis with the pavement grip values μ_{PWS} after 270.000 passes after which the stage with approx. 3% has a very low influence on the test results. The composition of the asphalt shows with 51% the biggest influence, the interaction of stage and distance has with 34% a lower influence.

SMA 8 S				single variance analysis	LSD-Test (EP, MW, BK) ranking in homogen groups: 1. group	2. group	3. groüp	multiple variance analysis: factor	rejection H0-Hypo.	%	multiple variance analysis: factor	rejection H0-Hypo.	%
μ_{PWS} after 270.000 passes	3	SMA 8 S	PmB NV 45	signifi.	BK, EP	MW					stage	yes	31,47
	4	SMA 8 S	PmB NV 45	n. signifi.	EP, BK, MW						site	yes	-
								stage	yes	2,66	stage/site	yes	58,74
								site	yes	50,61	error		9,79
	13	SMA 8 S	25/55-55 A	n. signifi.	BK, EP, MW			stage/			stage	yes	-
	8	SMA 8 S	25/55-55 A	signifi.	MW, EP	BK		site	yes	34,34	site	yes	22,07
	9	SMA 8 S	25/55-55 A	n. signifi.	EP, BK, MW			error		12,38	stage/		
	11	SMA 8 S	25/55-55 A	n. signifi.	EP, BK, MW						site	yes	49,79
	12	SMA 8 S	25/55-55 A	n. signifi.	BK, MW, EP						error		28,14
	19	SMA 8 S	25/55-55 A	signifi.	BK, MW, EP								
	20	SMA 8 S	25/55-55 A	n. signifi.	BK	MW, EP							

Table 1: Results of the statistical analysis pavement grip values μ_{PWS} after 270.000 passes for SMA 8 S

If one considers the used bitumen in the multiple variance analysis the size of the factors of influence changes clearly. Regarding 25/55-55 A the stage has no influence on the pavement grip values μ_{PWS} after 270.000 passes, the sites influences only with 22% and the interaction between stage and sites has a raised influence on the pavement grip measuring values. With the PmB 45 NV no influence of the distance, but with 32% a clear influence of the stage (table 1) arises.

Highest mean value of middle profile depth for nine SMA 8 s. (Figure 7) was observed for the BK-stage (0.79mm), followed by EP-stage (.68mm), and MW-stage (0.62mm). The stages EP and MW show similar levels. A consistent distribution of MPD at the different the sites and the three stages is not recognizable. This can be displayed by site 19 and 20 representing highest values in the BK-stage with the highest values. Another example is site 3 and 4 which represent lowest values in the MW-stage. In EP they are higher about approx. 0,2 mm. The spread between maximum and more minimally middle profile depth within the stages EP, MW or BK lies with 0,33 mm, 0,43 mm or 0,48 mm.

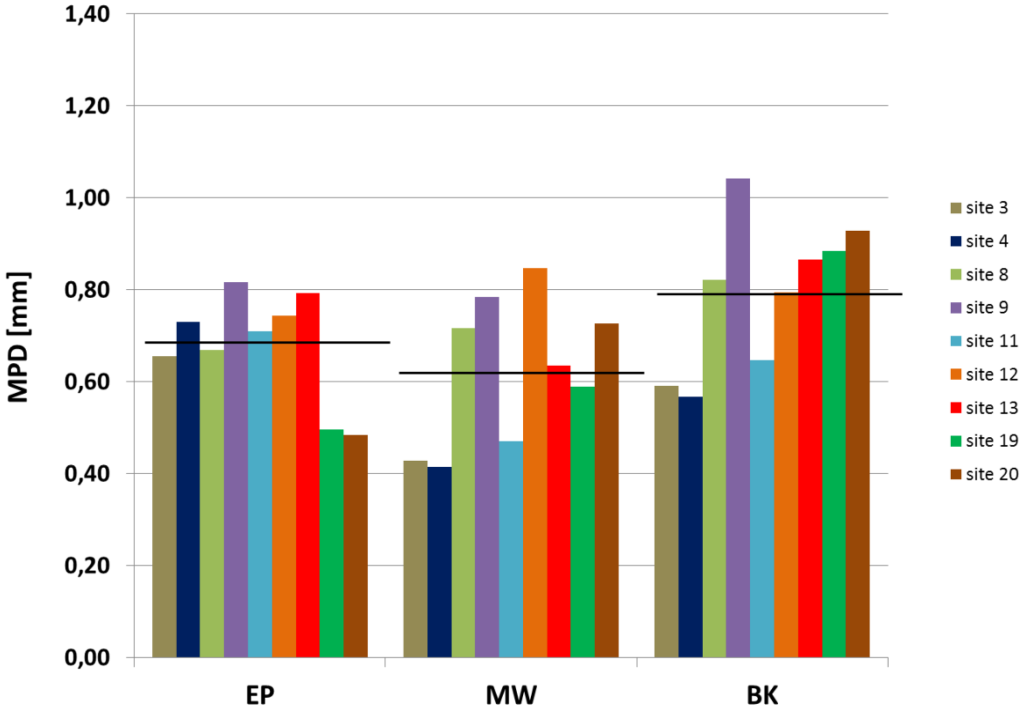

Figure 7: Mean Profile Depth MPD SMA 8 S

Stone Mastic Asphalt SMA 11 S.

The mean values (picture 8) of the final pavement grips PWS_{270} of the five stone mastic asphalts (SMA 11 S) with bitumen 25/55-55 A, examined in stage BK, are higher (0.306) than in the stages EP (0.262) and MW (0.264) .

The spread between maximum and minimum final pavement grip for stages EP, MW and BK are 0,105, 0,092 or 0,119. The stage BK lies with the exception of the site 1 in each case in own homogeneous group. Furthermore, for three of the five sites (sites 5, 17 and 18) the stages MW and EP can be summarized into a homogeneous group, the stages MW and EP deliver comparable results. Therefore the stages influence the result of the final pavement grip (table 2).

This is also reflected in the results of the multiple variance analysis with the pavement grip values μ_{PWS} after 270,000 passes - therefore, the stage with 19% has an influence on the test results. The single site shows with 73% the biggest one, the interaction of stage and distance with 5% very much a lower influence.

Since bitumen 25/55-55 A was used with SMA 11 in all five sites, the influence of this specific variable could not be analyzed.

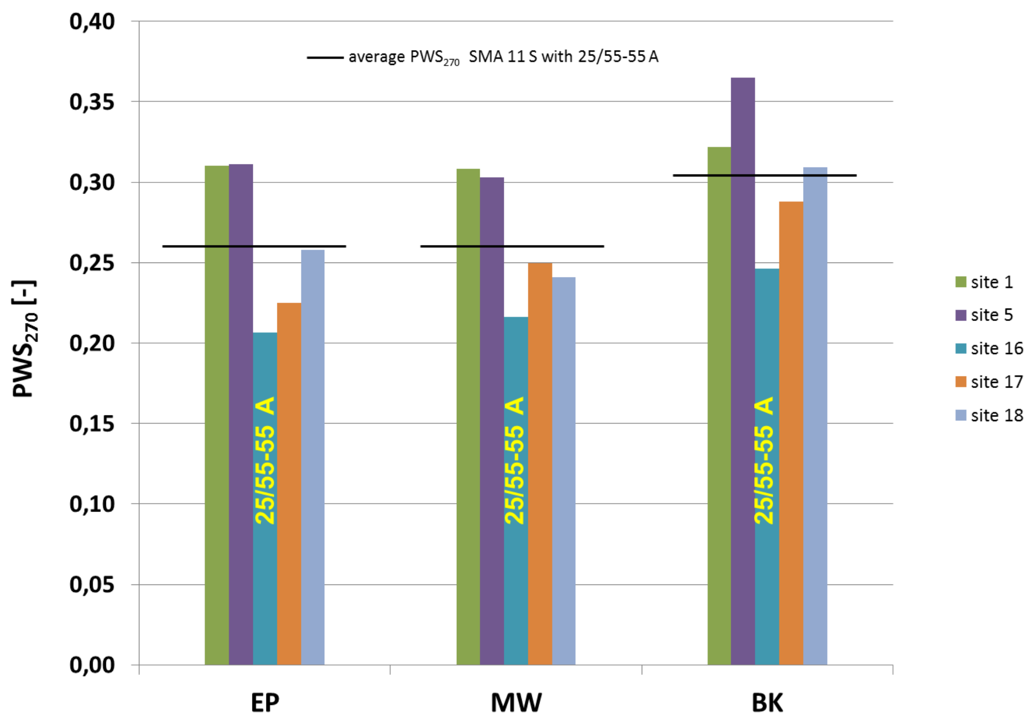

Figure 8: Final pavement grips PWS_{270} for SMA 11 S

SMA 11 S				single variance analysis	LSD-Test: ranking in homogen groups (EP, MW, BK) 1. group	2. group	3. groüp	multiple variance analysis: factor	rejection H0-Hypo.	%
μPWS after 270.000 passes	1	SMA 11 S	25/55-55 A	n. signifi.	BK, EP, MW			stage	yes	18,85
	5	SMA 11 S	25/55-55 A	signifi.	BK	MW, EP		site	yes	72,63
	16	SMA 11 S	25/55-55 A	signifi.	BK	MW	EP	stage/		
	17	SMA 11 S	25/55-55 A	signifi.	BK	MW, EP		site	yes	4,80
	18	SMA 11 S	25/55-55 A	signifi.	BK	MW, EP		error		3,72

Table 2: Results of the statistical analysis pavement grip values μ_{PWS} after 270.000 passes for SMA 11 S

The highest average of the middle profile depth (figure 9) was determined for the stage BK (0,94 mm), followed by the stage MW (0,67 mm) and EP with (0,66 mm). The stages EP and MW lie again at a comparable level. The spread between maximum and more minimally middle profile depth within the stages is clearly raised in the stage EP with 0,75 mm. The stages MW or BK lie with 0,30 mm or 0,32 mm. A steady array of the middle profile depth of the sites in the respective stages is not recognizable again.

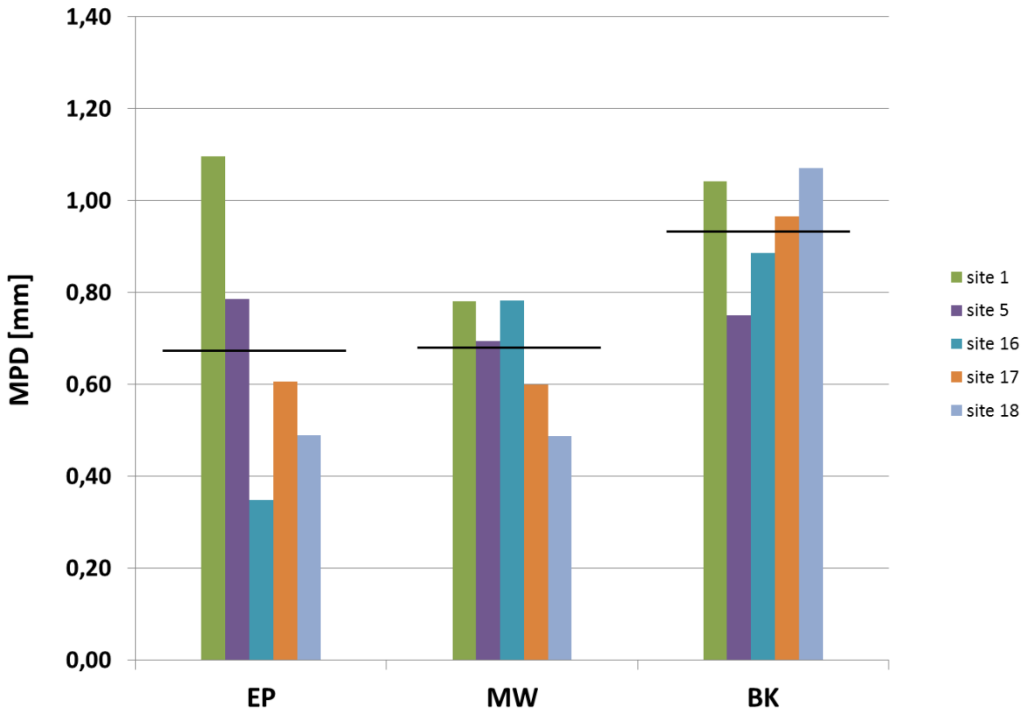

Figure 9: Mean Profile Depth MPD SMA 11 S

Asphalt AC 11 D S.

The averages (figure 10) of the final pavement grips PWS_{270} for three AC 11 D S of the stages EP, MW and BK lie with 0,299, 0,297 or 0,302 on nearly at an identical level. The spread between maximum and minimum final pavement grip within the stages EP, MW or BK lies with 0,083, 0,029 or 0,033.

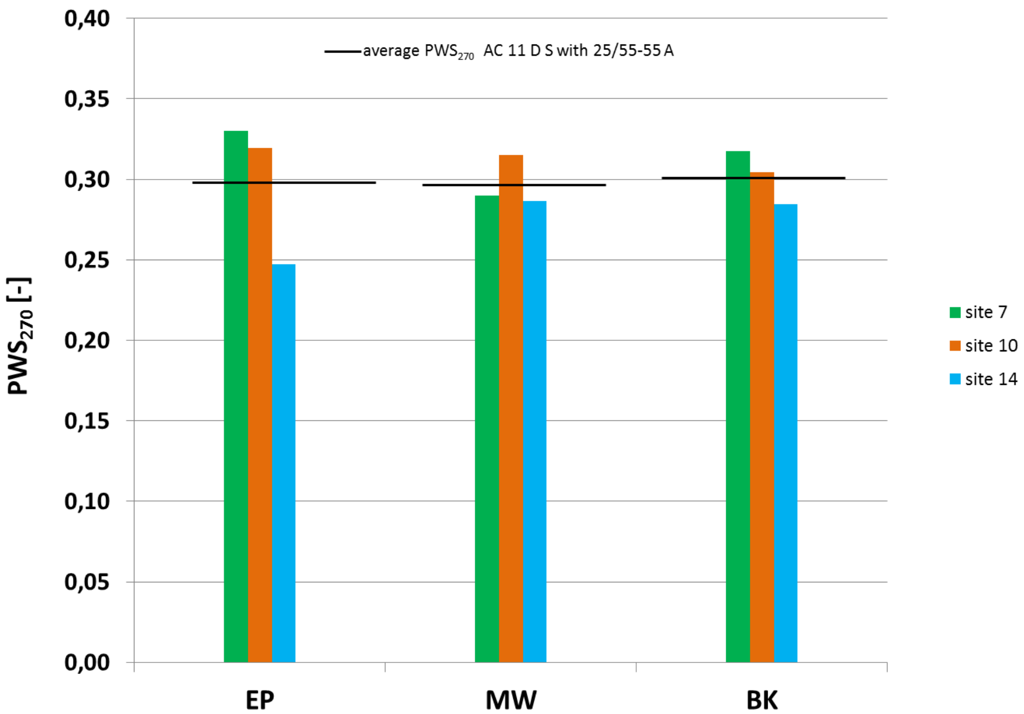

Figure 10: Final pavement grips PWS_{270} for AC 11 D S

An array of the stages with the pavement grip values μ_{PWS} after 270.000 passes is not recognizable. This is also reflected in the results of the multiple variance analysis with the pavement grip values μ_{PWS} after 270.000 Passes where the stage has no influence on the test results. The authoritative influence the site has followed with 52% from the interaction from stage and distance with 44% (table 3).

AC 11 D S				single variance analysis	LSD-Test (EP, MW, BK) ranking in homogen groups			multiple variance analysis		
					1. group	2. group	3. groüp	factor	rejection H0-Hypo.	%
μ_{PWS} after 270.000 passes								stage	no	-
	7	AC 11 D S	25/55-55 A	signifi.	EP, BK, MW			site	yes	43,87
	10	AC 11 D S	25/55-55 A	signifi.	EP	BK, MW		stage/		
	14	AC 11 D S	25/55-55 A	signifi.	MW, BK	EP		site	yes	51,72
								error		4,41

Table 3: Results of the statistical analysis pavement grip values μ_{PWS} after 270.000 passes for AC 11 D S

The highest average of the middle profile depth (figure11) was determined at 0,66 mm for the stage EP, followed from of the stages BK and MW with 0,62 mm and 0,57 mm. The span between maximum and more minimally middle profile depth within the stages EP, MW or BK lies at 0,12 mm, 0,43 mm or 0,40 mm. A steady array of the middle profile depth of the distances in the respective stages also does not appear here.

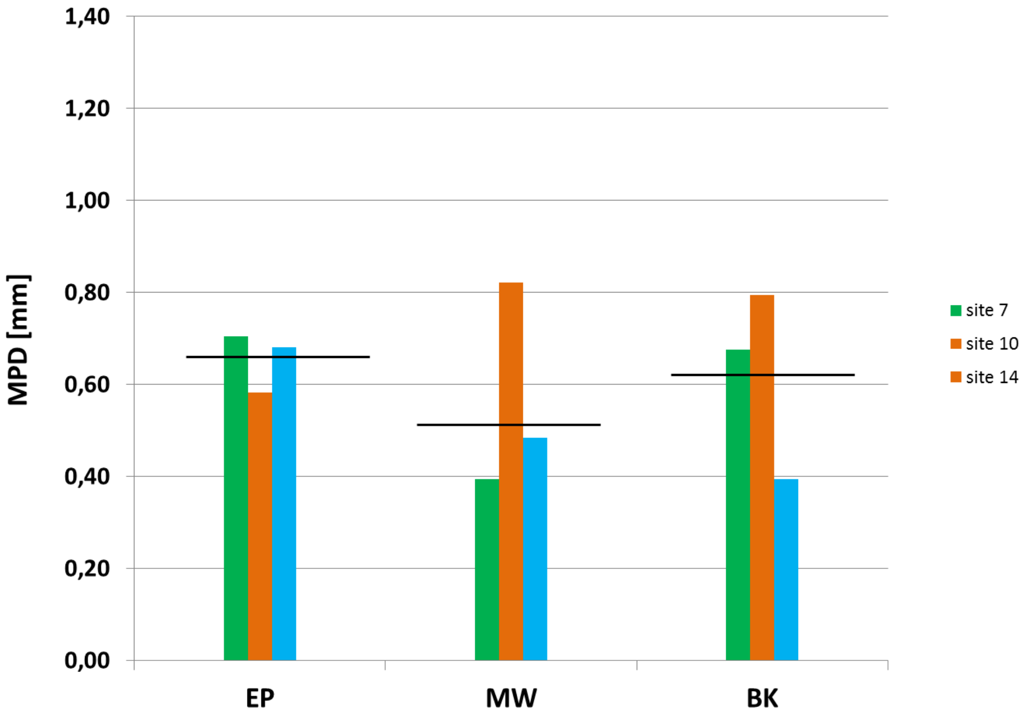

Figure 11: Mean Profile Depth MPD AC 11 D 11 S

3. SUMMARY

The aim of the research project was to determine the pavement grip of asphalt surfaces in a total of 21 sites for the asphalt overlayers in order to gain experiences with measurements of the pavement grip after polishing or to create conditions of the contract if necessary building up on it. Moreover the final pavement grips PWS_{270} were recorded after 270.000 passes in the stages of the asphalt mixing (stage EP), the asphalt production (stage MW) and after the asphalt installation (stage BK). The determined pavement grip values μ_{PWS} became the interpretation of the test results after 270.000 Passes mathematical-statistically are evaluated.

The results of the obtained final pavement grips PWS_{270} from all 21 sites in three stages can be summarised as follows:
All averages of the final pavement grips PWS_{270} of the stages EP, MW and BK for the asphalt-variations and - variations of stone mastic asphalt (SMA) as well as asphalt concrete (AC) were observed to be above 0,250. The highest

final pavement grip PWS_{270} was observed at site 5 in stage BK (0,365). The lowest one was observed at site 16 in the stage EP (0,207).

The lowest middle profile depth was found at site 16 in stage EP (0,348 mm).

A universally valid connection between the final pavement grips to PWS_{270} and the middle profile depths between the sites and the different asphalt kinds and asphalt kinds cannot be derived. Reason for this is that the asphalt SMA and AC D are composed differently and therefore have different surface textures. The differences within one asphalt-sort result from the different composition of the asphalt mixture.

Furthermore, the different sample production and sample preparation in stages EP, MW and BK seem to have an influence on the resulting grip value. But it is also found that a statistically provable influence of the stage exists only with the SMA 11 S on the pavement grip values μ_{PWS} after 270.000 passes.

The actual versions of EN 13108-1,-5 and -6: [9, 10, 11] „Bituminous mixtures - Material specifications " doesn't require a test of friction after polishing, The new drafts of thes standards [12, 13, 14] include this tests. Indeed, still no sufficient experiences with the testing method are given topically, so that no requirement values were taken up. Further data regarding values according to EN 12697-49 on voluntary base is warranted. prEN 13108-1:20144 has categories for "Minimum friction after polishing, FAP" between 0,30 and 0,50; these values are to high for the asphalts used in Germany. A supplement of other categories with lower Minimum friction after polishing must be implemented.

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