

## IMPROVED PREDICTION OF AGGREGATE SKID RESISTANCE USING MODIFIED PSV TESTS

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### Abstract

The British polish stone value or PSV test method is widely used around the world to measure the skid resistance of aggregate. It has been a British Standard for many years and forms the basis of the specification for surfacing aggregate in the United Kingdom. It has recently become a European Standard. With various modifications the test equipment is used in many other countries around the world. However, the method was developed about 60 years ago and has remained relatively unchanged since. In contrast there has been tremendous change in the amount of traffic and the stressing experienced by surfacing aggregate. This paper reports on research carried out to improve understanding between the laboratory prediction of aggregate skid resistance and actual performance in-service

### Introduction

The United Kingdom (UK) has the highest requirements for skid resistance in the world. When a road surface falls below a certain value it must be resurfaced to renew skid resistance. Monitoring is typically carried out using the Sideways Coefficient Routine Investigation Machine (SCRIM) to provide Sideways Force Coefficient (SFC) values. GripTester may also be used with the GripNumber values obtained converted into SFC values. In the laboratory, aggregate skid resistance is predicted using the polished stone value (PSV) test. The relationship between PSV, SFC and traffic volumes was established using an empirical model (Szatkowski and Hosking, 1972). Roe and Hartshorne (1998) raised concerns about the ability of this original model to predict in-service skid resistance. They found that some aggregates perform better whilst others appear to polish more. Although they further modified the models, it was difficult to explain these phenomena and which were subsequently addressed by the collaborative SKIDPREDICT and SKIDGRIP projects carried out at the University of Ulster at Jordanstown (UUJ).

This paper reports on research carried out during these and other projects at the UUJ to improve understanding between the laboratory prediction of aggregate skid resistance and actual performance in-service. The paper details modified test methods based on the accelerated polishing equipment used in the standard PSV test. The aim of the research reported was to determine whether by modifying the laboratory stressing conditions, the aggregates being tested behaved differently in response to the applied stressing. The data-base on which the British model relating PSV, SFC and trafficking were developed apply predominately to specific asphalt mixes and rock types typically not used elsewhere in the world i.e. the majority of data relates to mature (3 to 10 years old) hot rolled asphalt with 20mm single sized gritstone chippings applied to the surface to give texture depth and skid resistance. Whilst many of the studies carried out at UUJ utilized gritstone aggregate, the findings would not be applicable to many countries around the world that do not possess, or do not quarry such aggregate types. Due to various factors ranging from their geology to no requirement for skid resistance in specifications, many countries use different aggregates to those in the UK. These may be summarized as either soft or hard. Soft aggregates such as limestone are easy to quarry and very abundant around the world. However, under traffic they easily wear

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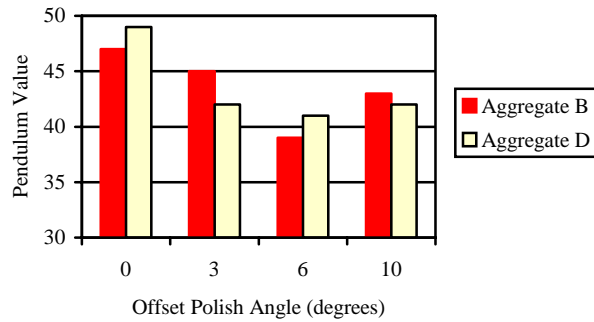
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and will polish giving poor skid resistance and dangerous wet driving conditions. Recognizing this problem of safety, many countries have been seeking to use what they term as hard aggregate in the surfacing layer. This is more durable, does not wear away as quick so maintaining texture depth. Although they will polish, their in-service wet skid resistance is better than soft limestones. The data reported in this paper therefore relates to hard aggregates typical of those now being used by many countries in asphalt surfacing mixes.

### **Development of modified PSV test methods**

The PSV is regarded as a measure of the resistance of coarse aggregate to the polishing action of a tyre under conditions similar to those on the surface of a road. The test became a British Standard in 1960. It has become a European Standard (BS EN 1097-8, 2000) and has modified versions in other countries such as America (ASTM D3319, 1999). Maclean and Shergold (1958) report its original development. Woodside (1981) used the equipment to assess non-standard test conditions to examine the effect of load, contact area, contact length and contact stress with tyre pressure. He found that contact stress and contact area were directly related to the rate of polishing and thus frictional resistance of a PSV test specimen. Woodward (1995) extended polishing to 12 hours using two consecutive standard 6 hour tests and found that 25 of 27 test specimens showed a reduction in PSV of typically 10%. Perry (1996) induced higher contact stress during testing by offsetting the polishing tyre at an angle of 20° and found reductions to 24% below standard PSV for a range of UK gritstone aggregates. During the recent Skidpredict and Skidgrip projects, UJJ looked at further test regimes that utilised either part or all of the standard test equipment (Jellie, 2003). They were designed to induce conditions which simulate different levels of wear and polishing experienced throughout a road network. They included wet and dry testing without abrasive, coarse or fine abrasive only, offset angle polishing to simulate cornering or braking stresses, extended polishing to 50 hours test duration, inclusion of roughening cycles to renew micro-texture and inclusion of freezing cycles to simulate winter roughening.

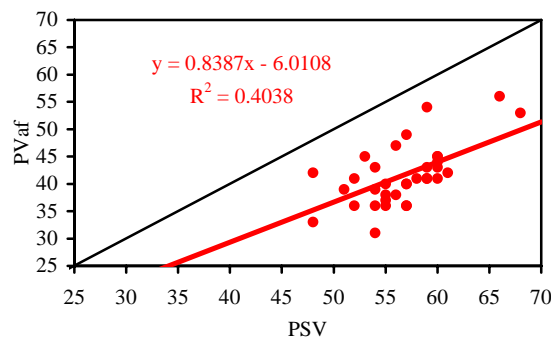
Of these, the offset method of polishing appeared to offer the most promise as a quick, simple method. Initial testing was carried out at an offset angle of 20°. Despite using only the self-weight of the arm assemblage and 50% of the specified test speed this angle was considered too high as it caused excessive wear of the solid rubber test tyre. The arm on the accelerated polishing machine was redesigned allowing angles of 3°, 6° and 10° to be assessed. Figure 1 shows the results for 2 aggregates tested for 3 hours at the standard speed of 320rpm using fine emery and water at standard rates of 3g/min and 6cc/min respectively. Each data point is the mean of 8 test specimens. Testing at 3° offset caused an increase in interfacial stress causing the skid resistance as measured using Pendulum Value (PV) to decrease below the standard PSV. For most aggregates assessed, 6° testing resulted in the lowest skid resistance i.e. the optimum angle to achieve maximum polishing or reduction in skid resistance. The increase at 10° probably reflects the onset of abrasive plucking effects on the aggregate surface rather than polishing. This was accompanied by stone loss from the test specimens, heating and wear of the solid rubber tyre confirming the high interfacial stresses induced. This initial work indicated that aggregates were effected by varying the amount of inter-facial stress and suggested that these methods could be used to model road sites of different stressing e.g. bends of different radii, braking / accelerating locations etc.



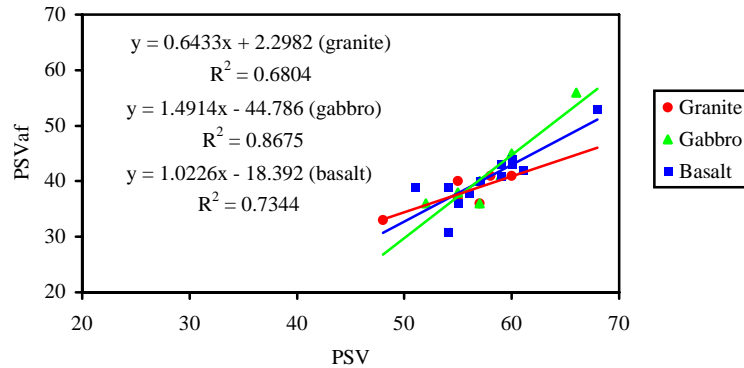
**Figure 1 Comparison of offset polishing angles**

**6° offset angled polishing of hard aggregate**

The data reported in this paper was determined using 10mm single sized, de-flaked aggregate from 34 sources of hard aggregate used in hot asphalt surfacing mixes in Europe. They included basalt, dolerite, granite, dunite, gabbro, diabase, andesite, amphibolite and slag. Four test specimens were prepared for each aggregate and subjected to the standard 6 hour British Standard test method to determine their PSV. Each test specimen was then subjected to a further 3 hours of 6° angle polishing and their new skid resistance measured to give PSVaf. PSV and PSVaf are plotted in Figure 2 along with a line of equality. It can be seen that for all 34 hard aggregates, the additional 6° polishing caused further reduction in aggregate skid resistance i.e. the standard PSV test was underestimating their level of skid resistance under heavier stressing conditions. The mean reduction was found to be 15 points or 27%. The R<sup>2</sup> value of 0.4 suggests poor correlation between the two values for all the hard aggregates i.e. it would be difficult to accurately predict PSVaf from PSV. However, further examination with the data sub-divided into different rock-types improved the correlation between PSV and PSVaf. Figure 3 plots the data for granite, gabbro and basalt and shows improved R<sup>2</sup> values of 0.68, 0.86 and 0.73 respectively. This shows the importance of rock type and how performance prediction may be improved by considering similar rock types. It also highlights that different types of aggregate react differently to the application of stress. It would be expected that is reflected in their performance in-service.



**Figure 2 Plot of PSV and Pvf for all hard aggregates**



**Figure 3 Plot of PSV and Pvf for granite, gabbro and basalt aggregate**

### Conclusions

Ongoing research at UUI is trying to understand the phenomena at the tyre / road surface interface. This paper reports on modified testing of hard aggregates such as granite, gabbro and basalt typically used in many countries in the production of hot asphalt surfacing mixes. These should not be confused with the high PSV gritstone aggregates used in the UK or the low PSV soft sources such as limestone. Testing of many different types of aggregate clearly show that these hard aggregates have PSV values approximately in the range 40 to 60, although individual sources may fall outside this range. The data reported shows that the standard PSV test does not give the lowest level of skid resistance possessed by a hard aggregate. Additional testing using a 6° offset wheel caused on average a further 27% reduction.

Rather, an aggregate's PSV is a simple ranking of one aggregate against another in relation to the test conditions. Change the test conditions and the aggregate will respond in different ways. The 6° offset angled data simply shows that by increasing the interfacial stress the value of skid resistance will on average drop by 27% for the aggregates assessed. Change the test conditions again and different values of skid resistance should result. Whilst this makes the specification of aggregate difficult, this research clearly shows that methods now exist to offer improved prediction of performance. The future for successful sustainable highway construction is understanding risk. This paper shows a relatively quick and simple test method that may be used to assess the skid resistance of surfacing aggregate that is more representative of conditions at higher stress sites on the road network i.e. it allows better understanding of risk.

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