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Re-Evaluating the Risk of Using Higher-Skid-Resistance Aggregates †

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Abstract: Aggregate with higher skid resistance is used in many countries around the world to improve road safety. It has been tested for skid resistance in the laboratory and measured in service for many years. Certain rock types and asphalt mixes offer more skid resistance. The laboratory test methods have not changed for many years. Road surfaces achieve a state of in-service equilibrium depending on many factors, and roads are now experiencing additional changes due to issues ranging from greater use of electric vehicles to climate change in its many forms. This paper considers whether the previous methods are still able to offer reliable prediction. The paper re-evaluates research performed in the period 1990 to 2010 to consider whether the testing of road surface aggregate needs to be updated for the early 21st century. The authors believe this paper is significant for all countries to optimize the performance of their road networks in line with changes in service conditions.

Keywords: re-evaluation; aggregate; skid resistance; performance

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1. Introduction

Road surfacing asphalt used around the world contains approximately 92 to 95% aggregate. In-service performance depends on what happens at the tire/asphalt interface as a vehicle travels along a road. European aggregate, asphalt and concrete products used in roads are covered by the Construction Products Regulation (CPR) [1]. This regulation refers to performance over the life of the product, i.e., from initial design, through in-service life, to when it is recycled. This paper considers this statement and asks whether it is possible to improve the prediction of aggregate performance in the laboratory. The paper re-evaluates research projects carried out over a 20-year period between 1990 and 2010 with methods used in the laboratory to test aggregate. This re-evaluation has been prompted by developing 21st century issues, such as the move to semi-autonomous vehicles, the change from petrol/diesel power to electric and hydrogen, and the governmental response to climate change and all of its associated issues.

2. Why Re-Evaluate Old Research?

Much happened in the UK during the 1990s and early 2000s with regard to road surfacing products. Hot Rolled Asphalt (HRA) had previously been the dominant road surfacing material. However, a short period of higher-than-normal summer temperature caused the bitumen-rich HRA laid on the heavier trafficked networks to suffer widespread premature deformation failure. In response, the road industry looked to countries with high summer temperatures and the asphalt mixes they used. Coarse aggregate skeleton mixes, such as Stone Mastic Asphalt (SMA) and Porous Asphalt (PA), were researched for use in the UK. At this time, the UK had much higher requirements for aggregate, in-service skid resistance and texture depth than countries such as Germany and France. The high stone skeleton SMA and PA mixes were developed into proprietary Thin Surface Course Systems (TSCS), which were optimized for in-service characteristics such as high-speed skid resistance, lower noise or improved rolling resistance.

A parallel factor during this period was the process of removing European trade barriers with the Construction Products Directive (CPD) published in 1998. This led to the first European Standards in 2004 and the Construction Products Regulation (CPR) in 2011 [1]. The CPR is based on the ideal of performance for the life of the product. It has seven generic requirements for all products used in construction, i.e., mechanical resistance and stability; safety in case of fire; hygiene, health and environment; safety and accessibility in use; protection against noise; energy economy and heat retention; and sustainable use of natural resources. These seven requirements were a response to how the world of construction was perceived to be moving into the 21st century.

In practice, the selection of European test methods for aggregate was not based on research to develop improved predictive test methods. Instead, they were existing methods that had been used for many years and had not changed since the early-to-mid-20th century when they were developed. The prediction of in-service risk based on laboratory testing was considered by Woodward [2]. This study concluded that standard test methods offer limited insight into structural and functional performance. Few aggregate test methods considered what happened during the life of the product and predict whether it would remain fit for purpose during the life of the surfacing.

On one hand was the expectation for performance for the life of the product and test methods which offer limited prediction. On the other hand was traffic growth, with new types of vehicle interfacing with the road surface in new ways and the impact of climate change in all of its different forms, from changing weather to government response. This perfect storm scenario forms the basis of this re-evaluation to determine whether anything can be learnt from the research carried out in the 1990s [2] to enhance roads in the early 21st century.

3. What Research Is Being Re-Evaluated?

It has been known for many years that not all aggregate is suitable for highway surfacing. The Travers Morgan Report in 1993 [3] and the Capita Symonds Report in 2004 [4] provided information regarding aggregates considered suitable for road surfacing. They remain a valuable resource for aggregates with higher skid resistance. A limitation of these reports is that they are based on data from standard aggregate testing. Recognizing this limitation, Woodward [2] investigated whether laboratory prediction of surfacing aggregate performance could be improved.

The subsequent SKIDPREDICT [5] and SKIDGRIP [6] projects considered whether the standard Polished Stone Value (PSV) test was a measure of the ultimate state of polish for an aggregate, and how skid resistance of asphalt mixes evolved in service, respectively. A wide range of rock types, asphalt mixes and in-service trafficking conditions were assessed. The projects evaluated the effect of test regimes simulating the conditions that aggregate experienced in different surfacing asphalt mixes in service; for example, increasing the load or induced stressing during PSV testing, or the effect of testing wet aggregate.

4. What Has the Re-Evaluation Identified with Respect to Current Trafficking?

A feature of the work by Woodward [4], SKIDPREDICT [5] and SKIDGRIP [6] was the deconstruction of standard test methods to determine whether a modified version offered better prediction of what happened in service. For example, increasing load during PSV testing found that the laboratory test result for skid resistance decreased. This deconstructed regime may be compared to the increasing use of electric vehicles, which tend to be heavier, more torque and smaller road/surface contact patches.

4.1. Deconstruction of Test Methods

Deconstructing the laboratory test regimes based on in-service conditions provided insight into how different aggregates in different types of asphalt mix react to different stress conditions around the road network. The tire/aggregate interface on the fast lane of a motorway is different to braking for a road junction or going around a bend. For each condition, the tire/aggregate creates an equilibrium condition that can, for example, be measured in terms of wet skid resistance.

4.2. Widening the Types of Aggregate That Would Typically Be Used

The UK has a wide range of aggregates. Not all are perceived as suitable for road surfacing. This has obvious issues with the greater use of local sources and other sustainable issues. Aggregates traditionally not used were considered. Selection was based on the hierarchy of rock types typically used in the UK as surfacing aggregate. Greywackes and sandstone would typically be used for the highest levels of skid resistance. Igneous rocks, such as basalts and granites, would be used on lesser trafficked roads. The projects also examined rock types such as limestones that would not be used in the UK because of their lower wet skid resistance. This questioned the traditional perception of what is considered a good surfacing aggregate. In simple terms, development in vehicle and tire technologies probably do not require the network use of high PSV aggregates, except in localized locations with the greatest skidding risk.

4.3. The PSV Test

With regard to road surface aggregate properties, skid resistance has always been considered the most important in the UK. The European test method to predict aggregate skid resistance in the laboratory is the Polished Stone Value (PSV). This has been a British Standard since 1960 before becoming the test method used across all European countries. Deconstructions of the standard 6 h test included the loss in skid resistance due to wetting the interface during pendulum testing for unpolished aggregate; how skid resistance changed during the standard 6 h PSV test; and what happened if fine emery polishing was extended up to an additional 30 h after initial 3 h polishing with coarse emery. Freeze/thaw cycles were used to investigate winter increase in measured in-service skid resistance. Sideways polishing was used to assess additional tire/surface interface stressing at bends of different radii.

These found that the standard PSV test offers limited insight into what happens at the tire/surface interface during the life of an asphalt mix. If the same aggregate is tested using deconstructed versions of the standard test, the result is different levels of equilibrium, agreeing with what happens in service.

4.4. PSV and Other Aggregate Properties

An important consideration was relating skid resistance data with other deconstructed aggregate test methods for measuring properties, such as strength, wear and durability. This confirmed the ranking that PSV depends on rock type. More importantly, for a given rock type, higher PSV was gained at the expense of all other properties, such as wet resistance to wear. Woodward [2] concluded that specifications that did not recognize rock type do not offer a sustainable solution.

4.5. Consideration of Rainfall

Surprisingly, it was found that a simple improvement in testing aggregate would be to determine what happens when the aggregate is wetted by rain. Irrespective of the extremes in climate change being experienced around the world, something as simple as rain fall is not considered. The most common aggregate tests used around the world are the ASTM or EN versions of the Los Angeles test. This is carried out on dry aggregate. Testing wet aggregate can, for some rock types, cause strength reductions greater than 50% compared to testing dry aggregate. Simple changes to accommodate climate change, such as more rainfall events, would be a significant addition to a risk-based sustainable optimization specification including dry and wet testing and a percentage change.

4.6. Aggregate Homogeneity

Many assume that an aggregate source is homogenous in composition and behaves in a predictable manner. However, many aggregate sources are heterogeneous, with the quarried product offering different responses to a tire at the interface, and to the many other climate-change-related factors such as rain. Woodward [2] gives examples illustrating how aggregate in the stockpile may be a mix of durable and less-durable particles. Under trafficking and environmental factors, such as rain, freezing, or application of deicing salt, the less-durable particles will perform differentially. This will affect the tire/surface interface and within the aggregate skeleton of the asphalt mix. Such problems may become more common due to more environmental stressors such as freeze/thaw, wetting and drying.

5. Conclusions

This paper has re-evaluated what may be perceived as old data dating back to projects carried out between 1990 to 2010. The authors believe this re-evaluation has highlighted the need to give more recognition to how road surfaces may be responding to changes in trafficking and climate around the world. Surfacing aggregate is not an inert material with constant engineering properties. There are complex interactions at the tire/aggregate interface which are primarily dependent on rock type. Deconstructing standard test methods to simulate what happens in service offers the opportunity to readdress how aggregate and asphalt mixes may better achieve the expectation of performance for the life of the product.

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