New laboratory procedures for assessing polishing and skid resistance – review

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NEW LABORATORY PROCEDURES FOR ASSESSING POLISHING AND SKID RESISTANCE – REVIEW

by A Dunford


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Executive summary

The Highways Agency’s Wehner/Schulze (W/S) machine, the first in the UK, has shown potential for use in determining the long-term skid resistance of aggregates, asphalt mixtures and cores. This report describes the first stages of a project to evaluate its use as a procedure for assessing the polishing resistance and skid resistance of aggregate used in the UK.

Technical exchange visits to the national laboratories in France (LCPC) and Germany (BASf) have allowed discussion with researchers carrying out evaluation programmes of their own W/S machines. Relevant literature is briefly reviewed.

There have been various experiments using the machine and, frequently, tests on the machine’s abilities. The literature typically describes the procedure favourably, often describing benefits such as:

- Good correlation with Polished Stone Value (PSV) test.
- Good correlation with skid resistance testing equipment.
- Better precision or range of readings than PSV or skid resistance testing equipment.

Furthermore, the machine is often chosen for use in investigations because of its unique ability to test not only samples of aggregate, but laboratory manufactured asphalt specimens and 225mm diameter cores from road sites. This function of the machine is likely to be its greatest advantage and could lead to better use of existing resources – by accurately determining a mixture’s ability to perform, or by assessing the effect of including in the asphalt mixture more abundant but less highly specified, i.e. lower PSV, aggregate.

More in-depth evaluation of the machine itself has examined the extent to which the action of trafficking is mimicked. Estimates of the equivalent traffic polishing that is achieved by the full procedure vary between 4 and 10 years. Initial results from the LCPC work programme show that the W/S machine may provide a close match to the evolution of road skid resistance, at least during the early phase of polishing.

Although the literature describes these uses for the W/S machine, the main goal of this project is to evaluate its use as a tool for assessing the polishing resistance of road aggregate. In this way, the most interesting experiments are those comparisons with the current standard method, the PSV test. The literature therefore supports the need to make similar comparisons using the range of aggregate used in the UK. Details about the ability of the W/S procedure to replicate polishing by traffic are not conclusive and this supports the strategy of research planned under this project, to compare polishing on samples placed in the road with polishing by the machine.

In all cases, the research that has been undertaken or that is currently underway confirms the need for the research planned in the UK under this project. The work planned here is complementary to that being carried out in Europe and more closely aligned to specific UK materials and the needs of the Agency and UK road construction industry.

The use, and public profile, of the W/S machine is rapidly expanding across Europe. It is therefore recommended that Highways Agency continues to support research into the use of the machine and maintains close contact with the work in Europe so that the UK is well placed to contribute constructively to any efforts to make the W/S procedure a European standard.
1 Introduction

Highways Agency has commissioned TRL to assess whether a new laboratory procedure – the Wehner/Schulze (referred to as W/S for the remainder of this report) test – has the potential to provide a better prediction of in situ skid resistance than the Polished Stone Value (PSV) test and, if so, if it would be appropriate to replace the PSV test in the Design Manual for Roads and Bridges. The overall project has been conceived in two phases:

- Phase 1 to determine whether the W/S test has the potential to predict in-service skid resistance and, if appropriate, to provide a basis for introduction of the W/S test into the UK.
- Phase 2 of the research would consider a wider range of aggregates and conditions to ensure that the procedure is robust and sufficiently precise for the diverse aggregates available in the UK and conditions that are found in practice.

This report has been written as part of Task 1 of the first phase: Review wider experience and application of the W/S test. The intended purpose of this review task was to:

- Establish what past, current and future research has or is being carried out by other operators of the equipment.
- Find out what precision data exists and what further work is needed to establish the necessary precision to consider using this test for specification purposes.
- Examine how test data is applied by others to predict polishing and skid resistance in situ.
- Support and help define the specific test programmes to complete Tasks 2 and 3.

The task had two elements: a literature review and face to face discussions with other users of the equipment in Europe.

The equipment was originally developed at the Technical University of Berlin and discussions with that organisation had been held prior to our initial purchase of the machine. The equipment is now used more widely in Germany and to obtain a view of its use in that country, discussions were held with the Bundesanstalt für Straßenwesen (BASt, the German Federal Highway Research Institute). The Laboratoire Central des Ponts et Chaussée (LCPC) has also recently acquired a machine and is actively assessing its potential for use in France. A visit was therefore made to LCPC to discuss their experience so far. Both proved to be valuable sources of literature and information, so the technical visits have been reported first in the chapters below.

There are a number of reports in the literature concerning the W/S test, largely from Germany. Most describe its use as a tool in experiments to characterise surfaces or aggregates. More recently, as the machine’s reputation has grown, published work has included descriptions of the features, limitations and capabilities of the machine itself.
2 Background

The W/S test equipment, shown in Figure 2.1, was developed during the 1960s in Germany, at the Technical University of Berlin (TUB), as an alternative laboratory test procedure for assessing the polishing of aggregates in road surfacings. At that time, it was considered that the PSV test was not satisfactory because it gave relatively small numerical differences between different aggregates used in Germany and had poor reproducibility. Since then, however, the reproducibility of the PSV test has been much improved and, especially in the UK, considerable experience of the relationship between PSV and skid resistance has been developed.

The W/S procedure, similarly to the PSV test, is designed to simulate accelerated polishing on road surfacing materials and test the friction provided by the specimen before and after that polishing. An important difference between the PSV test and the W/S procedure, however, is that the latter uses large, flat specimens (usually 225mm diameter) that can be obtained from actual road surfaces, asphalt test specimens manufactured in the laboratory or laboratory-manufactured test plates using aggregate alone. The test is carried out using a purpose-designed machine that is now available commercially.

There are essentially three processes involved in the complete W/S procedure: friction testing, polishing and grit-blasting. The specimen (a 225mm core or a 320mm by 260mm rectangular slab) is held in an aluminium mould and attached firmly to the mounting table in the machine so that the table and specimen surfaces are accurately parallel. The mounting table can slide between the friction testing station and the polishing station.

The friction measuring head comprises a metal support onto which three sole plates with attached rubber sliders are fitted at a regular spacing, each slider being 30mm long and 14.5mm wide. In the standard test, the measuring head is accelerated until it is rotating at 3000rpm, which is equivalent to a tangential speed for the rubber sliders of 100km/h. Just before the head has reached the target speed, water at 10°C is sprayed on to the test surface to attain a theoretical water film thickness of about 0.5mm and the assembly is dropped onto the surface of the test specimen from a height of about 10mm, imparting a pressure of 0.2 Nmm⁻², equivalent to 2 bar (29 psi) in tyre pressure.

The test head decelerates to a stop while a proximity sensor system records the rotation of the head and torque transducers in the mounting table continuously measure the reaction force. The data is sent directly to a dedicated computer that automatically calculates the coefficient of friction (using an assumed static load) and speed at any instant and generates a smoothed friction/speed curve for the test. The single values, reported as standard, are the values of coefficient of friction at 60km/h. Before each friction test on a sample, a friction test on a ‘calibration plate’ of rippled toughened glass is carried out. The latter should generate readings within closely defined boundaries.

At the polishing station, three rubber-covered conical form rollers are lowered into contact with the test surface. During the polishing operation, each roller is independently forced onto the test surface at a contact pressure of approximately 0.4 Nmm⁻², equivalent to 4 bar (58psi), typical of the tyre pressures of a commercial vehicle. The mounting bearings are engineered to provide some friction so that, although the rollers are free to rotate, there is some drag, giving a slight slip of 0.5 to 1.0%. Grooves about 2mm wide, 2mm deep and about 20mm apart are cut in the roller rubber, running from the apex to base of the rollers, to simulate tyre treads. In the standard test, the roller head is rotated at 500 rpm for 1 hour, giving a total of 30,000 revolutions of the head and 90,000 roller passes over the sample surface. A suspension consisting of about 5% quartz powder in 95% tap water is mixed at a controlled temperature of 20°C in a separate tank and is pumped onto the specimen during this process. This replicates the detritus on a road surface and assists in the polishing process.

The grit blasting stage is usually used to ‘roughen’ the specimen surfaces in order to simulate the action of winter weather. For this purpose, a custom-designed grit blasting cabinet is used. The cabinet has several automatic settings which control the duration and evenness of the blasting over the specimen surface. The grit blasting process can also be used to clean excess bitumen from new asphalt specimens.
A full cycle of the test (as developed by TUB) for specimens taken from the road has the following stages:

- Friction test new core *determine in situ friction*
- Polish for 1 hour *simulate summer polishing*
- Friction test
- Grit blast *simulate winter weathering*
- Friction test
- Polish for 1 hour
- Friction test
- Friction test ‘to the limit’ *determine lowest friction*

The test on the new core is carried out because, in Germany (unlike the UK), there are contractual requirements for skid resistance on newly-laid surfaces.

Experience with the equipment in Germany has suggested that the final level of friction, after both polishing stages have been carried out, simulates the state of skid resistance that occurs after four to six years of traffic on aggregates in situ. Further experimentation in Germany has mirrored findings using the PSV test in the UK and observations on the road: the level of skid resistance drops very quickly to an equilibrium level that reduces only slowly over the remainder of the test, or road service life.

![Figure 2.1 The Wehner/Schulze test equipment](image)

*Figure 2.1 The Wehner/Schulze test equipment*
3 Technical exchange visits to German and French laboratories

3.1 Germany

The Bundesanstalt für Straßenwesen (BASt), the German Federal Highway Research Institute, is a technical and scientific institute under the Federal Ministry of Transport, Building and Urban Affairs. BASt provides the Ministry with scientifically-backed data and information for technical and traffic related issues and plays a significant role in developing regulations and standards. At its testing facilities, the Institute conducts its own research on issues of special significance.

Discussions at the BASt facility in Cologne took place on 10th September 2007 between TRL and BASt staff. Since Germany is the centre of research with the W/S machine, communication with TRL’s German counterparts is extremely important.

3.1.1 History

The machine was developed at the Technical University in West Berlin (TUB) in the 1960s in response to a need to use fine aggregates or recycled building materials due to a lack of availability of high specification road aggregates, which at the time were difficult to import from West Germany.

BASt received their first machine in 1983, but it was not heavily used until after the reunification of Germany, when close connections between BASt and the TUB initiated further development and research.

In Germany, road companies are required to guarantee the performance of the road (including structure, evenness, skid resistance etc.) for up to 5 years after its construction. There was therefore a need for prediction of material characteristics after this length of time. The PSV test, which already existed, was not thought to deliver sufficiently accurate results. For example, regulations initially gave a range of required PSV values (e.g. 50-53) and an average PSV value at the lower limit for an aggregate source (e.g. 50) was acceptable. Regulations were then updated to give minimum values only (e.g. 50) so that a source was only acceptable if all PSV results were above 50, rather than the average value. This is effectively a higher requirement and, after discussion with industry, the regulations were further updated with lower minimum values (e.g. 48). These changes have led to the German road industry being in favour of the W/S procedure because of the long-held view that it is nonsensical to have a requirement range of 3 PSV points when the test itself is barely accurate to that degree. In the UK, the level of accuracy is not so much of a problem because of the wider range of aggregates available.

The test is already a standard for aggregates (Technical Test Manual paragraph 5.5.2, and the PSV test is paragraph 5.5.1), but whereas PSV is used for all mineral aggregates, W/S is used only in specific cases. There is a medium term goal (2-3 years) to replace the PSV test in German standards.

3.1.2 Use of Wehner/Schulze machine

Many German roads were re surfaced in the 1990s with stone mastic asphalt, especially East-West roads, but a very hot summer in 1995 led to problems with surface deformation. In reaction to this, several states rebuilt roads with cement concrete and now up to one third of the major highway network is surfaced with cement concrete. So, investigation into the skid resistance of this concrete and its constituents is quite important, particularly since it has been found that the skid resistance properties of the sand component is very important to the development of the overall skid resistance of the surface.

The view at BASt is that the W/S machine has two distinct functions:

- Testing the polishing limit of aggregate, like the PSV test. (Limit value for most aggregates is thought to be approx 270,000 roller passes).
- Prediction of skid resistance.
In theory, the W/S procedure polishes aggregate to its limit in order to assess the worst case scenario for low skid resistance. However, other factors may affect skid resistance and current BASt research includes looking at the effect of freezing/thawing specimens, age of bitumen and texture of samples. It is recognised that trafficking is more complex than can be reproduced by a machine.

The full test process used at BASt is the same as that developed by TUB (given on page 3) but it is generally thought that the grit blasting stage does not simulate what happens on the road. However, there is a need to represent the whole trafficking process, as opposed to just the polishing phase, in a reproducible manner. Furthermore, it is necessary to remove bitumen, especially on laboratory-manufactured samples, because its effect on skid resistance may be considerable.

3.2 Inter-laboratory collaboration

There is a ‘working group’ in Germany that discusses the use of the machine, with approximately 20 members, including representatives from Austria and the Netherlands. Professor Huschek, working closely with the equipment manufacturers, Freundl, has been a central figure in the development of the machine, and there are some concerns about a loss of momentum with his imminent retirement. Some round-robin testing has been carried out by the group, organised by the German consultancy Asphalta, using asphalt samples prepared centrally and distributed to participants. There is a further proposed scheme of ‘round robin’ testing including all current W/S machines. In this second instance the proposal is to test a standard aggregate, but made into specimens in the individual laboratories. This is intended to review the reproducibility of the whole process, in comparison with the PSV test where it is known that differences in specimen manufacture can greatly affect results.

3.3 France

The Laboratoire Central des Ponts et Chaussées (LCPC), is a publicly owned organisation under the joint supervision of the Ministry for Ecology, Sustainable Development and Spatial Planning (MEDAD) and the Ministry of Research. The LCPC concentrates on road safety, environment and sustainable development and infrastructures. In addition to the LCPC, there are a number of Regional Laboratories (LRPC) responsible for day to day work.

3.3.1 Background

At the time of visiting, the W/S machine at the LCPC in Nantes was the only one in France, but the Regional Laboratory in Angers was preparing to commission a second. Research has been carried out at LCPC since 2004 to meet two requirements:

- To have a test method to quickly evaluate the polishing resistance of asphalt surfacings.
- To have a model for predicting the skid resistance trend over time, taking into account the characteristics of the materials.

It was quickly discovered that, although there are many methods available to test the polishing resistance of aggregates, the W/S machine is one of the only ones to be able to assess the whole asphalt mixture.

3.3.2 Research

The overall research objective is to correlate tests on the machine with skid resistance measurements on the road. Initial experiments considered removal of the bitumen film on test specimens before polishing using solvents, but it was found that the initial $\mu$ in this case is unrealistically high. Furthermore, the grit blasting process has been dropped in favour of polishing alone because this is thought to be more representative of the action of traffic and the development of skid resistance on the road. The test method employed at LCPC takes measurements of $\mu_{PWS}$, the coefficient of friction measured in the
W/S procedure, throughout the polishing cycle, every 1,000 polishing passes until a peak is reached, and then at 15,000, 20,000, 90,000 and 180,000 polishing passes. This allows the development of $\mu_{PWS}$ against time to be plotted, as shown in Figure 3.1, which demonstrates typical measurements from an asphalt core with the bitumen removed by solvent (red line) and with the bitumen present (black line).

![Figure 3.1 Development of $\mu_{PWS}$ with polishing](image)

Further research carried out by the group at LCPC is summarised in Section 4.3.

The implications of the research outcomes were discussed with LCPC and they consider that, if the results are favourable, then there is a (long-term) possibility of making the W/S procedure an additional requirement to, or replacement for, the PSV test in France. It is the intention of LCPC, in a first step to achieving widespread approval of the W/S machine, to approach major road companies (e.g. COLAS, Eurovia), who may view the potential to allow optimization of materials before laying or aid maintenance during service-life as one of its benefits. As an example, French aggregate companies producing <50PSV could use the W/S machine to show that adding a proportion of higher PSV aggregate could give overall results >50PSV.
4 Literature: Assessing the Wehner/Schulze machine

4.1 Comparison of results with PSV

Professor Huschek notes that the PSV test is the oldest and most commonly used test for assessing aggregate polishing. He cites as disadvantages of the test the small range of test results and poor reproducibility and repeatability which is a problem in countries with a limited range of aggregates because the PSV test does not sufficiently discriminate between them. For comparison, Figure 4.1 shows the correlation between PSV and W/S results. The point is made that whereas the PSV values are spread between 40 and 60, with a resolution of 1, the W/S values are spread between 0.2 and 0.5, with a resolution of 0.005 (i.e. 3 times as many potential data points). Furthermore, the reproducibility of the tests is quoted, as a percentage of the spread of results, as 13% and 6.6% for the PSV and W/S tests respectively. The formula for correlation, using 88 points, is PSV = 56.3W/S + 30.1 (r=0.87).

![PSV against W/S](image)

**Figure 4.1 PSV against $\mu_{PWS60}$**
(Reproduced from Huschek (2004))

As part of long term experiments using a series of test sites on the A70 autobahn constructed in 1991, researchers in Germany compared W/S results with PSV results for 8/11mm aggregate using several aggregate types (Figure 4.2). Similar conclusions were drawn, insofar as both testing methods rank the aggregates in the same order with regard to polishing resistance. There is good correlation between the two methods, but the W/S method spread the results to a greater degree. The relationship derived in this case, using 31 points, is PSV = 68.26W/S + 26.07 (r=0.885).
These results are some of the many that have been generated from experiments made on the test sections on the A70 autobahn. The sections were specifically laid to determine to what extent the polishing resistance of mineral aggregates and compositional properties impact on the development of skid resistance under real traffic and weather conditions. A huge amount of research over the last twenty years has been based on these test sections, and experiments using them are recorded in the literature, especially with reference to the test sections at Bamberg on which the most extensive measurements have been made.

Researchers at LCPC have demonstrated a correlation between PSV and W/S. The test method employed at LCPC differs slightly from that used in the German experiments referred to above, because no grit blasting was used, and μPWS was measured after 90,000 passes. However, since the tests were carried out on resin samples, and no bitumen was present, the lack of grit blasting may not be a factor. Figure 4.3 shows the correlation from the seven specimens tested. The equivalent formula for the relationship is $PSV = 67.57W/S + 27.7 \ (r^2=0.71)$.
4.2 Comparison of results with road testing equipment

Researchers in Germany carried out an investigation into the development of the grip of the surface of asphaltic concrete when subjected to heavy traffic using asphalt mixtures with different aggregate blends. Five aggregates of varying polishing resistance were used: greywacke, limestone, granite, basalt and a second greywacke with PSVs ranging from 33 to 69. A comparison between pendulum tests (skid resistance tester, SRT) on the samples after polishing in the W/S machine and the $\mu_{PWS}$ values themselves is shown in the graph in Figure 4.4. The linear regression shown has the equivalent form $\text{SRT} = 73.53\text{W/S} + 30.76$ ($r=0.94$).

![Figure 4.4 Correlation between pendulum value and Wehner/Schulze friction coefficient](Reproduced from Löffler et al)

There are various examples comparing friction measurements made in the W/S machine with friction measurements made on the road using standard skid resistance equipment. One such example directly compares W/S friction results on cores taken from the wheel-path of a road that has been tested with, and so has corresponding friction measurements from, the Sideway-force Coefficient Routine Investigatory Machine (SCRIM) and with the Stuttgarter Reibungsmesser (SRM). It is not clear which operating procedure is used with the SCRIM or SRM in these experiments, but their relationships with W/S measurements are striking, as shown in Figure 4.5.
4.3 Comparison with trafficking

As mentioned previously, the purposes of the W/S test are two-fold (Section 3.1.2). The test has been shown to correlate well with PSV, so it is capable of testing the polishing limit. The second consideration is its ability to accurately predict the skid resistance that can be expected on a road after the road has been polished by trafficking.

There have been some experiments to assess how well the polishing imparted by the W/S procedure compares to the action of traffic. The paragraphs below describe some of the results from such experiments.

Testing on the German Bamberg test sections provides skid resistance data (SRM) over a period of ten years. These measurements have been used to develop a universal performance function for skid resistance:

$$\mu_{SRM} = c(t+1)^b$$

where $c$ is the initial skid resistance;
$t$ is the service time [years];
$b$ coefficient to be determined by adjustment.

The most recent literature details part of ongoing research at LCPC. In 2004, three newly laid road sites were selected and the level of skid resistance, as measured in situ by SCRIM and Adhera (a locked-wheel friction measuring device developed at LCPC), on these sites was compared with W/S measurements of cores taken from the sites. Four or five cores were taken every six months; three
from the wheel-path, and one or two from untrafficked areas at the side of the road. The new asphalt sites are:

- Dense asphalt surfacing (BBSG) (~53PSV).
- Thin asphalt, 0/6mm (55PSV).
- Thin asphalt 0/10 (51PSV).

Figure 4.7 shows graphs comparing the evolution of skid resistance in the W/S procedure (left) with the evolution of skid resistance in situ. The author notes that these results are very promising and it appears that the polishing simulation by the W/S machine reflects the change in skid resistance due to traffic well. LCPC consider that more data is required to confirm these initial trends.

Another finding from this experiment is that there seems to be an increase in friction even when there is no traffic action to wear away the binder film, measured by W/S on the cores from untrafficked areas. It is thought that this could be caused by oxidation or ageing of the bitumen.

Further work has begun to determine an analytical model to represent the friction evolution curves, as simulated by the W/S machine, in order to build upon the universal performance function proposed by Huschek (above). Two formulas are presented, the first to describe the whole polishing process, and the second, a simplified formula to predict the evolution only after binder-removal:

$$\mu_{PWS} = a(e^{-bN} - e^{-cN}) - dN + e$$

where $\mu_{PWS}$ is the friction coefficient measured in the WS machine; $N$ is the number of roller passes; $a,b,c,d$ are coefficients to be determined by adjustment.

Which can be simplified to $\mu_{PWS} = ae^{-bN} - cN + d$, if the whole process of binder removal is not to be simulated.

In earlier experimental work, evidence of the ability of the W/S machine to simulate trafficking has been found. Once again, on the Bamberg test sections in Germany, where the influence of various mixture designs on skid resistance was tested over a 12 year period, researchers compared W/S measurements (after traffic simulation, including grit blasting) made on laboratory compacted cores at the start of the project against SRM measurements made at the site 5 years later. The comparison is shown in Figure 4.8, and the equation calculated is $SRM = 0.61W/S + 0.22, r = 0.869$. 
Given that the correlation between SRM and W/S measurements taken at the same time is approximately 1:1 (see Figure 4.5), this comparison implies that the simulated polishing procedure in the machine is over estimating the skid resistance somewhat. Exact details of the polishing procedure used (including the number of polishing passes made) are not given in the paper. The results then show that the W/S machine does simulate trafficking (given the good correlation) but it does not advise about the length of time, or level of trafficking, that is simulated.

Further results from the same experiment show that the grit blasting procedure is an important step in the simulation process. The same comparison is made between initial W/S measurements (after traffic simulation, but not including grit blasting) and SRM results after 5 years. This comparison is shown in Figure 4.9, and it can be seen that the correlation is not so good; r = 0.703.
5 Literature: Using the machine

Another interesting analysis made using the same Bamberg test sections considered the skid resistance of various proportional mixtures of greywacke (high PSV aggregate) and dolomite (low PSV aggregate). This time, instead of testing each mixture in the machine, only pure greywacke and pure dolomite samples were tested and a calculation formula was used to estimate the resultant skid resistance of a mixture based on the mass ratio of its constituents. Figure 5.1 shows a table of the mixtures used in the test sections along with the calculation rule, and the calculated \( P_{WS_{res}} \) W/S values and average SCRIM measurements made on the mixtures in the field 8 to 10 years later. The graph shows that the calculated values, based on W/S measurements, correlate very well with SCRIM measurements.

![Figure 5.1 Calculated Wehner/Schulze values compared with in situ SCRIM measurements](Reproduced from Huschek (2004))

\[
P_{WS_{res}} = \sum m_{FI} \cdot P_{WS_{FI}}
\]

\( m_{FI} \) = Mass ratio of fraction FI

* Average of measurement results from 1999 and 2001 after 8 to 10 years traffic.

There have been several investigations into the influence on skid resistance of the fine particles in asphaltic concrete, or sand in cement concrete. In many cases, the W/S machine has been used because it is ideally suited to making measurements on complete mixture samples of road cores, or indeed on the sand itself – which is achieved by sticking a layer of sand to a wooden disc.

One conclusion states that under little or no stress, the traction of textured cement mortar surfaces is determined to a great extent by the impressed macrotexture, and the polishing resistance of the sand plays only a negligible role. However, depending on the mortar strength and the traffic load, the macrotexture tends to decrease within roughly 2 to 3 years. After that period, traction is maintained mainly by the cement mortar’s microtexture, which is related to the sand’s polishing resistance. Consequently, the traction of a concrete carriageway following the end of the guarantee period needs to be maintained by a correspondingly high polishing resistance of sand.

In fact, the conclusion that the skid resistance of the sand used is highly important to the skid resistance of the mixture as a whole is widely upheld. Indeed, it seems to have been one of the main uses of the W/S procedure, and experiments tend to ideally utilise the device’s unique abilities.
6 Discussion

6.1 Technical visits

The visit to BASt in Germany provided an interesting and useful insight into the background and developmental history of the device. The machine is much better recognised in Germany, where its development began, and it has benefited from widespread industry acceptance. Researchers for BASt are carrying ongoing research into areas such as the effect of weathering and ageing on road surfaces using the W/S machine. The main focus, however, is to take steps towards making the W/S a standard test for all new road surfaces. The visit also brought news of a round-robin style experiment, to include all existing W/S machines and organised by a German consultancy, to investigate the reproducibility of the test. It will be important for the UK to take part in such an experiment, and to keep contact with staff at BASt in order to keep up to date with developments in the W/S.

In contrast, while there is some consideration in France towards making the W/S test a standard, and there has been internal discussion as to the best way to bring this about, their research is focussed on understanding the capabilities of the machine. In particular, there is much interest in the simulation of traffic polishing. In terms of experience, they are at a comparable stage to that in the UK. The research being carried out in France seems to be innovative and liaison will be useful to enhance research undertaken there, and here, and to avoid duplication of effort or repetition of mistakes.

A major part of discussion at both national laboratories revolved around the way the machine was used, and in particular the use of the gritblasting stage. In France, they have largely discontinued use because it was not felt to be representative of traffic polishing, but in Germany (including at the TUB) the stage is always included because of the need to remove the binder film from asphalt samples (cores taken from a road surface or manufactured by compaction in the laboratory). More investigation is likely to be required to assess the function of this stage of the W/S procedure, but the likelihood is that a ‘standard’ test on asphalt samples would necessarily include some way to remove bitumen to be sure just the aggregate itself is being tested.

6.2 Literature

The machine is still regarded as relatively new, and probably because of this, a large number of the accounts of its use include some tests or reference to tests that demonstrate its good correlation with the PSV test. This good correlation bodes well for its acceptance as a new standard, with the possibility of simply updating current specifications by converting to W/S measurements. It would, however, be more robust to start development of specifications from scratch, and in this context, comparison back to the PSV test would be detrimental to W/S development as long as PSV remains the ‘gold standard’.

The friction testing stage of the W/S procedure has been shown to correlate very well with results from various in situ skid resistance testers (examples given are British Pendulum, SCRIM and SRM). This makes measurements made on cores taken from the road more meaningful. The W/S test then has role as an additional assessment tool for use in road surfacing trials, and this function is unique.

Research to compare the effect of polishing in the machine with the effect of polishing by traffic is typically much more recent and seems still to be in its infancy. There are various suggestions as to how long a W/S polishing cycle represents in on-road terms, including consideration of the level of trafficking on-road. In fact, past research carried out in the UK shows that the weight and changes in the level of traffic as well as the length of time is important to the evolution of skid resistance on the road. It is likely that the trafficking process is too complex to be properly simulated, and artificial polishing will depend too heavily on the material being examined and the situation in which it is to be used. However, as a tool for carrying out research, particularly in comparing different materials expected to experience similar (and non-event) traffic conditions, the machine shows a lot of promise.
The machine has been used extensively to investigate the influence on overall skid resistance of different sands in concrete surfaces (partly as a result of the proliferation of cement concrete roads in Germany). Similar work has also been carried out looking at various mixes of aggregates, and this ability to test a whole mixture, without the need to carry out a full-scale trial, is surely one of the machine’s major advantages over the PSV test and worthy of further investigation on UK materials.

6.3 Keys areas for research

The literature frequently refers to comparisons with the PSV test, and to the advantages of the W/S procedure over that test. It would therefore be important, in assessing the W/S machine as a standard test for aggregate polishing in the UK, to carry out comparisons with the PSV test using UK aggregates. The aggregates available in the UK are typically more varied than found in France and Germany, and cover a greater range of polishing resistance.

Linked to this comparison, the method used to test aggregates in the W/S machine should be considered – particularly the issue of whether or not to gritblast – with respect to the goal of the test procedure and its simulation of road conditions.

Several reports in the literature compare the extent of polishing in the machine with the extent of polishing by traffic on the road. However, there is little detail about the actual mechanisms of polishing observed in each case. The innovative research already under way in this project, to compare the polishing experienced by samples placed in the road surface with polishing experienced in the machine, should prove informative in this regard. It will also be important to consider how realistic the W/S simulated polishing is compared with PSV test simulated polishing.

One of the key features of the machine, which is referred to in the literature on many occasions, is the ability to test whole mixtures. The use of this function should be practised on those mixtures used on UK roads. This is not the main aim of the current project, but could be considered complementary since the skid resistance of the whole road is determined by more than the aggregate alone.
7 Conclusions

This review of the use of the W/S test in Europe has been carried out to provide additional background to a project for Highways Agency to assess the suitability of the test for use in the UK as part of the process of assessing aggregates for use in road surface courses.

A technical visit to the German laboratories at BASt revealed that the W/S procedure is being considered for implementation as a standard test in Germany. However, at present this is a medium term goal and their research is ongoing.

A similar visit to the Central Laboratory of LCPC in France revealed that the long term goal in France is also to investigate the potential for using the W/S machine as a standard for specification of aggregate. However, their main emphasis at present is investigation of the working parameters of the machine itself, which is much more aligned to the work under way or planned under this project.

In terms of using the W/S machine as a test to determine the polishing resistance of aggregates, the literature reviewed shows that the machine has been compared extensively against the PSV test, and correlation is very favourable.

In all cases, the research that has been undertaken or that is currently underway confirms the need for the research planned in the UK under this project. The work planned here is complementary to that being carried out in Europe and more closely aligned to specific UK materials and the needs of the Agency and UK road construction industry.

The use, and public profile, of the W/S machine is rapidly expanding across Europe. It is therefore recommended that Highways Agency continues to support research into the use of the machine and maintains close contact with the work in Europe so that the UK is well placed to contribute constructively to any efforts to make the W/S procedure a European standard.
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References


Koch C. Optimierung von Betonrezepturen für den Straßenoberbau im Hinblick auf Standfestigkeit und Griffigkeit, ausgelöst durch das neue Regelwerk “ZTV Beton-StB 01”.


New laboratory procedures for assessing polishing and skid resistance – review

The Highways Agency’s Wehner/Schulze (W/S) machine, the first in the UK, has shown potential for use in determining the long-term skid resistance of aggregates, asphalt mixtures and cores. This report describes the first stages of a project to evaluate its use as a procedure for assessing the polishing resistance and skid resistance of aggregate used in the UK.

Technical exchange visits to the national laboratories in France (LCPC) and Germany (BASt) have allowed discussion with researchers carrying out evaluation programmes of their own W/S machines. Relevant literature is briefly reviewed.

The main goal of the overall project is to evaluate the machine’s use as a tool for assessing the polishing resistance of road aggregate. In this way, the most interesting experiments described in the literature are those comparisons with the current standard method, the polished stone value test. Generally, the research described confirms the need to experiment further, using the machine with UK-specific materials.

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