Early and mid life SMA skid resistance

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ABSTRACT

Safety applies to all stages of highway or airfield construction i.e. from initial design, selection of materials to use of the surface by the user. In the UK, a range of criteria including noise, negative texture, spray generation, layer thickness, availability and cost of higher PSV aggregate, the need for more sustainable technologies have caused a shift towards thinner, smoother and quieter types of asphalt surfacing materials. These typically use modified bitumen or have thicker bitumen coatings to hold the aggregate particles together. The authors recognised that the early life safety of these materials needed consideration given that a bitumen rich surface tends to have poorer wet skid resistance. This paper considers the development of skid resistance for an SMA surface using high PSV greywacke aggregate and polymer-modified bitumen. The SMA surface has been periodically measured using a GripTester to determine how skid resistance has developed from early life through to mid life. The findings show how this is different from a conventional chip seal or positive textured asphalt surface. A new theory is proposed that explains how skid resistance may develop for this type of surfacing.

KEY WORDS

PSV, aggregate, performance, GripTester, prediction, risk

1. INTRODUCTION

The last decade has been a period of tremendous change for the United Kingdom highway industry. Many new types of materials and technologies have been developed or adopted. Highway surface materials now tend to have negative or porous textures with improved rolling resistance and fuel efficiency. Concrete surfaces are considered noisy and are being re-surfaced with quieter types of asphalt material. The different suppliers have developed suites of product that fit niche markets ranging from motorway to residential areas. Innovation is being affected by sustainability i.e. how will the actions of today impact those of the future. Sustainability is now being considered in the design, manufacture, laying and in-service expectations. It implies an understanding of material properties over the duration its engineering life. Phillips (2004) and Woodward et al (2004) concluded that to accommodate sustainability in terms of highway construction materials, one of the major developments within the industry must be to improve understanding of the risk of its actions.

For example, aggregate is a natural product and once quarried will start to deteriorate in quality. Different aggregates will change in different ways depending on factors such as type, use, environmental and trafficking conditions. A combination of aggregate and texture is considered to control the skid resistance of a given highway depending on trafficking and climatic conditions. Simple observation during the early life of these newer types of asphalt surfacing materials show that this basic assumption is flawed. In certain examples, observation shows that even after 4 years a polymer modified surfacing did not have any exposed aggregate i.e. it could be said that the polymer modified binder was too good in its elastic and cohesive properties and the trafficking and climatic conditions were not severe enough to remove the bitumen on the surface.

Consider this scenario on a badly designed or manufactured mix where there is excess bitumen. In terms of risk, the road user has a surface that will probably be dangerous when wet and may also be susceptible to dry skidding events. For example, the use of SMA is currently not permitted in Ireland where the speed exceeds 30mph due to these fears (Fleming, 2002). Put in context, SMA was initially developed 30 years ago for use on German autobahns were speeds may be unlimited. During a study tour in Holland about 10 years ago, to evaluate the latest develops in porous asphalts, the authors first became aware that these types of bitumen rich surfacings took a period of time for the aggregate to become exposed. This happened first in the wheel-paths and then with time widened with trafficking. The Dutch engineer was able to state the age of the surfacing based on how well the aggregate was exposed.

The drawback with using negatively or porous textured materials is that the high proportion of coarse aggregate requires a modified binder to ensure the materials integrity. This may be achieved by the use of an additive such as cellulose fibres to create a thicker binder film on the aggregate, modification of the binder using a polymer. This is a fundamental change in the type of surfacing material i.e. from positive texture to smoother negatively textured. The addition of fibres or polymer modification of the bitumen produces either a thicker binder film on the aggregate or stronger bond between binder and aggregate. Either way this will affect the rate at which trafficking can remove the binder and expose the aggregate.

The authors recognised that the early life safety of these materials needed consideration given that a bitumen rich surface tends to have poorer wet skid resistance. This paper considers the development of skid resistance for an SMA surface using high PSV greywacke aggregate and polymer-modified bitumen. This has included both periodic measurement of the surface using GripTester and the development of laboratory predictive techniques.

2. PREDICTING FOR RISK

In the UK there is now a trend towards specifying performance characteristics such as skid resistance, surface texture or noise requirements. In its simplest form, this implies that as long as the surface performs it could be made of anything. This ideal requires two basic abilities (i) on-site measurement and (ii) laboratory prediction. A performance specification transfers risk to the contractor. There is now growing feeling among UK contractors that this transfer of risk requires improved understanding of material performance and measurement techniques. These are essentially risk based guarantees and it is possible that the number of surfacing contractors willing to accept the risk of premature failure may cause their numbers to decline. This may then increase the price of materials and make better use of sustainability principles through better understanding of performance characteristics. For example, in-service skid resistance performance may be achieved with a lower PSV aggregate used in an alternative way.

Predicting for risk is essentially testing for failure and applies to both on-site measurement and laboratory prediction. Woodward et al (2004) felt that recognition of failure mechanisms would provide better insight into a materials ability to perform. There are two fundamentally different approaches to laboratory and on-site testing:

- Meet basic specification requirements using existing methods such as British or European standard test methods.
- Test to destruction using a suite of methods specifically developed to find the type and mode of failure in relation to time.

This second approach is based on risk prediction. Being able to quantify risk will enable better utilisation of sustainable technologies by determining performance time lines that show how material properties change with time under differing in-service conditions. In terms of skid resistance, this quantification of risk must consider not only the aggregate, but also the type of application, type of binder, trafficking and environmental conditions. It requires predictive test methods and measurement techniques that are able to quantify what actually happens. For example, if it is possible to design a surface mix for high speed roads then its high speed skid resistance characteristics must be measured. There is little point in measuring skid resistance at 30mph on a high speed motorway.

If the methods used do not adequately consider risk, for example the effect of a polymer binder used in a thin surfacing material on early and mid life skid resistance for a lightly trafficked road, then there is a considerable element of uncertainty or risk involved in its use in terms of sustainability or safety of the road user. On-site measurement must consider the influencing factors such as temperature, time of year whilst laboratory prediction must consider their ability to predict.

3. THE SKIDPREDICT AND SKIPGRIP PROJECTS

The SKIDGRIP project investigated the frictional interaction and contact stresses between tyre and road surface (Woodward, 2003). This followed SKIDPREDICT (Roe and Woodward, 2004) a collaborative project between the Transport Research Laboratory and the University of Ulster, funded by the Highways Agency, Country Surveyors Society and Quarry Products Association. The SKIDPREDICT project addressed two of the recommendations set out in an earlier study by TRL (Roe and Hartshorne, 1998) calling for studies of in-service performance and possible developments to the PSV test procedures for natural aggregates.

The SKIDPREDICT project concluded that it was not necessary to change the current PSV test procedure or the requirements in the Design Manual for Roads and Bridges in HD26/99.

SKIDGRIP aimed to improve the prediction of early life in-service skid resistance performance of new asphalt surfacing materials. A range of aggregates, typical of those used in the UK was selected for laboratory evaluation using a range of standard and non-standard test methods developed as part of the SKIDPREDICT project. These have been reported elsewhere (Woodward et. al. 2002, 2003).

As part of the SKIDGRIP project over 250 friction measurements were taken at sites constructed using a set of 12 aggregates that were evaluated in the laboratory. The sites covered a range of types including surface dressing, hra, porous asphalt, sma, micro-aspahlts, thin and high friction surfacings. At each site a friction survey was carried out as soon as possible after the surface was installed to determine their very early life skid resistance. At selected sites repeat friction surveys were carried out periodically to determine how skid resistance and other surfacing properties changed with trafficking. For example this assessed aggregate exposure with time, changes in texture to the effect of trafficking on the physical form of aggregate particles.

The sites were spread across Britain and Ireland so the number and frequency of the repeat surveys varied with geographical distance from the University of Ulster's Highway Engineering Laboratory near Belfast. The SMA site considered in this paper was close to the university and so was studied in depth. It was a busy roundabout at a motorway junction, and within a short distance the surfacing material was subjected to a wide range of in-service trafficking conditions such as cornering, braking, accelerating and slow moving slewing traffic.

4. VARIATION OF SMA SKID RESISTANCE WITH TIME

Figure 1 shows the variation in road surface skid resistance over the first 2 year period. Depending on the specific stress condition:

- The SMA appeared to be relatively unchanged with every aggregate particle still coated in bitumen.
- The bitumen coatings were removed showing exposed aggregate within defined wheel-paths.
- The aggregate showed severe rounding of its particle shape and there was loss of SMA texture depth.

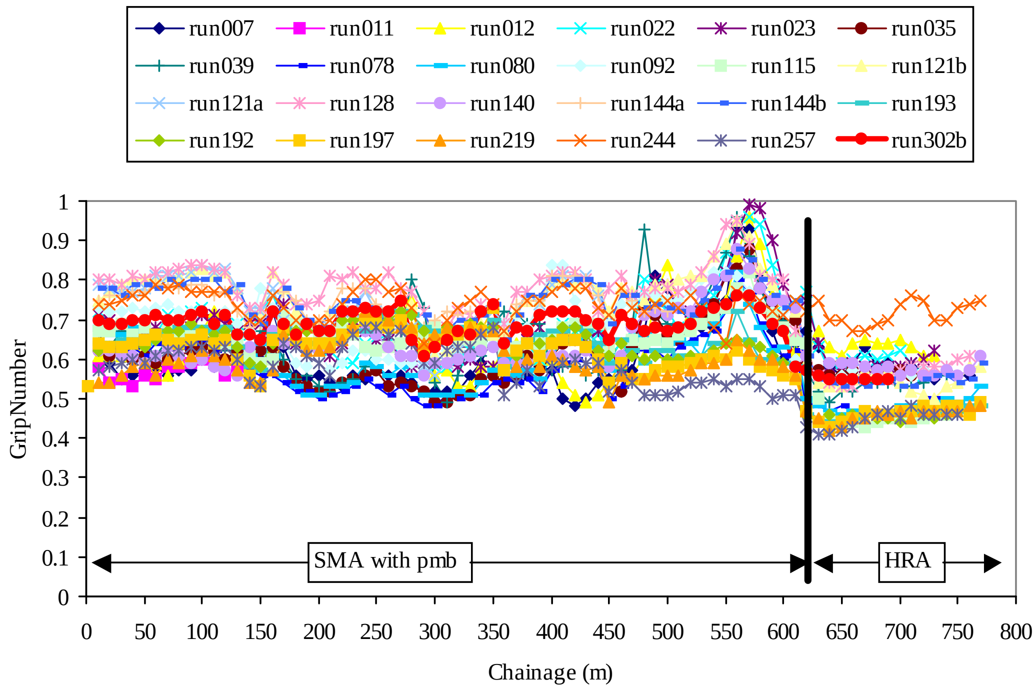

Figure 1 Variation in GripNumber for a roundabout surfaced in a modified SMA over a 2-year period from construction

Figure 1 illustrates the problem of predicting how an aggregate will perform in-service in terms of skid resistance. Depending on factors such as type of use, type of binder, environmental and trafficking conditions the aggregate may still remain coated with bitumen and choice of aggregate based on PSV may have been irrelevant resulting in over-specification. In contrast, an adjoining section of road may be showing signs of premature loss of performance characteristics.

5. DEVELOPMENT OF EARLY AND MID LIFE SKID RESISTANCE OF SMA

An important aspect of this research was to measure change and observe what happened to the different materials. Analysis of the data showed a range of different stages in the development of skid resistance from a very early life or infancy period. Figure 2 shows the change in skid resistance. The surface was laid in February 2001. It can be seen that its initial skid resistance was quite low and reduced further when initially trafficked. Thereafter there was a steady increase in GripNumber over the subsequent 12 months of testing. After 12 months heavy trafficking there was little aggregate exposed.

A model has been proposed to explain this early life phenomena for SMA i.e. drop followed by increase (Jellie et. al. 2004). Road surface observation and laboratory testing showed the bitumen coatings quickly became smoothed and it was this that probably explained the very early low values of friction. A secondary texture then started to develop on the surface of the bitumen coated aggregate particle as fine aggregate trapped in the SMA mastic coating become exposed due to the smoothing. The contact surface area of the coarse aggregate particles in the SMA was sometimes increased by mastic containing slightly larger fine aggregate. With increased traffic, eventual exposure of the aggregate surface contributed to this secondary texture. It is this developing secondary texture that results in the rapid increase in friction measured.

However, experience with sites has shown that if the mix is not properly designed or manufactured there may be the issue of early life wet skidding or dry bitu-planning problems. If there is too much bitumen, the secondary texture on the aggregate coating and on the exposed mastic may not develop. If there are insufficient surface voids and / or excess bitumen in the mix, trafficking smears the bitumen off the exposed surface and in-fills the voids leading to what may be a bitumen rich, slippery dangerous surface.

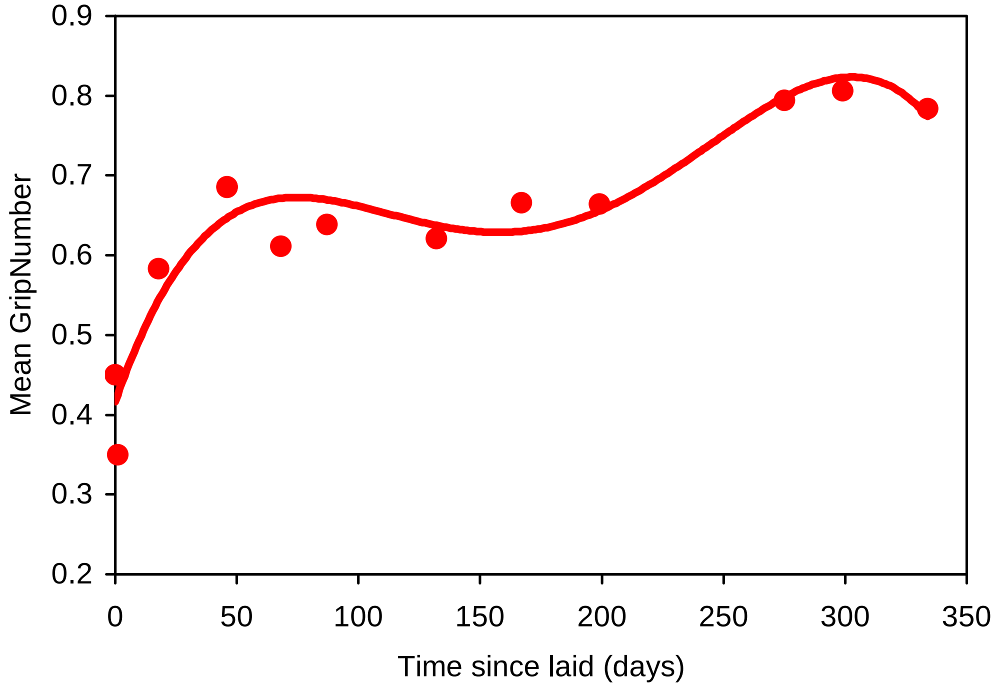

Figure 2 Change in GripNumber with time for a section of 14mm SMA

6. COMBINATIONS OF AGGREGATE AND BITUMEN

The SKIDGRIP project found that the combination of aggregate, bitumen, type of texture, trafficking and environmental conditions has a significant effect on the subsequent development of skid resistance during the early life of a highway surfacing. Skid resistance of the aggregate only becomes important as its surface is exposed. Some aggregates become exposed faster with water induced stripping appearing to be beneficial in terms of accelerating skid resistance. Reliance on the use of higher PSV does not ensure high skid resistance during early life. Rather, a lower PSV aggregate which strips quickly may perform similarly, and in some cases better, than a much higher PSV aggregate. Certain types may perform as well as a higher PSV aggregate under lesser trafficking stress conditions or when it is used in a smaller aggregate mix.

To ensure optimum levels of early life skid resistance, the research has shown that the aggregate / bitumen combination should be readily effected by the presence of water and strip. Or, it should be subjected to additional stressing that accelerates the removal of bitumen i.e. conditions such as heavy trafficking or higher levels of interfacial stressing.

7. THE EFFECT OF BITUMEN COATINGS ON EARLY LIFE SKID RESISTANCE

Different types of laboratory simulation were evaluated to consider the factors involved. One of these adapted the standard PSV test method equipment to simulate trafficking on PSV test specimens which had been coated with bitumen. Preliminary testing found that: Attempts to use pre-coated chippings were not successful, as the resin binder used in the manufacture of the test specimens could not hold them.

Painting each aggregate particle with heated bitumen offered the best solution to coating the aggregate particles. Testing without water produced a high carryover of bitumen giving erroneous results. Testing with emery caused the emery to become embedded in the bitumen, forming a false texture that increased apparent skid resistance. Testing with water alone offered the most promising results.

Each test specimen was first weighed and its wet unpolished skid resistance determined using the British Pendulum Tester to give a British Pendulum Number (BPN). Approximately 100ml of bitumen was heated so that it could be painted onto the surface of each aggregate particle. After cooling, the test specimens were again weighed to determine the weight of bitumen on its surface. The bitumen coated PSV test specimens were then trafficked with water applied at a rate of 30cc/min. The tests were stopped periodically to determine the percentage of exposed stones and to measure wet friction. After completing a test, each test specimen was weighed to determine the amount of bitumen removal.

Figure 3 shows the change in pendulum number for 7 aggregates coated with unmodified 200pen bitumen. Initially, there was fall during the first minutes probably due to initial smoothing of the bitumen rich surface. By 20 minutes all of the aggregates had attained approximately 75% of their maximum final value. Figure 4 shows the rate of bitumen removal from each aggregate. The rate of bitumen loss was quickest for the lower PSV igneous sources and slower for the higher PSV greywacke sources.

Figures 1 and 2 suggest that when coated with bitumen, gain of early life skid resistance is not simply related to PSV but rather to the rate of bitumen loss which in turn is related to rock type. In practical terms, lower PSV igneous rocks could perform similar to higher PSV aggregate during early life.

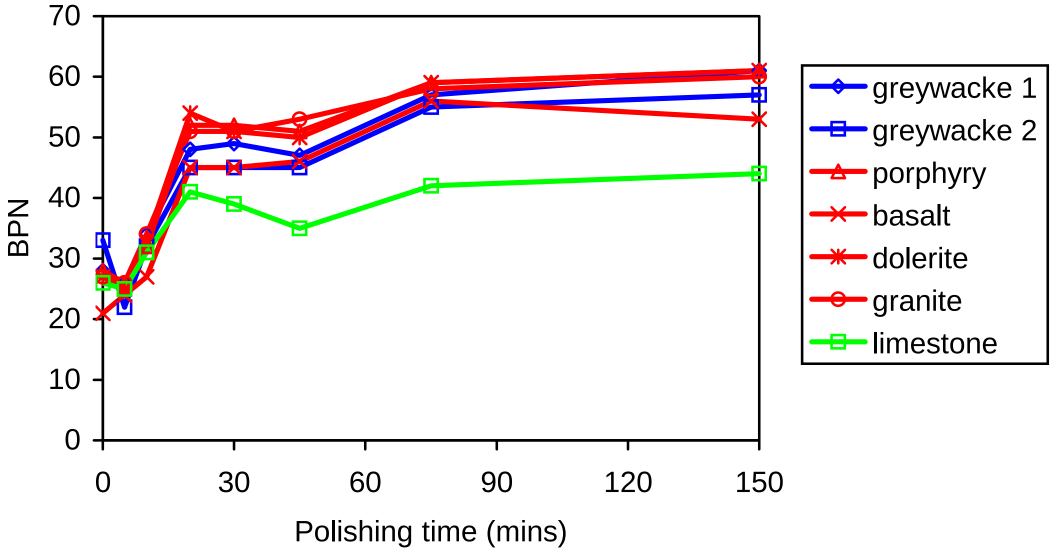

Figure 3 Change in skid resistance for different rock types (200pen bitumen

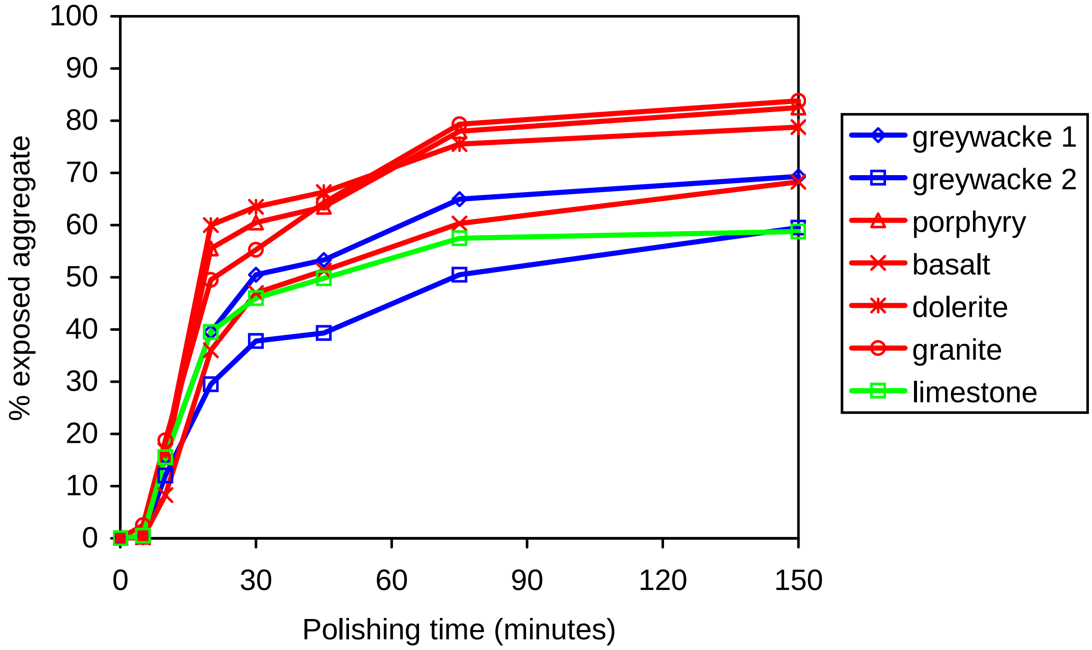

Figure 4 Exposure of aggregate during testing depending on rock type (200pen)

Observation of thin surfacing mixtures using polymer modified binders laid on straight sections of road showed that the aggregate remained coated for a longer period of time when compared to an unmodified binder. Figure 5 shows comparison of aggregate test specimens coated with 200pen and 100pen polymer modified binder. With the exception of a single aggregate, the BPN does not change for the polymer modified specimens.

After 11 hours testing there was still no aggregate exposed and no resulting increase in skid resistance. The one aggregate that increased was a lower PSV granite where water used during testing caused stripping quite early during testing so exposing the underlying aggregate. This simple laboratory investigation suggests that reliance on the use of high PSV may not result in high skid resistance during the early life of surfacings when using modified binders. When comparing surface mixes which use modified and unmodified bitumen, it was found that non-stressful trafficking will take longer to expose the aggregate. Such surfacings may pose a greater threat for bitu-planning during skidding related situations for a longer period of time.

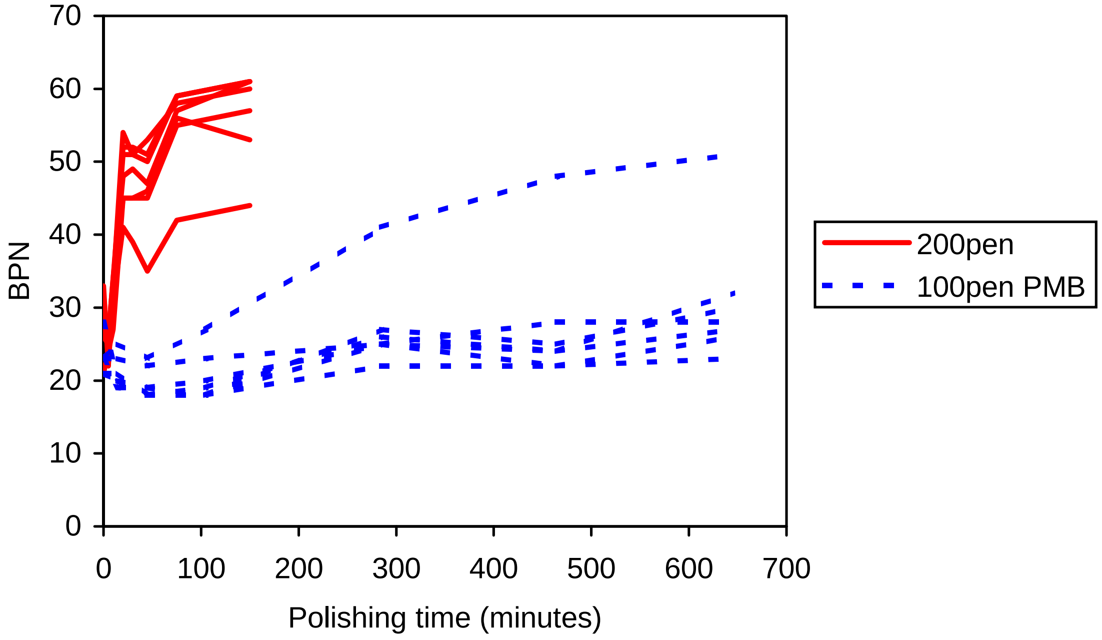

Figure 5 Comparison of change in BPN for a 200pen and 100pen polymer modified binder

8. CONCLUSIONS

This paper has considered the development of early life skid resistance measured on-site and in the laboratory. It highlights that there are complicated inter-relationships between many factors such as type of aggregate, bitumen, composition, surface texture, time of the year, road geometry and trafficking conditions. There are two basic types of asphalt surfacing. Those that are positive textured where the aggregate embeds into the tyre and the aggregate micro-texture is either exposed or becomes quickly exposed. Vehicle dynamics are applied to what is essentially a series of point loads leading to conventional polishing of the surface starting to take place relatively quickly.

The second type that have a smoother, negative or porous texture, where the aggregate does not embed into the tyre to the same degree e.g. SMA, Porous Asphalt, thin surfacings. Loading is spread over a greater area of thickly coated aggregate / matrix and it takes longer to wear away the bitumen and expose the aggregate. As there is less aggregate embedment so the contribution of hysterisis effects on friction may be reduced.

The research has found that the combination of aggregate and bitumen has a significant effect on skid resistance during their early life. Aggregate type is important for unmodified bitumen, particularly those with variable composition as the weaker / softer / unsound particles will loose their bitumen coatings faster.

Reliance on the use of higher PSV does not ensure high skid resistance during early life. Rather, a lower PSV aggregate which strips quickly may perform similarly, and in some cases better, than a much higher PSV aggregate.

These conclusions contradict all other properties required of a surfacing mix i.e. the development of good aggregate / bitumen bond to resist moisture induced loss of stiffness, cohesion and surface ravelling. Therefore, in terms of ensuring early life skid resistance, there is a balance between safety and durability which needs to be considered.

This paper has considered the expectation of highway materials to perform. The simple examples illustrate that it may be possible to better understand the process involved in the development of early life skid resistance. There is much more than reliance on PSV and texture depth when considering risk and predicting whether a carefully designed highway surface will be not only sustainable but safe for the user.

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