PREDICTING THE EARLY LIFE SKID RESISTANCE OF ASPHALT SURFACINGS

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Abstract

Safety is the most important responsibility of anyone involved in highway transportation. This applies at all stages from initial design, selection of materials to use of the highway by the user. However, it has been found that some aggregates perform better than expected whilst others give a lower in-service skid resistance. This is not unexpected as surfacing aggregate is now used in ways that were not considered in the development of skid resistance standards and specification recommendations that have been used as the basis for many countries throughout the world. Criteria such as noise, negative texture, spray generation, layer thickness, availability and cost of limited sources of high PSV aggregate have resulted in a shift towards thinner, smoother and quieter surfacings. To achieve higher performance these materials typically require the use of modified bitumen or have thicker coatings of bitumen to hold the aggregate particles together. Given that bitumen has poor wet skid resistance, the early life safety of such materials is an issue that needs consideration. The research outlined in this paper considers whether it is possible to develop predictive models that address this issue. A laboratory evaluation using a range of aggregate and bitumen types is detailed. It was decided to use the standard accelerated polishing apparatus used to determine PSV values. The research has shown the effect of rock type, bitumen type and test conditions such as the presence of water on the development of early life skid resistance of test samples in the laboratory. Road-trial data has been obtained from a range of asphalt surfacing types. These have been periodically assessed using a GripTester to assess how their skid resistance has developed from initial construction. The research has shown how the safety of new road surfacings may be better predicted so as to minimize risk to the user whilst helping to improve the performance of asphalt road surfacings.

1. Introduction

The United Kingdom has undergone considerable change in the types of asphalt materials used to surface its highway network during the last few years. All new and re-surfaced highway surfacings are now expected to provide a level of performance that meets the demand of the highway user. This expectation of performance covers a broad range of requirements:

1. Wet skid resistance to improve road safety
2. Resistance to permanent deformation
3. Resistance to cracking
4. Low noise generation
5. Low spray generation when wet
6. Minimise use of high quality surfacing aggregate and bituminous binders
7. Use sustainable technologies and be recyclable

In response, the UK highway industry has responded with new and innovative materials that are being designed to provide higher levels of performance. This has seen an almost total change from the traditional use of hot rolled asphalt and 20mm chips to give texture and skid resistance, to smooth, thinner surfacings with a negative or porous texture. New materials typically utilise the high stone content properties of SMA to achieve resistance to permanent deformation. Their surface is therefore smoother resulting in improved rolling resistance and less road noise. They are typically less than 40mmin thickness and so use less high quality aggregates.

However, because of the large percentage of coarse aggregate used to ensure the necessary negative or porous texture these mixtures need their bitumen to be modified by the use of cellulose fibres to create a thicker binder film thickness, use some form of polymer modification, or both. The result is a smoother surface where the aggregate is coated with either a thicker coating of bitumen or one with a better bond. This is a fundamental change in the type of surfacing material i.e. from positive textured surfacings such as HRA towards smoother negatively textured thin surfacings.

The research detailed in this paper forms the latest in a series of related studies at the University of Ulster relating the phenomena that occur at tyre / highway surface interface i.e. within the contact patch (1 - 5). This particular research project is known as SKIDGRIP and aims 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 project. To compliment the laboratory testing, sites were selected across the British Isles where these were used. Their early life skid resistance was measured periodically using a GripTester to determine whether this changed with time.

2. UK importance on wet skid resistance and safety

In the UK the Mean Summer SCRIM Coefficient (MSSC) is used as the basis for a national skid resistance specification (6). Below a certain limit of MSSC the risk of a skidding related accident for a given location is such as to warrant resurfacing to renew skid resistance to an appropriate higher level. Research in the early 1950's (7) developed what is now known as the Polish Stone Value (PSV) test method to measure the skid resistance of aggregate. The method is now Euro Norm to measure skid resistance (8). The method simulates a period of trafficking although the values obtained simply rank one aggregate in relation to another. Of the many aggregate types available, those belonging to the gritstone grouping give the highest values of PSV. As a result, the majority of heavily trafficked roads in the UK are surfaced using this single type of aggregate. Correlation by Szatkowski and Hosking (9) of aggregate PSV, road surface MSSC and expected traffic level in terms of commercial vehicles per lane per day (CVD) established a formula which was used as the basis for a standard for construction of new roads (Design Manual for Roads and Bridges). Another property specified is that of texture depth. This, coupled with high specification requirements for skid resistance, has had a profound influence on the types of surfacing material that can be used in the UK. The need for a minimum texture depth of 1.5mm prior to trafficking meant that the majority of highways in the UK were traditionally surfaced with HRA and 20mm high PSV gritstone chippings. This formed the basis for the correlations upon which the national specification requirements are based.

Recently, there has been concern as to the ability of the original relationships to predict the skid resistance achieved of a road surfacing (10). Some aggregates appear to perform better than expected whilst others give lower in-service skid resistance (11). It is suggested that the complex inter-relationships between aggregate properties, texture depth, type of surface texture (whether positive or negative), tyre / aggregate interaction, ability to remove surface water may be different for the new, smoother surfaced highways in comparison to those of HRA upon which the existing specifications are based. These concerns have prompted renewed interest in the measurement and prediction of skid resistance in the laboratory. The SKIDGRIP project has allowed the University of Ulster to build upon previous experiences in areas such as the influence of other aggregate properties on skid resistance, dynamic contact stressing to understanding what happens within the contact patch.

3. Observation of new asphalt surfacings

Development of the new test method was based on observation of visual changes in the different surfacings selected for on-site measurement using the GripTester. This has provided a valuable insight into the processes involved and the means whereby laboratory based simulated testing can be improved. There are complicated inter-relationships between factors such as type of aggregate, bitumen, composition, surface texture, time of year and site location. Observation of different types of surfacing and onsite conditions showed this to be true. The high PSV aggregate being used was being exposed at different rates and appeared to be influencing the GripTester data being obtained. For example, the aggregate surface of newly laid 20mm chips in HRA was typically quickly exposed. In comparison, thin surfacings remained elatively unchanged with little exposure of aggregate. Clearly the issue of surface texture was having an influence. The action of lightly coated aggregates (as in 20mm chippings in hra) were subject to hysterisis effects where the aggregate was embedding into the rubber of the tyre. This embedment quickly wears away the binder coating exposing the aggregate. However, this may also make the aggregate more prone to becoming polished. With a smooth surfaced SMA for example, there is not the same degree of hysteresis effect and so is less effective in exposing the aggregate micro-texture.

4. Development of simulation test methods

Different types of laboratory simulation have been 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:

1. 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.
2. Painting each aggregate particle with heated bitumen offered the best solution to coating the aggregate particles.
3. Testing without water produced a high “carryover” of bitumen giving erroneous results.
4. Testing with emery caused the emery to become embedded in the bitumen, forming a false texture that increased apparent skid resistance.
5. 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.

5. Predicting the effect of bitumen on early life skid resistance

Figure 1 shows the change in BPN for 7 different types of aggregate coated with unmodified 200pen bitumen subjected to accelerated polishing. Initially, there was fall during the first minutes of testing probably to initial levelling of the bitumen rich surface. By 20 minutes all of the aggregates had attained at 75% of their maximum BPN.

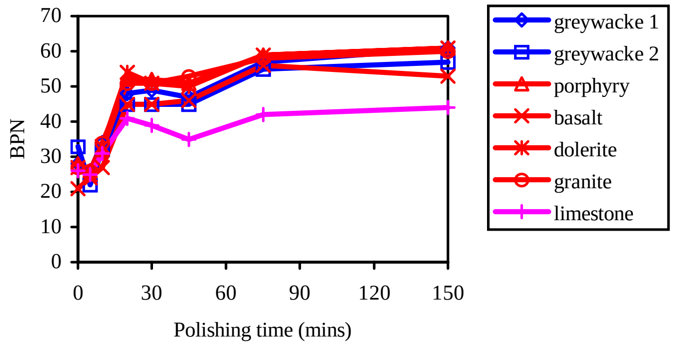

Figure 1 Change in skid resistance during testing depending on rock type (200pen bitumen

Figure 2 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 shows a typical plot of increasing BPN as the greywacke aggregate becomes exposed. 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 3 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 the water used during testing caused stripping to occur 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.

6. Onsite measurement of early life skid resistance

The SKIDGRIP project is monitoring the development of early life skid resistance of newly laid asphalt surfacings. A wide selection of sites located around the United Kingdom have been assessed using a GripTester. The GripTester is a three-wheeled portable trailer, which measures friction using the braked wheel, fixed slip principle. A gearing ratio between the drive wheel axle and measuring wheel axle induces braking and generates 15% slip in the measuring wheel. The load and drag on the measuring wheel allows the friction co-efficient (load/drag), referred to as GripNumber, to be calculated every 10m.

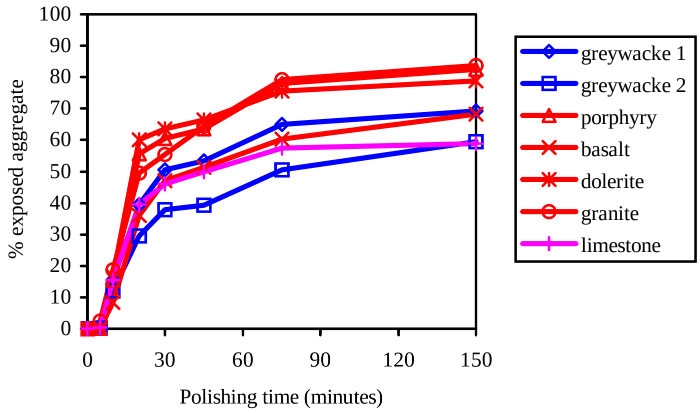

Figure 2 Exposure of aggregate during testing depending on rock type (200pen)

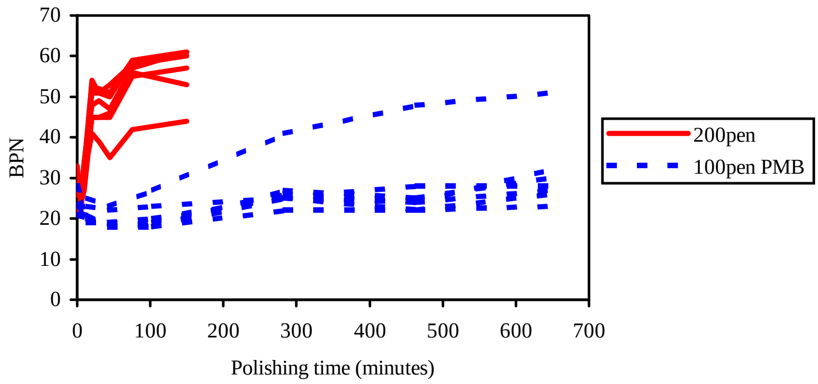

Figure 3 Comparison of change in BPN for a 200pen and 100pen polymer modified binder

All standard testing was carried out on dry roads at a speed of 50km/h. A water deposition rate of 10.4 litres per minute in front of the measuring tyre gave a theoretical water film thickness of 0.25mm as recommended for testing roads. Figure 4 gives an example of data obtained for a heavily trafficked section of SMA with a polymer modified binder and high PSV 14mm gritstone coarse aggregate. 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. It should be pointed out that even after 12 months heavy trafficking there is little aggregate exposed.

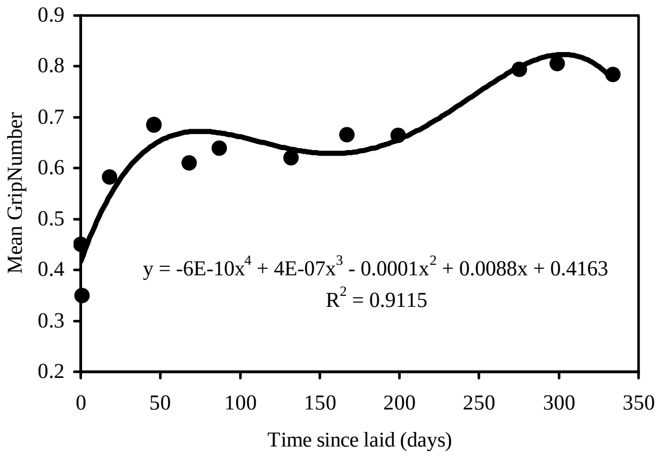

Figure 4 Change in GripNumber with time for a section of 14mm SMA

7. Discussion

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 many important issues that need to be addressed in order to improve understanding of the forces / stresses within the contact patch. It may be possible to split most types of asphalt surfacings into 2 groups based on their texture. Those that are positive textured where the aggregate embeds into the tyre rubber – surface dressing, hot rolled asphalt. In this type the aggregate is quickly exposed and conventional polishing of the surface results. The second type have a smooth or negative texture where the aggregate does not embed into the rubber as much – SMA, Porous Asphalt, thin surfacings. In this type the loading is spread over a greater area of thickly coated aggregate / matrix and takes longer to wear away the bitumen and expose the aggregate. The coarse aggregate does not embed into the tyre and so the contribution of hysterisis effects on friction is reduced. During their early life, severe braking may result in bitu-planning as the bitumen softens and act as a lubricant.

8. Conclusions

The research covered in this paper has implications in the design and specification of highway surfacings. The combination of aggregate and bitumen has a significant effect on skid resistance during the early life of aspahlt surfacing materials. The type of aggregate is important, as this appears to control the value of wet skid resistance as it becomes exposed. The presence of water is a key factor as some aggregates become exposed faster i.e. water induced stripping appears to be beneficial in terms of improving skid resistance. Reliance on the use of high PSV may not ensure high skid resistance during the early life. Rather, a lower PSV aggregate which strips quickly may perform similarly, and in some cases better, than a much higher PSV aggregate. 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. However, these conclusions contradict other properties of a surfacing mix i.e. good aggregate / bitumen bond to resist moisture induced failures such as 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.

9. References

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