CONSIDERATION OF SAND POLISHING RESISTANCE IN THE AUSTRIAN STANDARD – THE WEHNER/SCHULZE SAND POLISHING TEST

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Abstract

Skid resistance of dense road surface layers beside the texture profile also depends on the polishing resistance of fine and coarse aggregates. The test procedure according to Wehner/Schulze, which is used for testing the polishing resistance of sand, has gained acceptance on a scientific – technical level throughout Europe. Up to now, published results and limiting values for the polishing resistance of fine mineral aggregates are based on experiences with a testing device of an older design. This paper details a new Austrian evaluation background for the polishing resistance of sand using a Wehner/Schulze testing device of the latest design. Based on the evaluation background requirements concerning the sand polishing resistance are set for highly stressed wearing courses in the Austrian standard. The test procedure as well as the testing device is briefly described. The research results prove that the polishing resistance between coarse and fine aggregates differs, thus separate requirements for different particle sizes are necessary, because only the combination of highly polishing resistant sand and gravel enables a sustainable skid resistance of road surface layers. Since the Wehner/Schulze testing device is not very widespread in Austrian national material testing laboratories, an alternative test method for determination of the polishing resistance of sand using the accelerated polishing machine is presented. The research results allow sand-producing enterprises a first assessment of the polishing characteristics of their sands using the accelerated polishing machine.

Keywords: polishing resistance, Wehner/Schulze, skid resistance, fine aggregates, PWS

1 Introduction

To ensure the safety of road users during driving maneuvers, e.g. deceleration or cornering, at high speed on wet conditions an adequate skid resistance level of the wearing courses is required. Both the actual and the time-dependent development of skid resistance beside the texture profile mainly depend on the polishing resistance of coarse (> 2 mm) and fine (≤ 2 mm) mineral aggregates used in surface layers. Previous studies conducted on basalt and blast furnace slag showed that the polishing behavior of coarse and fine aggregates may differ significantly due to the microcrystalline surface structure and dependent on aggregate size due to different mineral constituent [1].

In the Austrian standard requirements concerning the polishing resistance of mineral aggregates are given merely with regard to the PSV (Polished Stone Value) [2], tested on stone chippings 8/11 mm. No specific specifications are set for the sand fraction 0/2 mm except for concrete wearing courses. In order to use only fine aggregates with a low carbonate content in concrete pavements, thus to reduce the risk of using aggregates with a low polishing resistance, the expeditious determination of the carbon dioxide content of sand is required. On the basis of researches conducted at the University of Berlin and the University of Technology Vienna [3] [4] the alternative method to determine the polishing resistance of sand using the Wehner/Schulze testing device was established in the Austrian standard in 2007 [5]. The laboratory test procedure according to Wehner/Schulze is already discussed as a replacement to the existing PSV test method in Europe. Up to now, most published results and limiting values for the polishing resistance of fine mineral aggregates are based on experiences with a testing device of an older design. Since 2006 the Research Centre for Road Engineering at the University of Technology Vienna possesses a Wehner/Schulze testing device of the latest design.

2 Polishing resistance of aggregates

Wearing courses stressed by heavy traffic load are exposed to a polishing effect which develops between a rotating wheel and the road surface while the vehicle is de- or accelerating. Especially in curves, slopes and in braking zones in front of intersections this effect is notable. Due to this polishing effect the micro-texture (amplitudes with wavelengths less than 0.5mm) of aggregates exposed to wheels will be leveled. Depending on the kind of wearing course (e.g. asphalt concrete, stone mastic asphalt, etc.) requirements regarding the polishing resistance of sand and/or gravel are stipulated. Fine aggregates of limestone before and after a polishing impact are shown in Fig. 1.

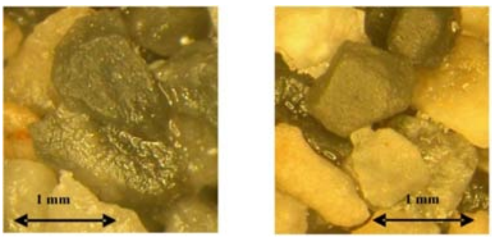

Figure 1 Limestone sand from fraction 0.63/1.0mm before (left) and after (right) the polishing process [6].

Before polishing, the micro-texture is clearly visible even on limestone sand, whereas the surfaces of the fine aggregates on the right hand side in Fig. 1 are well polished. Furthermore, the polished sand particles lost their sharp edges. As a consequence, a thin waterfilm on top of the particles are not pierced and friction forces between tire and aggregate can't be activated. In further consequence, the coefficient of friction declines and the braking distance for road users increases.

3 Polishing tests for fine and coarse aggregates

In Europe so far only one method using an accelerated polishing wheel and a skid tester for measuring polishing resistance of coarse aggregates is standardised [2]. However more devices were developed for determination of polishing resistance of coarse and fine aggregates, e.g. the so-called "Frictometer" [7] and the Wehner/Schulze (W/S) device.

3.1 Accelerated polishing wheel and pendulum skid tester

Determination of polishing resistance of aggregates using the accelerated polishing wheel and the skid tester is very widespread throughout Europe. For this test single sized particles (7.2/10mm) are used to make curved specimens, which are subjected to two three-hour stages of simulated polishing using coarse and fine emery corundum. Afterwards the test specimens are washed and their skid resistance is measured using the pendulum skid tester. The value obtained is the so-called PSV.

Preparation of test specimens as stated in [2] is limited to coarse aggregates only. Based on works carried out at the Technical University Munich [8], a new method for preparation of test specimens with particle size 0.63/1.0mm was developed at the Vienna University of Technology. As shown in Fig. 2 the fine particles are gradually added onto raw specimens made of putty for the accelerated polishing wheel. The actual determination of polishing resistance follows the same procedure than stated in the European standard for coarse aggregates [2]. The value obtained is called PSV_{fGK} (Polished Stone Value of Fine Aggregates).

Figure 2 Preparation of sand specimens for the accelerated polishing wheel.

3.2 Wehner/Schulze device

The first Wehner/Schulze polishing machine was developed in Berlin during the 1960's to survey and assess the development of skid resistance of wearing courses. Contrary to specimens for the PSV-test, specimens for the Wehner/Schulze device are flat. Therefore aggregate, concrete or asphalt slabs produced in the laboratory as well as cores with 225mm diameter obtained directly from road surfaces can be tested. Modifications of the old design led to the testing device shown in Fig. 3. Up to now, there are over 15 devices in operation all over Europe.

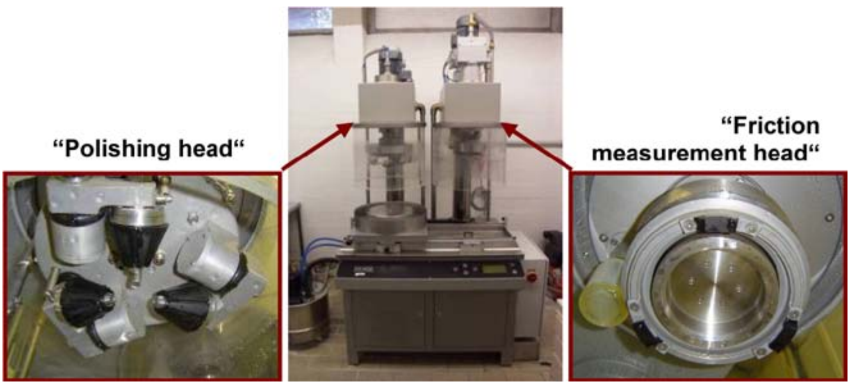

Figure 3 Wehner/Schulze testing device of the latest design at TU Vienna.

Unlike the separated polishing and friction measurment test procedure mentioned in 3.1, the Wehner/Schulze testing device combines the polishing and the friction measurement process. The polishing is done by a rotating head with three rubber covered conical rollers rotating at 500 rpm. For increasing the polishing effect a water-quartz mixture is added. After 90.000 passes the test specimens are washed and a friction coefficient is measured using a friction measurement head with three rubber sliding shoes (shore hardness 65 ± 3). During the friction measurement process first the rotating head is accelerated to a tangential speed of 100 km/h. While water is being added the rotating head is then lowered onto the specimen surface. As the test head decelerates the friction coefficient is measured against speed. The sliding friction coefficient at 60 km/h is reported as the PWS (Polishing value Wehner/Schulze).

4 Evaluation background for sand polishing resistance

To establish an evaluation background for sand polishing resistance eleven samples of sand (laboratory code G 201 - G 211) were examined. The test routine included sand sources with well known high polishing resistance, sand with high carbonate content and fractured gravel with high quartz content. Therefore the chosen samples of sand are a representative cross-section of Austrian sands used for road construction. Within this mass screening the polishing value (PWS) was determined for two grain-size fractions (0.2/0.4 and 0.63/1.0 mm). For each sand sample the PWS was obtained from three individual measurements. Using the manufacturing method described in chapter 3.1, eight sand specimens (fraction 0.63/1.0 mm) per sand sample were produced to determine the PSV_{fGK}. To compare the polishing resistance of fine and coarse particle sizes from the same rock sources, the PSV according to EN 1097-8 [2] was examined as well.
The measured PWS of the eleven samples of sand for both grain-size fractions 0.2/0.4 and 0.63/1.0 mm, the PSV_{fGK} (fraction 0.63/1.0 mm) and the PSV are given in Table 1. Furthermore, the standard deviation obtained from the individual measurements is expressed for each category to indicate test accuracy.

Table 1 Measuring results.

Nr.	rock type	PWS [n=3]		PWS [n=3]		PSV [n=4]		PSV_{fGK} [n=8]	
		0.2/ 0.4	Stdev	0.63/ 1.0	Stdev	7.2/ 10	Stdev	0.63/ 1.0	Stdev
G 201	Granite	0.517	0.009	0.562	0.006	49	1.4	66	1.6
G 202	Basalt	0.536	0.011	0.585	0.022	47	1.5	62	2.1
G 203	Diabase	0.534	0.010	0.593	0.019	53	1.8	64	2.0
G 204	crushed gravel	0.572	0.020	0.584	0.012	48	2.5	63	1.4
G 205	Serpentinite	0.450	0.010	0.499	0.021	51	0.7	59	2.4
G 206	gravel	0.352	0.003	0.387	0.006	41	2.7	52	1.6
G 207	crushed gravel	0.578	0.008	0.619	0.013	47	1.2	62	1.7
G 208	greenschist	0.412	0.006	0.436	0.017	46	0.7	58	1.3
G 209	silicate marble	0.357	0.008	0.390	0.008	52	1.0	57	1.6
G 210	Kersantite	0.538	0.019	0.609	0.030	49	1.5	62	1.4
G 211	Dolomite	0.410	0.022	0.400	0.015	40	2.9	54	1.2
	mean standard deviation:		0.012	—	0.015	—	1.6	—	1.7
	max.:	0.578	—	0.619	—	53	—	66	—
	min.:	0.352	—	0.387	—	40	—	52	—
	difference:	0.226	—	0.232	—	13	—	14	—

As can be seen from Table 1 with 1.6 [-] respectively 1.7 [-] the mean standard deviation for measurements using the accelerated polishing wheel and the pendulum skid tester (PSV and PSV_{fGK}) is nearly the same for both sand and stone chippings as is the standard deviation obtained with the W/S for both sand fractions. The PSV_{fGK} is higher than the PSV, which results from the sand specimens' rougher surface. For the PWS the relative difference between highest and lowest measured polishing value with nearly 38 %, is much higher than for the PSV_{fGK} (21 %) and the PSV (25 %). As a result, distinctive classes for high and low polishing resistance, which also take the test accuracy into consideration, can be defined easier for the PWS than for the PSV_{fGK} test method.
In general, the PWS of grain-size fraction 0.63/1.0 mm is higher than of fraction 0.2/0.4 mm and the ranking of the sands is almost the same for both fractions tested, as shown in Fig. 4. For the grain-size fraction 0.2/0.4 mm only two samples of sand achieved a PWS of 0.55 [-] as was stipulated for concrete pavements in Austria. The value of 0.55 was set by referring to

research studies conducted in Germany using a Wehner/Schulze testing device of an older design. Since also sand from sources with well known high polishing resistance performance didn't achieve the stipulated PWS, this threshold has been set too high to guarantee a region wide supply with sand. With a new threshold set at 0.50 [-] six samples of sand (54.5 %) meet the criterion and guarantee an adequate supply of sand with a sufficient high polishing resistance for pavement construction in all Austrian regions.

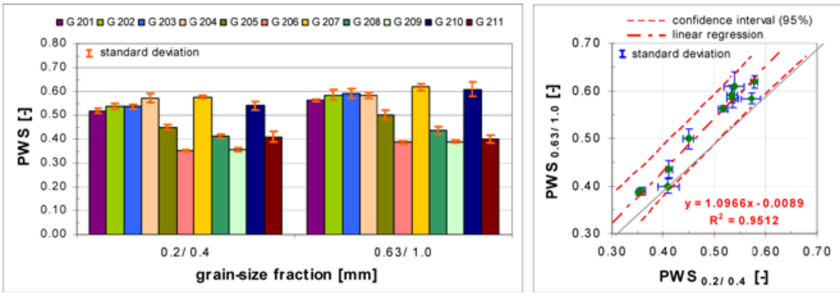

Figure 4 PWS for sand fraction 0.2/0.4 and 0.63/1.0mm.

In Fig. 5 the PSV is compared to the PWS of both grain-size fraction 0.2/0.4mm (left) and 0.63/1.0mm (right). Data points near the diagonal line indicate rock sources with the same polishing resistance for both sand and gravel. Data points above the line stand for rock sources those coarse aggregates (7.2/10mm) have a higher polishing resistance than the small particle sizes 0.2/0.4 or 0.63/1.0 mm and vice versa.

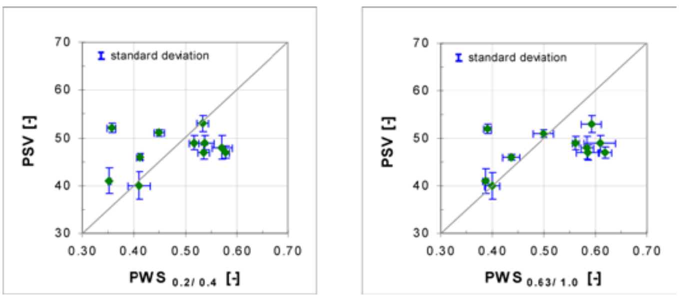

Figure 5 Correlation between PSV and PWS (0.2/0.4mm left, 0.63/1.0mm right).

As shown in Fig. 5 polishing behavior of coarse and fine aggregates from the same rock or stone source may significantly differ. Due to these differences, separate requirements for fine and coarse aggregates are necessary, because only the combination of highly polishing resistant fine and coarse aggregates enables a sustainable skid resistance of road surface layers. Since the Wehner/Schulze machine is not very widespread so far the alternative test method using the accelerated polishing machine was developed. By comparison the PSV_{FGK} obtained from grain-size fraction 0.63/1.0mm with the PWS obtained from fraction 0.2/0.4mm (see Fig. 6) following correlation was found:

$$PWS = 0.01166 \cdot PSV_{fGK} - 0.5179 \qquad (1)$$

Since the coefficient of determination in (1) is R2 = 0.75 a statistically reliable conversion of the different polishing resistance values is not feasible. Though, determination of the PSV_{fGK} allows sand-producing enterprises a first assessment of the polishing characteristics of their sands. For that purpose the PSV_{fGK} shall be divided into three categories, see Table 2.

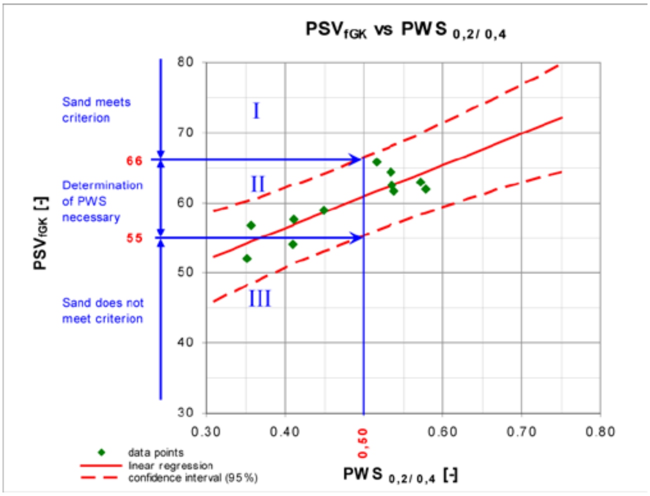

Figure 6 Correlation between PSV_{fGK} and PWS obtained from grain-size 0.2/0.4mm.

Table 2 PSV_{fGK}-categories for PWS ≥ 0.50 [-].

Category	PSV_{fGK} [-]	Assessment
I	> 66	adequate polishing resistance, PWS ≥ 0.50
II	55 - 66	polishing resistance shall be determined using the Wehner/ Schulze testing machine
III	< 55	inadequate polishing resistance

A PSV_{fGK} greater than 66 (category I) guarantees a PWS over 0.50 and therefore the polishing resistance of sand is sufficient. If the PSV_{fGK} obtained lies between 55 and 66 (category II) further tests using the Wehner/Schulze testing machine are required. A PSV_{fGK} below 55 imply that the polishing resistance won't meet the criterion of a PWS ≥ 0.50.

5 Sand polishing resistance in the Austrian standard

Since the field of application for asphalt pavements is very large ten different categories which summarize requirements on rock properties, e.g. grading curve, angularity, LA, etc. have been implemented in the Austrian standard. Stone material used for highly stressed motorways and expressways belongs to category GS (= rock category "Superior"). Specified therein, sand used in asphalt layers on motorways needs a PWS of 0.50 [-] tested on sand fraction 0.2/0.4mm. For other categories there are no requirements set on sand polishing resistance. For concrete pavements requirements regarding the polishing resistance of sand have already been set [5]. Although on motorways in Austria exposed aggregate concrete is the typical construction method for concrete pavements, justification for this requirement is given in spots where the cement mortar was not brushed out successfully. Based on the test results presented in chapter 4 the new limiting value for polishing resistance of sand (PWS) is set now with 0.50 [-].

6 Conclusion

This paper elucidates the first investigation of sand polishing resistance for a representative set of Austrian rock sources using a Wehner/Schulze testing device of the latest design. The aim was to determine whether the already established threshold for sand polishing resistance of 0.55 [-] set with a testing device of an older design is still appropriate. Furthermore, existing differences between polishing resistance of fine and coarse aggregates using the accelerated polishing wheel were investigated.
Results of a mass screening carried out on eleven samples of sand using grain-size fraction 0.2/0.4 mm showed that a threshold set at 0.50 [-] guarantee an adequate polishing behavior of sand. By using the accelerated polishing machine an alternative test method for the sand fraction has been developed. This method allows sand-producing enterprises a first estimation of the polishing properties of their sands. Since the polishing resistance between sand and gravel may widely differ separate requirements for fine and coarse aggregates are highly recommended.

References

[1] Dames, J.: Untersuchungen zur Sandpolierprüfung in Anlehnung an BS 812. Schluss-bericht zu FE-Nr. 06.068, Berlin, 2001.

[2] EN 1097-8. Test for Mechanical and Physical Properties of Aggregates – Determination of the Polished Stone Value, CEN European Committee for Standardization, 2009.

[3] Dames, J., Huschek, S. & Lindner, J.: Ermittlung der Endpolierwerte von im Straßen-bau verwendeten Gesteinen, Forschung Straßenbau und Straßenverkehrstechnik, Heft 574, Bonn, 1989.

[4] Litzka, J., Pfeiler, A. & Zieger, M.: Einfluss des Sandes auf das Griffigkeitsverhalten bi-tuminöser Decken, Schriftenreihe Straßenforschung des Bundesministeriums für Verkehr, Innovation und Technologie (BMVIT), Heft 534, 2003.

[5] RVS 08.17.02. Technical contract conditions, concrete pavements – pavement construction, Austrian Association for Research on Road–Rail–Transport (FSV), 2007.

[6] Kirchmaier, L.: Grain size dependency of the polishing resistance of sand using the Wehner/Schulze polishing test. Master's Thesis, TU Vienna, 2007.

[7] Augustin, H.: Ein neues Gerät zur Messung der Griffigkeit, Österreichische Bauwirt-schaft, Ausgabe 4, 1987.

[8] Wörner, Th., Westiner, E. & Böhnisch, S.: Entwicklung eines Prüfverfahrens zur Be-stimmung des Polierwiderstandes von Sand. Forschung Straßenbau und Straßen-verkehrstechnik, Heft 943, ISBN 978-3-86509-507-7, Bonn 2006.