The Wehner Schulze machine and its potential use to improve aggregate specification

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ABSTRACT

The Wehner Schulze (W/S) procedure, similarly to the Polished Stone Value (PSV) test, is designed to simulate accelerated wear on road surfacing materials and test the friction provided by the specimen before and after that wear. An important difference between the PSV test and the W/S procedure, however, is that the latter uses large, flat specimens that can be obtained from actual road surfaces, made in the laboratory from mixed materials or made in the laboratory as plates using aggregate alone. The test is carried out using a purpose-designed machine that is now available commercially. TRL Ltd operates one such machine on behalf of the Highways Agency who procured the device in 2005.

The ability of the machine to test the skid resistance offered by a sample of the whole mixture used in a surface course rather than just its aggregate components is a major advantage. In some cases there is opinion that the performance of aggregate in roads is not sufficiently characterised by the PSV test, and this has led to the requirement for in situ trials to be carried out before an aggregate can be used extensively in a road network.

TRL Ltd was commissioned by Tarmac Group to carry out initial investigations comparing aggregates with similar PSV, made into asphalt specimens, in the W/S machine. The work was carried out on an experimental basis, with the goal as much to expand understanding of the machine's abilities when used with UK materials, as to define the performance of the range of asphalt samples used. Nevertheless, the results are interesting and similar experiments may eventually prove to be useful in determining expected in situ performance of new asphalt mixtures thus informing maintenance requirements on existing roads.

This paper will describe the basic operation and principles of the W/S machine, and present some of the results and conclusions from the Tarmac experiment.

1. OPERATION AND PRINCIPLES OF THE WEHNER SCHULZE MACHINE

There are essentially three processes involved in the complete W/S procedure: polishing, friction testing, and grit-blasting. A large 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 specimens can consist of asphalt materials (prepared in the laboratory or taken directly from the road) or assemblages of selected aggregate particles embedded in epoxy resin.

Highways Agency purchased a W/S machine in 2005 in order to evaluate its potential use to enhance aggregate specification testing in the UK. The machine is operated by TRL, and is currently the only device of this type in the UK. A detailed description of the machine and the initial experiments can be found in the evaluation report (Woodbridge et al., 2006). Figure 1.1 shows the basic features of the machine.

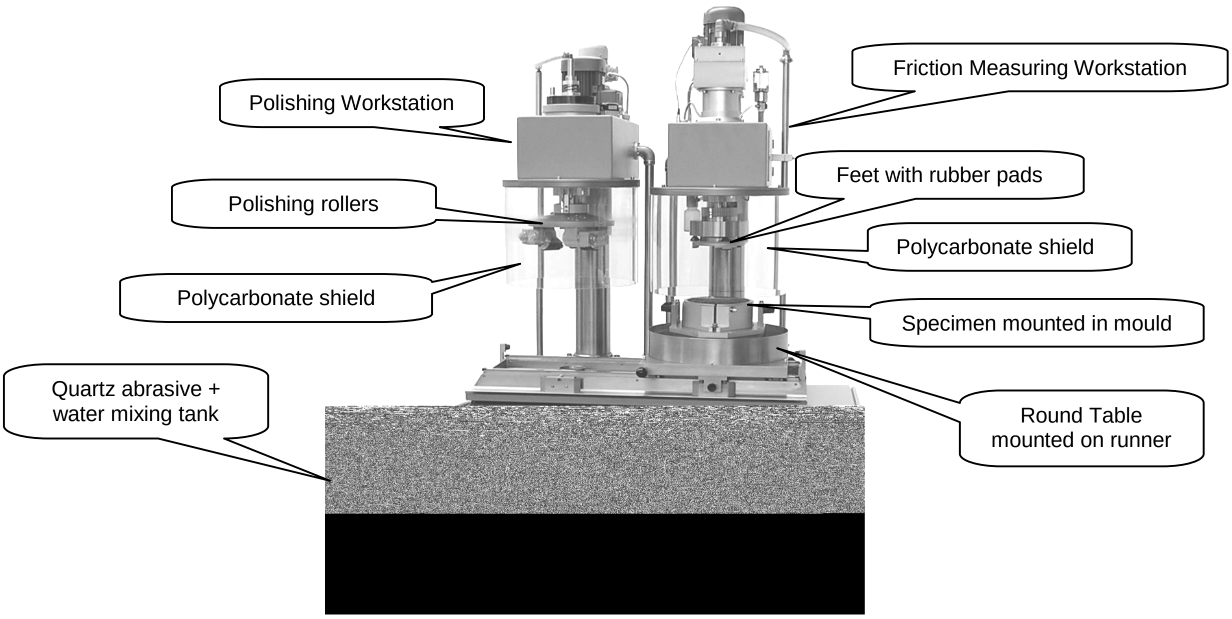

Figure 1.1: Wehner Schulze machine

1.1 THE POLISHING STAGE

At the polishing workstation, 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 $0.4Nmm^{-2}$, equivalent to 4bar (58psi), typically 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. 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 500rpm for 1 hour, giving a total of 30,000 revolutions of the head and 90,000 roller passes over (rovs) the sample surface. A suspension consisting of about 5% quartz powder in 95% tap water is mixed at a controlled temperature of 20^0C in a separate tank and is pumped onto the specimen during this process.

Figure 1.2 shows a test specimen just before the polishing operation, with the polycarbonate shield lowered and the rubber rollers suspended over the specimen.

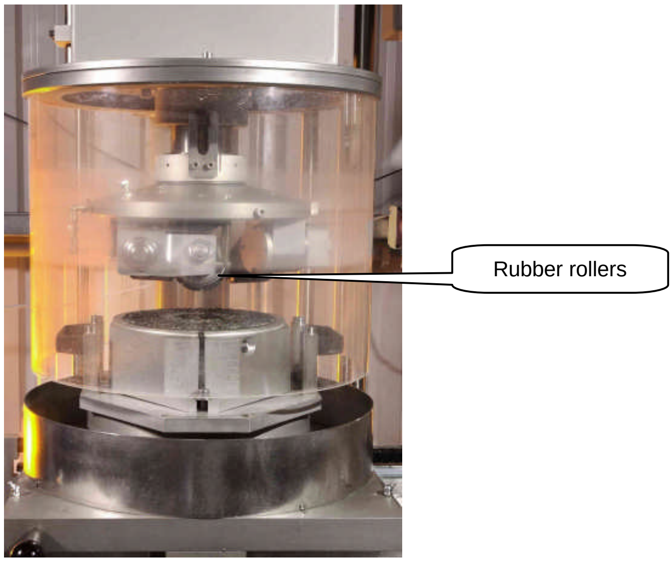

Figure 1.2 Specimen in polishing mode

On completion of the polishing phase, the sample is washed with tap water to remove all traces of abrasive before the friction is measured.

1.2 THE FRICTION MEASUREMENT STAGE

The friction measuring head comprises a metal support onto which three sole plates with attached rubber slider feet are fitted at a regular spacing, each foot 30mm long and 14.5mm wide. The mounted specimen is moved and locked into position under the measuring head and a polycarbonate shield is lowered over the table.

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 10^0C 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 from a height of about 10mm, imparting a pressure of $0.2Nmm^{-2}$, equivalent to 2bar (29psi) 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 information 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/time curve for the test. In the standard test, the coefficient of friction, μ, at 60km/h is taken to represent the test result. Before each friction test on a specimen, a friction test on a 'calibration plate' of rippled toughened glass is carried out. The latter should give readings within defined boundaries.

Figure 1.3 shows the specimen just before the measuring head is lowered ready to start a friction test on an asphalt specimen.

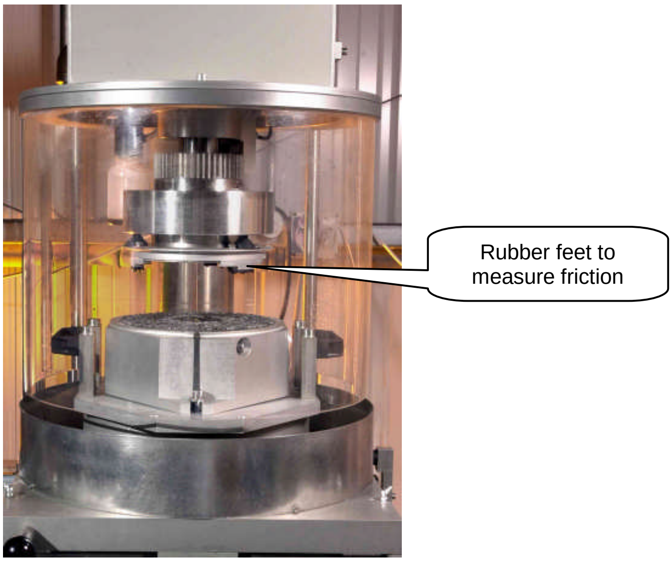

Figure 1.3 Mounted specimen with friction measuring head suspended above

1.3 GRIT BLASTING

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.

1.4 STANDARD TEST PROCEDURE

A standard sequence of polishing and measuring has been developed by researchers at the Technical University of Berlin (TUB):

- Friction test — 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 first friction test is more applicable to cores taken from the road and is often carried out on new surfaces because, in Germany (unlike the UK), there are contractual requirements for skid resistance on newly-laid surfaces.

2. AN EXPERIMENT TO TEST ASPHALT SAMPLES USING SIMILAR PSV AGGREGATE

In 2006, TRL Ltd was commissioned by Tarmac Group to carry out initial investigations comparing aggregates with similar PSV. The purpose of the experiment was to compare the polishing performance in asphalt of ‘unfamiliar’ sources of aggregate with sources of aggregate that have a well established pattern of use. Aggregates with similar PSV values may polish in different ways in the road and road trials are sometimes used to predict performance with greater certainty. In this case, it was hoped that by simulating road conditions in the W/S machine, a quicker way of making this evaluation and shortening the approval procedure would be possible.

The work was carried out on an experimental basis, with permission from Highways Agency, owner of the W/S machine, with the goal as much to expand understanding of the machine’s abilities when used with UK materials, as to define the performance of the range of asphalt samples used. Nevertheless, the results are interesting and similar experiments may eventually prove to be useful in determining expected in situ performance of unfamiliar aggregates in asphalt mixtures thus informing maintenance requirements on existing roads.

2.1 SAMPLES AND TESTING PROCEDURE

The experiment was carried out in two stages, with eight specimens tested in January 2007 (Stage 1), and eight specimens tested in June 2007 (Stage 2). At each stage, Tarmac delivered, for each aggregate, a pair of 300mm square slabs of identical asphalt composition. From these TRL cut 225mm cores for use in the W/S machine. The specimens were labelled with four or five digit codes which have been used throughout to identify them. The asphalt was manufactured in the laboratory using coarse and fine aggregate in various combinations from the ‘unfamiliar’ sources, and ‘tried and tested’ sources.

The standard procedure developed by the Technical University of Berlin (Section 1.4) was designed primarily to test asphalt samples that have been taken from an existing road or surfacing contract. For the purpose of this exercise a shortened form of the process was used.

Initially, the samples were grit-blasted to remove the excess bitumen from the surface and expose the aggregate. Each material was tested for friction in its “new” condition, subjected to a standard polishing cycle of one hour (90,000 roller passes) and then the friction was measured again. An additional series of repeat friction measurements was made on the samples after polishing in order to assess whether the friction would alter as a result of further polishing in the measurement process.

2.2 ACCURACY AND REPEATABILITY

The value reported by the W/S machine is the coefficient of friction measured at 60km/h, denoted $\mu_{PWS\,60}$. Extensive testing to determine the accuracy and repeatability of the W/S procedure has not yet been undertaken in the UK. The difference in values from a test repeated on two specimens depends on a number of factors. In this case these factors include:

- The difference between the specimens – it is not possible for two specimens of the sort tested here to be precisely identical, nor is it possible (due to the abrasive nature of the test itself) to test the same specimen twice. This is likely to be the largest influence.

- Changes that occur in the machine between tests – including wear on the testing sliders, temperature or volume of water applied and slight variations in polishing such as the concentration of the polishing medium. Most of these factors are reduced or mitigated where possible (using the calibration plate to check consistency of the rubber sliders for example).
- Random variation in the test – there will always be some variation in the test, and confidence in an average value is increased by repetition of the test.

Using the tests carried out here alone it is not possible to determine a rigorous value representing the error involved due to these factors. However, it may be possible to give an estimate of the significance in the difference between measured values by considering the differences between values measured on duplicate samples. For example, the average absolute difference in μ between duplicate pairs is 0.02, so, as a rule of thumb, if two measurements differ by twice this value (i.e. 0.04) or more, the two measurements may be considered to be significantly different.

2.3 RESULTS – AFTER STAGE 1

The graph in Figure 2.1 shows the measurements from samples in the Stage 1 of the experiment (January 2007) in order of decreasing $\mu_{PWS\ 60.}$ The blue and red columns represent values from each of the duplicate pairs, and the yellow columns in the foreground show the average values.

It may be considered that the repeatability of these tests (including the differences between the specimens) is sufficient to identify three groups of aggregate samples: (1567, 1567A, 1573) - high, (1569, 1570, 1571, 1572) – middle, and 1568 – low, highlighted by dashed red dividing lines. However it is unlikely that the differences between μ measured on the aggregates within these three groups can be regarded as significant. Although it has not been formally tested, the repeatability of the machine is thought to be better than the repeatability of sample preparation. It is possible that further differentiation between the mixtures may be possible by testing additional replicated samples.

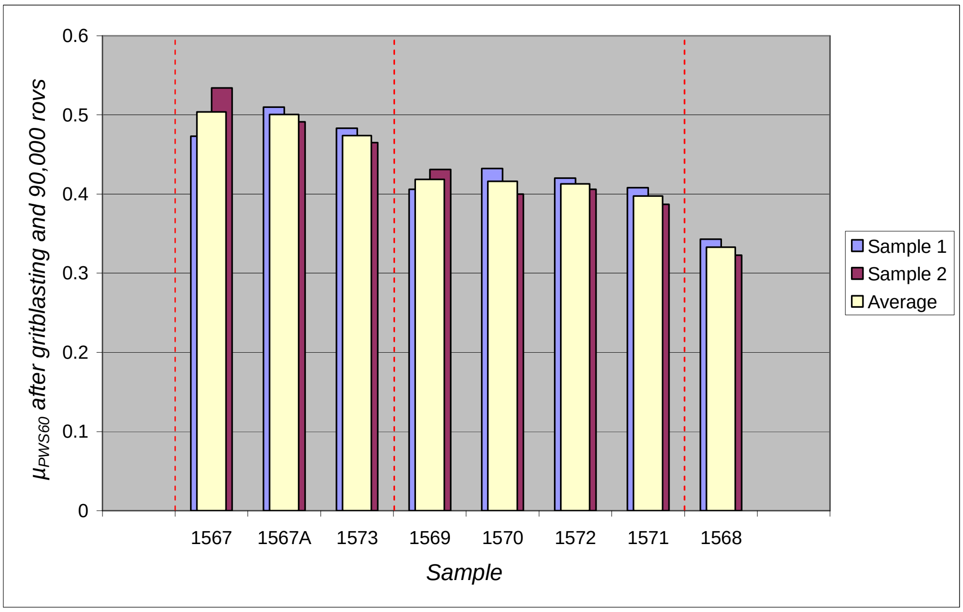

Figure 2.1 Results of Stage 1 $\mu_{PWS\ 60}$ measurements

2.4 RESULTS – AFTER STAGE 2

The graph in Figure 2.2 shows $\mu_{PWS\ 60}$ for all sixteen asphalt samples tested (Stage 1 and Stage 2 combined). In this case separate groups of values are not so easily defined because, with the exception of the two lowest samples, the difference between adjacent columns is less than 0.02 (the average difference between duplicates). It would be possible to create friction categories (e.g. 0.45 to 0.50; 0.40 to 0.45 etc.) which may be the methodology in the long term but the category boundaries would be arbitrary at this stage.

Some of the additional aggregates tested in this second stage allowed interesting further analysis – for example, one had high polish resistance, but was easily crushed and it was found that under repeated friction testing (which is very abrasive), results continued to decrease considerably.

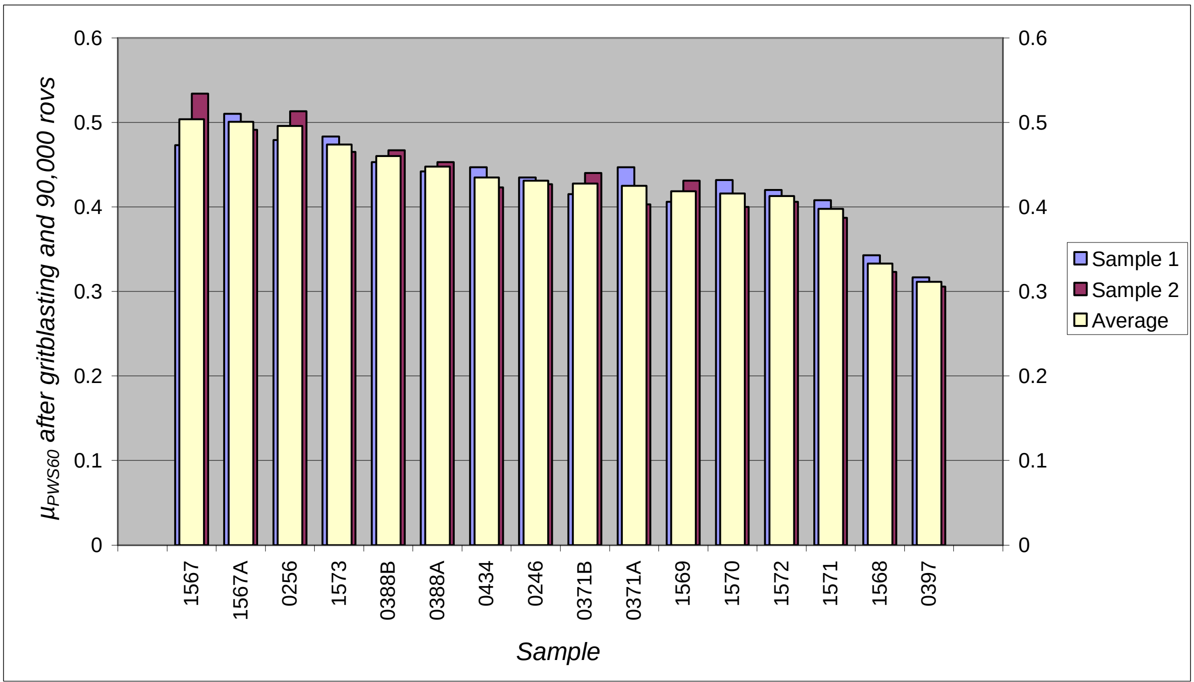

Figure 2.2 Results of W/S tests, $\mu_{PWS\ 60}$, on all asphalt samples

3. DISCUSSION

The behaviour of the W/S machine, and the context of the values for μ that can be measured, is not yet fully understood for the types of surface used in the UK. No direct comparison can be made therefore, and it is not known if there are linear relationships between μ, as measured here, and values from other skid resistance devices used in the UK such as the British Pendulum (and therefore Polished Stone Values) or the sideway-force coefficient routine investigation machine (SCRIM).

However, for reference, average values from measurements made by TRL during initial evaluation of the equipment are reproduced below (Woodbridge et al., 2006). These tests were carried out on samples prepared using uncoated aggregate embedded in a mosaic with epoxy resin. The aggregate chip sizes were selected so that they passed a 10mm sieve and were retained on a 7.2mm flake sorting sieve. It should be noted therefore that these samples are not of the same type as those tested above.

Coarse aggregate (PSV)	Average $\mu_{PWS\ 60}$
Gritstone (68)	0.51
Granite (53)	0.34
Limestone (42)	0.17

Tarmac were able to use the information from the first stage of testing to give a client confidence that their unfamiliar aggregate sources were of equal or better performance than more established and familiar sources already in use.

The capability of the W/S machine to test asphalt mixtures (both laboratory-prepared and paver-laid) as well as crushed, uncoated aggregate is a key advantage of the machine over alternative testing methods. Research into the capabilities of the machine is ongoing. For example, a current project sponsored by Highways Agency is investigating the characteristics of asphalt cores, made using various aggregates, before and after they have been inserted into a road surface and subjected to vehicle trafficking. By comparing these cores with duplicate samples polished by the W/S machine alone, it may be possible to infer the level of vehicle polishing mimicked by the machine and determine the realism of the artificial polishing.

4. REFERENCES

Woodbridge M E, Dunford A and Roe P G (2006). *Wehner-Schulze machine: First UK experiences with a new test for polishing resistance in aggregates.* TRL Published Project Report PPR 144 - Wokingham: TRL Limited

Paper reference PCN002