Performance Grading (PG) of Recycled Tire Rubber (RTR) Binders with Rubber Particles Smaller and Larger Than 30 Mesh and Using RTR in Place of, or in Combination with, Polymer to Provide a High Quality PG Binder

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In the 1990's a new binder specification was introduced, this was the Superpave binder specification. The Superpave binder specification is based on the rheological properties of the asphalt binder measured over a wide range of temperatures and aging conditions. Various pieces of equipment are used to measure stress strain relationships in the binder at the specified test temperatures. This equipment includes the Dynamic Shear Rheometer (DSR) and Bending Beam Rheometer (BBR). Measuring the binders' rheological properties over a wide range of temperatures, loading conditions, and aging conditions allows performance relationships to be established between the test results and the pavement. The details of this asphalt binder testing are described in the American Association State Highway and Transportation Officials AASHTO Specification (AASHTO) M 320.

The use of polymer modified asphalt binders has grown tremendously in the United States. This is due primarily to the increased stress on the highways from higher traffic volumes and heavier loads. The growth can also be attributed to the new Superpave specifications, which provide a procedure to evaluate the performance characteristics of the polymer modified binder. This allows the highway agencies some assurance in the quality and consistency of the binder. Currently almost 20% of the asphalt binder sold in the US for paving is polymer modified.

Scrap tire rubber, also known as recycled tire rubber (RTR), has been used since the 1960's to modify asphalt binder. Uses have included stress absorbing membranes, inter-layers, crack seals, hot mix asphalt, and open graded friction courses. RTR binder has also been used to address the issue of increased traffic and heavier loading. Historically the specifications for RTR binder in most of these applications have been recipe or method type. Method specifications describe very specific processes and amounts of material to produce a specific product. In many cases where contractors have experience with these specifications good performance is achieved. However, this makes transfer of these processes and specifications difficult from one location to another and increases the potential for failures. These issues make highway agencies very reluctant to try RTR technology.

Given the current economics with higher costs for materials highway agencies are looking for alternatives to the typical polymer modified binder systems such as Styrene Butadiene Styrene (SBS). Polymer modified binders, such as Superpave PG 76-22, have been used extensively on high volume highways to improve rutting and cracking performance. RTR binders have been used to provide this same type of improved performance. The issue with polymer modifiers such as SBS is that they are subject to supply demands and chemical production variations that can lead to supply shortages and higher costs. Scrap tire rubber for RTR modifieris in plentiful supply with a relatively stable cost which is attractive for use to produce improved binders. The biggest question is performance testing of the RTR binders to evaluate its properties.

Test procedures of a somewhat crude nature have been used to provide for field quality control for the various RTR binder processes. The primary device is the hand held rotational viscometer. This can provide some indication of viscosity increase from the addition and blending of rubber into the binder but has high variability. Some preliminary binder testing has been done using the Superpave binder tests on RTR binder but this has been limited to RTR sizes that can be handled in the 1 or 2 mm gap using DSR parallel plate geometries typically 30 mesh material or smaller. Figure 1 shows a comparison of a typical SBS modified PG 76-22 compared to a RTR PG 76-22. It can be clearly seen that the RTR PG 76-22 can meet all the binder requirements of the PG specification. These studies did show the increase in modulus of the binder with the addition of the RTR and that the size, percentage of rubber and base asphalt all had an effect on the binder properties.

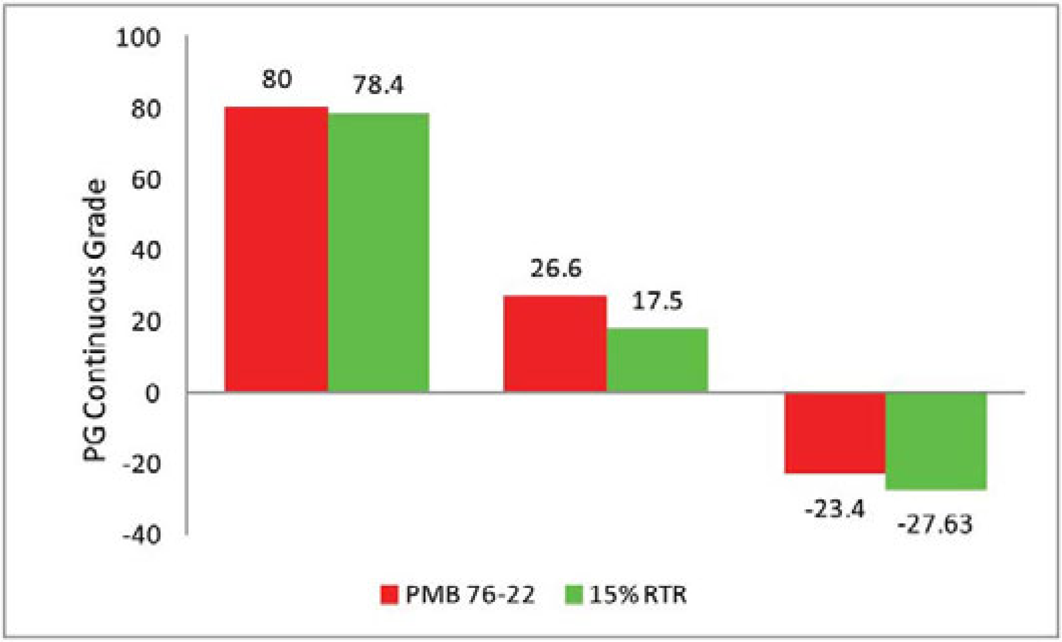

Figure 1. *Comparison of the grading of a typical SBS polymer modified binder to a RTR binder.*

However, to address RTR in general use, which comes in many different sizes, the most typical size is larger than 30 mesh, thus new approaches to testing are needed. This requires testing of the binder with larger particle sizes using geometries with larger gaps.

Many studies have shown that the RTR size, shape, mixing temperature and asphalt binder will all affect the final properties of the RTR binder. Without a well-defined binder specification adoption of the use of RTR binder by the US highway agencies will be almost impossible to achieve. Test procedures that can evaluate the performance characteristics of RTR binder are crucially needed.

Performing PG testing on RTR binders with larger particles will require using new geometries that will provide larger gap sizes that can accommodate those particle sizes. Rubber particles may range in size from 0.5 mm up to over 1 mm in size.

A 1 mm particle tested in a DSR with 1 mm gap parallel plate geometry would be touching both top and bottom plates at the same time so that test results would represent the rubber particle not a rubber modified binder. One approach that has been used in the food industries has been testing with concentric cylinder geometries. DSR's currently used for asphalt testing can be adapted to use a Searle system. This system is one where the center cylinder or bob rotates and the outside cylinder or cup is stationary.

This type of system can perform all the same type of testing that is currently used for asphalt binder grading. The advantage is that the cup and bob geometry can easily handle larger gaps up to 4 to 7 mm and therefore larger RTR particles. One disadvantage of the system is that it does require a much larger sample for testing. Graphics and pictures of the geometry are shown in Figure 2.

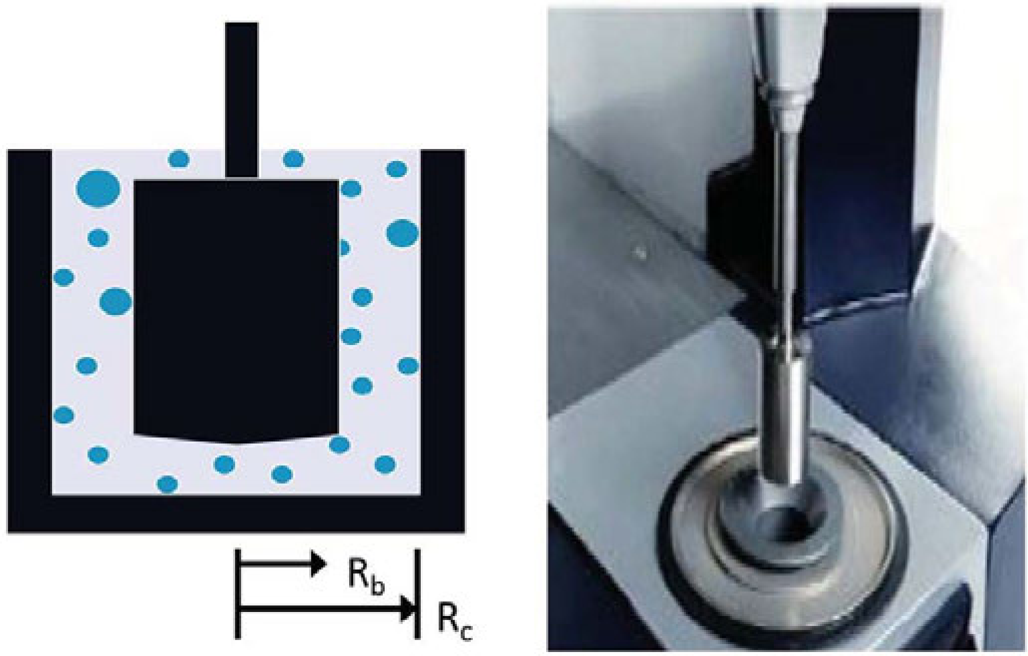

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Figure 2. *a) Graphic showing the bob submerged into the cup with RTR binder. b) Photograph of a cup and bob geometry with the bob extended above the cup.*

The Bending Beam Rheometer (BBR) is another primary piece of testing equipment used in the Superpave PG grading system. The BBR is used to measure the low temperature stiffness and relaxation properties of the binder. The testing is done on a beam of asphalt binder 6.4 X 12.7 X 127 mm. Since the beam has a cross section of 6.4 X 12.7 mm it can actually accommodate RTR particles of about 1 mm. Because of this size, no changes should be needed to test RTR binder in the BBR with the larger particle sizes.

Initial testing of the new DSR testing geometry to the existing 1 and 2 mm gape parallel plate geometry has shown that equivalent results can be obtained. The testing was done on both neat and RTR binders. PG testing of the RTR binders clearly shows the changes that occur to the base 64-22 with RTR size and percentage.

Figure 3 shows the comparison using the different geometries of the complete continuous grading of a base PG 64-22 binder to the base plus 10% 60 mesh blend. The 10% 60 mesh RTR increases the high temperature stiffness of the PG 64 to a PG 70. The addition of the RTR also lowers the intermediate DSR stiffness and BBR low temperature properties.

The 10 % 60 mesh RTR changed the PAV DSR continuous grade from 24.6^{o}C down to 20.4^{o}C. The addition of the RTR also lowered the low temperature continuous determined from the BBR from -22 to -25.5^{o}C. The testing demonstrated that results are equivalent for the different geometries and the improvement in properties with the addition of RTR.

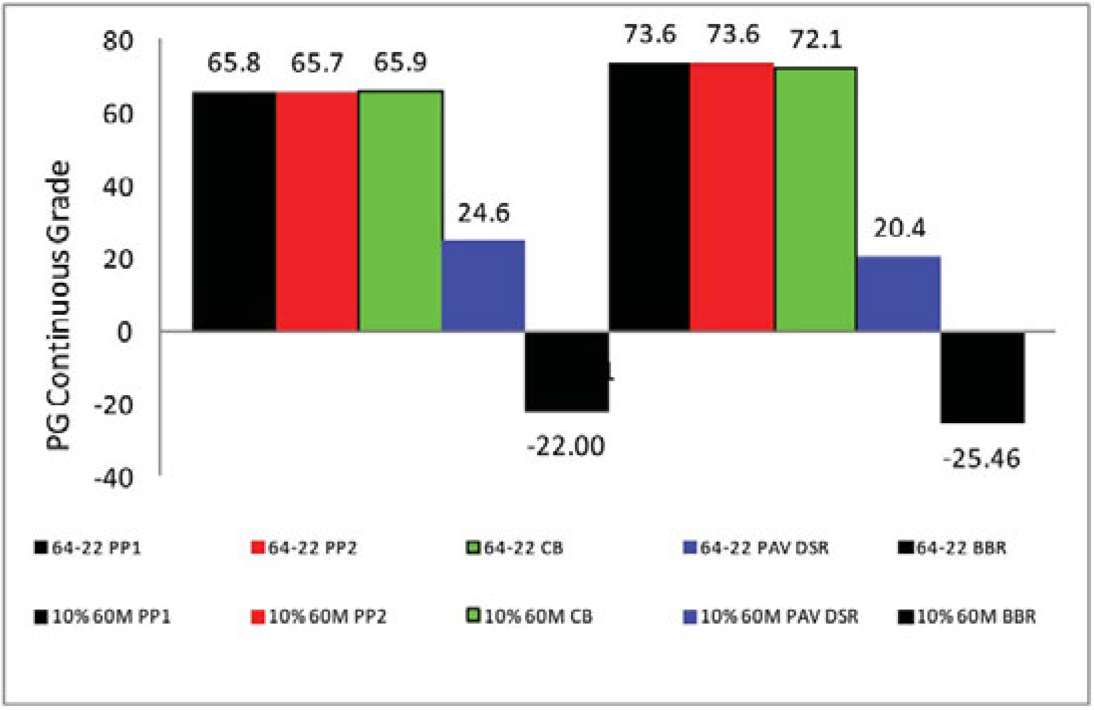

Figure 3. *Bar graph of the continuous PG grading of the base 64-22 and base + 10% 60 mesh RTR.*

Preliminary testing with the new geometry has shown that it will provide the same results as the standard parallel plate geometry in the DSR. Both course and fine ground RTR were evaluated and provide improvements in the properties of the binder.

Using the new geometry for the DSR and the BBR, RTR binders even with larger crumb size can be evaluated using the Superpave binder specification. This allows for direct comparisons of polymer modified binders to RTR binders.

History has demonstrated RTR binders will perform well in rutting and cracking. Using the new testing techniques, RTR binders can be compared directly to the polymer modified binders. This clearly demonstrates that RTR can be used in place of or in combination with polymer to provide a high quality performance graded, (PG) binder.

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