MODOT USING OF RECYCLED ASPHALT SHINGLES IN PAVEMENTS

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ABSTRACT

In recent years, the Missouri Department of Transportation (MoDOT) has allowed contractors to put used shingles that have been removed from rooftops into their asphalt mix. The result is very durable, more-rut resistant asphalt at a lower price.

MoDOT embraces new ideas that not only help become a more cost-efficient agency, but a more environmentally friendly one, too. By recycling asphalt shingles, they are kept out of landfills, petroleum resources are preserved and construction costs are lowered while maintaining high quality asphalt pavement. The use of recycled shingles can save $3 to $5 per ton of asphalt. Considering a typical resurfacing project would use about 30,000 tons, the savings could be $90,000 to $150,000.

Shingle recycling also helps MoDOT reduce the amount of petroleum it uses in its road construction program. By using reclaimed asphalt shingles, MoDOT reduces the amount of liquid asphalt in a mix design by 20 to 25 percent. MoDOT has incorporated a variety of waste materials on roadways. However, Missouri is on the leading edge nationally for its efforts to reuse roofing shingles. MoDOT is working with other agencies and organizations nationally to refine the specifications for the use of asphalt shingles in hot mix asphalt.

1. OVERVIEW

In 2002, the Missouri Department of Transportation (MoDOT) received a request by Pace Construction in St. Louis, MO to use reclaimed asphalt shingles (RAS) from tear-off shingles in hot mix asphalt (HMA). An investigation was begun of national and other state specifications to find if others were using shingles in this manner. While shingles had been in use in other states, it was found that tear-off shingles were specifically prohibited by specification or environmental laws in those states. In December 2004, Pace invited MoDOT to observe and test a mixture from a project at their plant site. Based on favorable volumetric and stripping test results, a pilot project was placed on Rte. 61/67 in St. Louis County in 2005. A specification to allow RAS in all HMA mixtures using a non-modified asphalt binder (PG 64-22) was incorporated into the Missouri Standard Specifications in February 2008 as a result of this pilot and additional testing by MoDOT and other agencies.

The primary MoDOT concerns from adding tear-off shingles to HMA have been demolition debris and resistance of the mixture to fatigue and cold weather cracking due the shingle binder being much stiffer than roadway asphalts. By limiting the amount of RAS in a mixture, the effect of both of these can be somewhat offset. Originally, the deleterious material content was limited to 0.5%. The limit was raised to 3.0% based on demolition material that was picked as cleanly as was practical. Wood may only be one-half of this quantity. The small percentage of shingles allowed in mixtures still keeps the deleterious material added by the shingles much lower than allowed in the aggregates. In general, nails are rarely included in this material because the processors effectively remove them.

Binders from the tear-off shingles, new shingles and roadway were blended to determine the performance grading (PG). When greater than 70 percent roadway or virgin asphalt was added to the blend, the low temperature grading was not greatly affected by the shingle asphalt. The shingle asphalt affected the blend more rapidly as the percentage of virgin asphalt decreased below 70 percent. Additional testing of the mixture will be required to determine the actual effect in the mixture. Until this testing is complete, PG 58-28 will be required in mixtures designed for PG 64-22 with less than 70 percent virgin binder. Mixtures requiring a polymer modified binder may not use shingles due to a lack of information at this point.

Fourteen contractors are currently using mixtures that include shingles from tear-offs or manufacturing waste. Seventeen contractors and recycling companies are processing the shingles for use in HMA. The Missouri Department of Natural Resources (MoDNR) allows them to process the shingles under the National Emissions Standards for Hazardous Air Pollutants (NESHAP) rules which do not require asbestos testing as long as the shingles are from residential demolition. Some testing has been required by the St. Louis County Health Department.

Changes made for the 2008 construction season allowed increased use of RAS. The maximum amount was raised from 5 percent to 7 percent. By using the 70 percent limit for virgin binder, mixtures may contain shingles closer to the maximum amount without changing the grade of binder. Also, a standard gradation for shingle aggregates is included to reduce exposure of laboratory technicians to the high levels of dust after removal of the asphalt binder and any potential asbestos fibers. Twenty percent of the projects in 2008 used mixtures containing RAS. The number of projects increased to 49 percent in 2010. The average amount of RAS used in mixtures during 2010 was 4.1 percent. Figure 1 demonstrates the increased rate of use for RAS. The MoDNR estimates 146,500 tons

(132,900 metric tons) of shingles annually are placed in landfills in Missouri. Mixtures placed by contractors in 2010 including their private and commercial work consumed over 115, 000 tons (104,326 metric tons) of RAS.

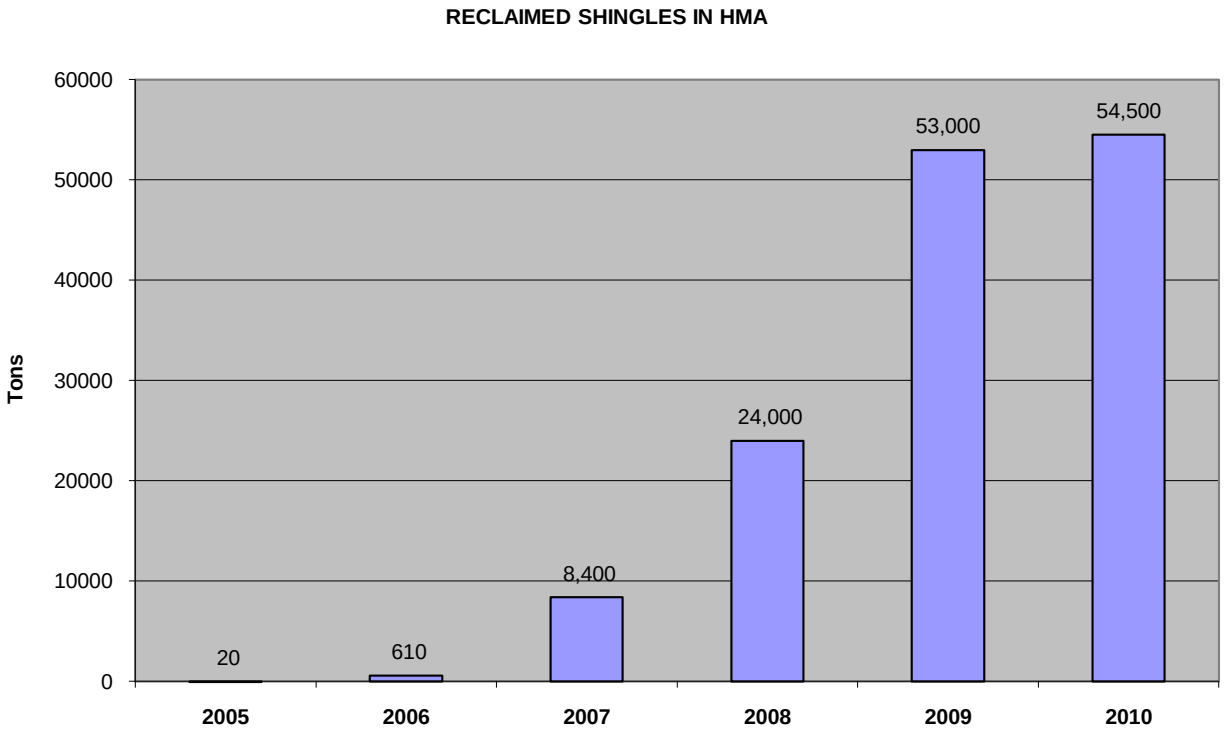

Figure 1 – RAS Use in MoDOT Mixtures

2. DISCUSSION

Landfills are filling up not only with garbage but material from construction and demolition projects. With landfill permitting becoming more difficult and expensive, owners are shifting their focus from disposing of everything to reclaiming materials for reuse or new uses. A particular problem with landfilling asphalt shingles is that if they are not properly dispersed, they can form an impenetrable layer that will trap methane gas. One solution is to remove the shingles from the waste stream.

On December 12, 2002 Roger Brown of Pace Construction, St. Louis, Dale Ann Behnen of Peerless Resource Recovery, Valley Park, and Dan Fester of the Missouri Department of Natural Resources (MoDNR) made a presentation to MoDOT personnel about the possible use of RAS in HMA mixtures. First impressions on the use of the material were not favorable. The sample of ground shingles had a large amount of material considered deleterious such as wood, plastic, fiberboard and insulation. Roger also had specimens of HMA made in one of Pace's plants where 20 percent of the aggregate portion was replaced by RAS. The specimen had the appearance of one that had been lying in the sun for a considerable time. Dan stated that some asbestos testing had been completed with negligible results and that MoDNR's opinion was that as long as proper monitoring of the material is performed, asbestos would be of no consequence. They were informed that MoDOT would look into the use of RAS.

Swift Asphalt, at their plant in Joplin, Missouri, has used manufacturing waste in their commercial mixtures for a number of years. There are no known complaints of poor

performance from these mixtures; however, there has been no documentation of performance.

Asphalt shingles typically are manufactured with approximations of the following ingredients: 20 percent asphalt, 15 percent fiberglass or organic matting, 25 percent mineral filler and 40 percent granules. Post-consumer or tear-off shingles have lost granules during their life on the roof resulting in a content of typically 30 percent asphalt. The asphalt in shingles has the same origins as the asphalt used in roadways. However it has been stiffened in order to perform differently in the shingles. More discussion on this issue is to follow. The aggregates used for the granules are generally harder than those used in Missouri in HMA, therefore beneficial to the mixture. Neither mineral filler nor matting will have any detrimental effects to HMA.

A search of other state's construction specifications showed some states allowed the use of manufacturing waste but were explicit in disallowing tear-off shingles. North Carolina was the only exception but when the DOT was contacted they indicated that none of their contractors used the tear-offs. Later it was discovered that the testing frequencies mandated by the North Carolina Department of Environment, Health and Natural Resources were too stringent to make recycling economically feasible.

The primary concerns with RAS in HMA are the hardness of the asphalt, deleterious material and the potential presence of asbestos. Roadway asphalts are generally soft in comparison to the asphalt used in shingles. These asphalts have to be stiff enough to resist pavement rutting in the summer months but soft enough to resist fatigue cracking due to repeated loading as well as cracking due to cold weather shrinkage of the pavement. Deleterious material may degrade the performance of the pavement or increase moisture damage in the mixture. Nails in tear-off shingles are removed by using a magnetic head pulley on the conveyer during the grinding operation. Complete removal of the nails can be attained by using multiple passes over the magnetic pulley. While asbestos was an initial concern, this is an issue that has been put to rest in Missouri.

For clarification in the remainder of this document, these terms will be defined:
Other Foreign Material – Deleterious material that is not inherent to the aggregate or RAS. In a demolition project, this may include any building material where in a re-roofing project it is most likely packaging, plywood, bush trimmings and other trash generated on the work site. A typical specification for other foreign material in asphalt aggregate is a maximum of 0.5 percent, which is MoDOT's specification. Nails are to be included as deleterious material.

Figure 2 – Deleterious Material

Binder – Asphalt in a mixture is referred to as binder since it binds the components together. Roadway binders are classified by performance grade (PG), which describes the high and low temperature operating temperature in degrees Celsius. Missouri's standard paving grade of PG 64-22, sixty-four minus twenty-two, should perform well over a range from 64C to -22C. The high temperature allows for stiffness to minimize rutting during hot weather. The low temperature allows for flexibility in cold weather to minimize cracking. The PG grade is changed in increments of 6C. Heavier traffic creates more potential for rutting. A stiffer binder is specified by raising the high temperature grade in order to offset the increased traffic loading. Therefore, interstate highways are paved with PG 76-22 which is the stiffest binder specified for Missouri's highways. To demonstrate the difference in hardness between a roadway binder and shingle binder, pictures were taken of the two binders side by side. A ball of PG 76-22 was rolled up and set beside the shingle binder as it was originally when poured 4 years ago. As can be seen in Figures 3 through 5, the shingle binder has retained its shape while the roadway binder flattened out in a relatively short time frame.

Figure 3

Figure 4

Figure 5

In order to understand the properties of the binders after mixing in the plant, several different grades of roadway binder were blended with the shingle binder to PG grade. The binder from tear-off shingles was obtained by chemical extraction. Binder representing shingle waste was donated by TAMKO Building Products, Inc. in Joplin, Missouri. This is called flux in the roofing industry. The material was obtained prior to incorporation into the shingle manufacturing process. Roadway paving binders blended with the shingle binder were provided by Conoco Phillips Company, Wood River, IL and Ergon Asphalt and Emulsions, Kansas City, MO. Since it was known that the shingle binder is much harder than a roadway binder, blending was performed using softer PG grades than the standard PG 64-22 since the goal was to maintain the -22 grading. The tear-off binder was so hard in fact; a cheese grater had to be used to get the binders to properly blend. A summary of the true grade (degrees Celsius) determined for each binder and blend is shown in Table 1.

Table 1 – Binder Grading Temperatures °C

			Percent Virgin Binder in Blend								Shingle Binder			
PG Grade	**Binder**		**80%**		**60%**		**40%**		**20%**		**Tear-off**		**Flux**	
58-22	59	-28	73	-25	108	-17	105	-1	123	+8	143	*		
52-28	56	-31	64	-28	80	-19	99	-4	126	*	143	*		
58-28	60	-30	73	-24	78	-14	107	+2	123	+43	143	*		
58-28	60	-30	68	-22	79	-16	86	-10	98	-4			116	+8

* indicates temperature above testing limits.

Low temperature cracking remained the primary concern after evaluating the results of the blending. The true grade determined for the shingle binders were above 0C (32F.) The tear-off binder results were higher than could be determined by the equipment. Blending with the flux, new shingle binder, was fairly linear through the range of normal use. It was noted that the effect of the tear-off binder increased at the same rate as the flux at higher

percentages of virgin binder. Between 60 and 80 percent virgin binder, the tear-off binder began to take control of the low temperature properties as seen in Figure 6.

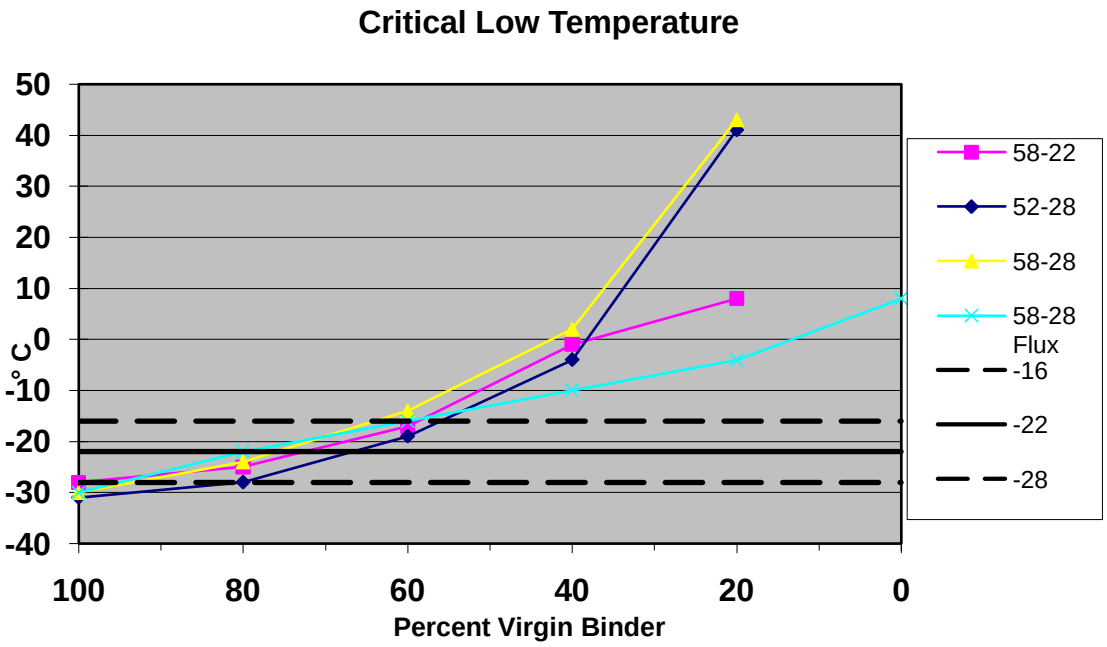

Figure 6 – Binder Blending

Pace Construction set up a demonstration at their plant location known Bussen Quarry at Antire, Missouri in December of 2004. Pace was paving the roadway into the quarry, which is in the St. Louis commercial hauling area which has a 120,000 lb.(54,431 kg) weight limit. The ground shingles used for the trial were tear-offs processed at Peerless. Peerless had collected the shingles as part of the construction and demolition landfill at their location. They had been handpicked to remove as much of the other foreign material (OFM) as possible and be cost effective. Initial samples contained approximately 10 percent but the amount was reduced below 3 percent. Roger Brown had set up the demonstration to show that the OFM would have no deleterious effects in the mixture. Also, he wanted to see how the mixture performed using the standard PG 64-22 instead of using a softer grade. The mixtures used for the demonstration were 12.5 mm and 19.0 mm nominal maximum aggregate size (MoDOT SP125 and SP190) Superpave designs with 5 percent RAS. Four inches (100 mm) of SP190 and 2 inches (50 mm) of SP125 were placed. There were no visible differences noticed during production and placement. Normal volumetric tests revealed no difference, as did moisture susceptibility testing by AASHTO T 283. The RAS contained pieces of plywood up to 2 inches (50 mm) long and ½ inch (13 mm) wide. The only evidence of the wood found in loose mix samples were basically splinters approximately ¼ inch (6 mm) long. A visual examination of the roadway in the fall of 2008 revealed no distress in the roadway.

Pace Construction Demonstration

Based on a successful demonstration by Pace Construction and use by other agencies, a material special provision was prepared for use by contractors. The primary difference between MoDOT and other agency specifications was that no distinction was made between tear-off and manufacturing waste. The RAS had a limit of 5 percent whether used in the mixture as the only reclaimed asphalt or in conjunction with RAP (Reclaimed Asphalt Pavement). When added with RAP, the limit of RAP is reduced by the amount of RAS before additional binder tests are required to determine the virgin binder grade. The maximum deleterious content for OFM was set at 3.0 percent with a limit of one-half of that amount being wood. Asbestos had no restrictions other than those by other regulatory agencies. Also when considering a 5 to 10 percent RAS allowance in HMA, the maximum amount of deleterious contributed by the shingle would only be 0.3 percent which is below the 0.5 percent allowed in the aggregate. Using data from binder blending, RAS in HMA required PG 58-28 as the virgin binder.

Softer asphalt grades are generally unavailable in the St. Louis area or have a higher cost removing the incentive to use RAS. Roger Brown requested substituting shingle mixtures for some of the binder course, SP190 containing PG 70-22, on Rte. 61/67 or Lindbergh Boulevard in St. Louis. He wanted to see if there were any performance differences in using PG 64-22 as opposed to the PG 58-28 required in the special provision. In August of 2005 a trial was set to look at the combinations shown in Table 2 with the remainder of the project as control using 20 percent RAP and the PG 70-22.

Table 2 – Experimental Plan and Locations

PG Grade	Percent RAS	Percent RAP	Location
58-22	0	20	Ronnie Lane to Workbench Dr.
58-22	5	15	Workbench Dr. to n/o Gravois
64-22	5	15	Gravois to Lindbergh H.S.
64-22	0	20	Lindbergh H.S. to Fox Meadows

Pace Construction's work consisted of cold milling 3-3/4 inches (95 mm) from the existing surface and replacing with 2 inches (50 mm) of SP190 and 1-3/4 inches (45 mm) of SP125.

The trial sections were placed south of Rte. 366 basically between Ronnie Lane and Lindbergh High School in the southbound driving lane and Lindbergh High School to Fox Meadows in the northbound driving lane. Pace hauled the PG 58-28 from the SemMaterials terminal in Tulsa, Oklahoma since it was not available locally at the time of the paving.

Lindbergh - Before Paving

Lindbergh - During Construction

While this project was being paved, Minnesota DOT (MnDOT) was paving a trial project comparing tear-off shingles and manufacturing waste. The University of Minnesota offered to perform indirect tensile strength (IDT) testing in conjunction with this study so MnDOT could look at cold weather cracking potential. The results of this study are published in the Association of Asphalt Paving Technologists (AAPT) Journal in 2007. [1] The stiffness of the shingle mixtures exceeded the capability of models to accurately determine the temperature at which cracking would occur. With the increase in stiffness also came an increase in strength, which may explain why the conclusions of the report have not been realized in the field.

An evaluation observing rutting and reflective cracking was made after 2 years in service. Since the RAS mix was in a subsurface layer, these were the only observations made. No rutting or cracking was noted in the experimental sections as there was none noted in the other areas of the project. At the 3 year observation in the fall of 2008, no rutting was observed but cracking had begun to appear in some of the control sections. Two cracks noted in the RAS section with PG 64-22 just south of Gravois Road may be the result of pavement geometry due to pavement widening and the end of the concrete shoulder. The following photographs show the typical appearance of the roadway at that time and cracking that was beginning to appear in the center lanes of the roadway. It was noted the transverse cracking in the center and passing lanes stopped at the joint adjacent to the driving or near lane, which contained RAS.

Typical Appearance of Lindbergh, 2008

Cracking in Center Lanes of Lindbergh, 2008

The special provision used in the experimental project was incorporated into Section 403 of the Missouri Standard Specifications for Highway Construction effective February 1, 2008. Two changes made as a result of the Lindbergh project and other states' experiences were that the limit for RAS was raised to 7 percent and PG 64-22 was allowed as long as the virgin binder content remained at or above 70 percent of the total binder.

Since the amount of RAS is limited, large changes in the gradation of the RAS aggregate makes small changes in the combined gradation of the mixture. The large percentage of mineral filler in the shingles causes determining the gradation to be messy in the laboratory. Several gradations determined in the MoDOT Central Laboratory were compared with contractor gradations to set a standard gradation which was added to the specification as an option for contractors.

Asbestos has been a chief concern of many agencies nationwide. Use of asbestos was discontinued in the early 1970's in residential shingles in the United States. The National Emissions Standards for Hazardous Air Pollutants (NESHAP) under the United States Environmental Protection Agency (EPA) has an exemption based on this fact. In the Appendix of Code of Federal Regulations (CFR) Section 40 Subpart M, shingles from four-plex or smaller residential dwellings are exempt from asbestos testing in accordance with local regulations. The MoDNR has no additional testing requirements for the shingles but some local agencies, such as the St. Louis County Department of Health, have a requirement to prove the absence of asbestos. Tests performed on shingles to date by MoDOT and processors in St. Louis County have been clear of asbestos for the most part. A few tests have had a trace of asbestos but no measurable levels. It is believed the asbestos was contained in mastics used for sealing joints in roofs. Most shingle processors in Missouri document the source of the shingles but do not routinely test following the NESHAP guidance.

The projects constructed thus far including RAS have not shown a reduction in performance to this point. A more detailed evaluation is planned for projects after more time has elapsed. The primary concern in using RAS from tear-off shingles from the beginning has been cold weather and fatigue cracking. There has been little cracking noted in projects since placement even with temperatures approaching -20C (-4F) with the critical cracking temperature of -22C (-7F).

Few problems have been reported on construction projects. Most contractors have progressed toward using finer grinds of the RAS in order to prevent plant feed problems. The normal introduction of RAS into the mixture is through the reclaim port on the plant which is usually about a 2 foot (0.6 m) square. Mixture tenderness evidenced by movement of the asphalt during placement has occurred in some mixtures necessitating a reduction in the amount of RAS. More contractors are beginning to be aware of the amount of moisture held by ground shingles since they can hold as much as 25 percent of their weight in water. Cold weather placement has resulted in low pavement density and when used in conjunction with warm mix asphalt, clogging at the plant discharge has been reported.

The use of RAS grew rapidly from 2006 through 2008. The large increase in 2008 was fueled by a steep increase in asphalt prices. The price rose from just under $400 per ton to over $900 per ton ($441 per metric ton to $992 per metric ton) in the fall of 2008. As the contractors sought ways to cut costs, a reduction in the virgin asphalt content appeared to be the most reasonable. A 20 to 30 percent reduction in virgin asphalt can be achieved in most mixtures within the 7 percent RAS limit. Between 2005 and 2009, the average virgin binder content of mixture designs approved by MoDOT dropped by approximately one percent. The savings, neglecting the cost of the RAS in the mixtures, at the current price of $450 per ton would have saved around $20 million for the 4.5 million tons placed in 2009. As processing facilities increase, more and more people are becoming environmentally aware while looking to recycle shingles in order to avoid more expensive landfill costs.

Using Any Means to Recycle Shingles

Since long-term performance data is unavailable, the unknown has been the main slow down in use of the RAS in HMA not only in Missouri but nationwide. A comprehensive study comparing laboratory testing with results on the roadway does not exist for tear-off residential shingles. The results from tests appear to be contradicted by performance. Testing would indicate a drastic rise in low temperature cracking; however, the pavements have not exhibited this behavior. The unknowns are the actual amount of blending between the harder shingle asphalt and roadway asphalt. Also unknown is the contribution of the fibers and filler in the RAS. To know more about these unknowns will require testing of the entire mixture and cannot be determined by only testing the binders.

MO Rte. 66

MO Rte. 171

3. CONCLUSIONS

One indicator of the performance of RAS mixtures is the determination of the dynamic modulus of an SP125 mixture containing 3 percent RAS in the Asphalt Mixture Performance Tester (AMPT.) Comparing the master curve to that of another SP125 mixture containing 20 percent RAP, the performance level should be equal.

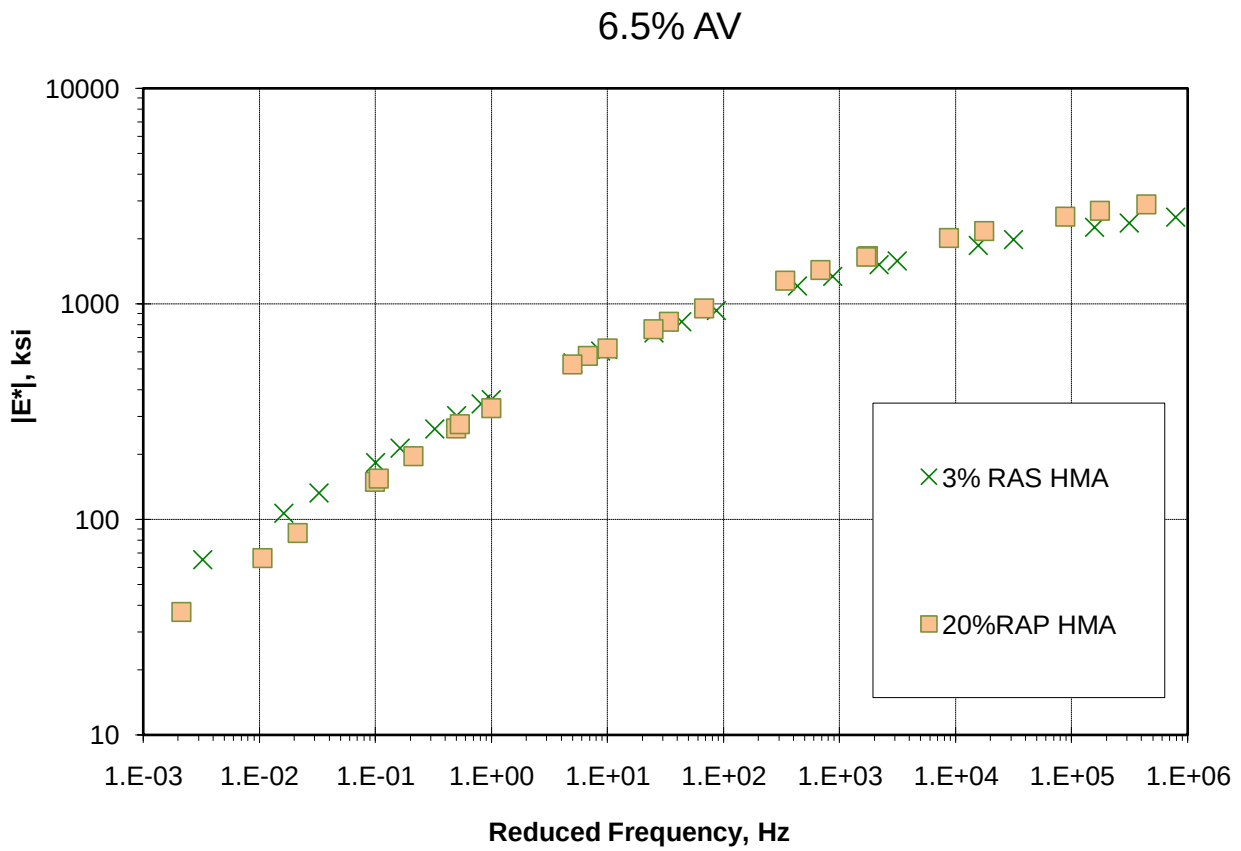

Figure 7 – Performance Data

Missouri Department of Transportation (MoDOT) has encouraged advancement of the use of RAS with a workshop sponsored by government and industry to promote and inform others of *"Missouri's Experience with RAS in HMA"* held in Joplin, Missouri in September 2008. MoDOT is also the lead state in a national Transportation Pooled Fund Study, Performance of Recycled Asphalt Shingles in Hot Mix Asphalt TFP 5-(213), to encourage other state DOT's acceptance and use of this innovative, cost saving and environmentally friendly technology.

The introduction of RAS into HMA mixtures came at an opportune time for MoDOT. It is hard to evaluate the cost savings due to various decisions made by the contractor but all but one or two of the suppliers of HMA to MoDOT projects are now using RAS. At the same time that the RAS specification became the standard, the cost of asphalt binder began its rapid rise and MoDOT adopted environmental responsiveness as a Tangible Result of its core values. Reduction of landfill waste was not MoDOT's goal in the use of RAS but it has led to an emphasis on use of other recycled materials that not only make use of valuable resources but are taken out of the waste stream. As landfills run out of space, other environmental regulations and public opinion are discouraging the construction of landfills. Beneficial use of waste materials helps MoDOT to both control costs and in its mission as a public agency.

REFERENCES

1. McGraw, Jim; Zofka, Adam; Krivit, Dan; Schroer, Joe; Olsen, Roger; and Marasteanu, Mihai, "Recycled Asphalt Shingles in Hot Mix Asphalt, 2007 AAPT Journal (V76), March 12-14, 2007.