MnROAD PPA Workshop
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Introductions

In 2007, in order to address concerns that had been raised about the performance properties of Polyphosphoric Acid (PPA) modified asphalt, the Minnesota Department of Transportation in cooperation with the Federal Highway Administration (FHWA) and the Phosphoric Acid industry initiated a study to evaluate field performance. Several different pavement sections were placed on the MnROAD Low Volume test track just northwest of Minneapolis. These sections included mixes modified with PPA along with PPA in combination with Styrene Butadiene Styrene (SBS) and PPA with Elvaloy. This workshop covers the performance of these sections after five years of trafficking and exposure to the environment at MnROAD.

The workshop was held in St. Louis, January 2013, in conjunction the North Central Asphalt User Producer Groups annual meeting. It included presentations on the field performance of the sections and a review of the mix testing done during the initial construction of the sections. A presentation on the state of the practice in the use of PPA was also, made. This report summarizes the findings at MnROAD regarding the use and performance of PPA presented in the workshop in addition to field data from the 2009 PPA workshop.

MnRoad Construction

The Minnesota Road Research Project (MnROAD) was constructed by the Minnesota Department of Transportation (Mn/DOT) in 1990-1993 as a full-scale accelerated pavement testing facility with traffic, opening in 1994. It is located near Albertville, Minnesota (40 miles northwest of St. Paul-Minneapolis).
MnROAD consists of two unique road segments located parallel to Interstate 94 [1]:

- A 3.5-mile Mainline interstate roadway carrying "live" traffic averaging 28,500 vehicles per day with 12.7 % trucks.

- A 2.5-mile closed-loop Low Volume Road carrying a MnROAD-operated 18-wheel, 5-axle, 80,000-lb tractor-semi-trailer to simulate the conditions of rural roads.

The layout of MnROAD is shown in Figure 1. The I 94 mainline is west of an alternate eastern mainline section which is used to place test sections and have I 94 diverted onto it for trafficking. The closed-loop Low Volume Road is just northeast, directly adjacent to the I 94 mainline test sections.

Figure 1. Aerial photo to the MnROAD layout .

Individual Sections

The PPA test sections were constructed in 2007 on the Low Volume Road portion of the test track. Six sections were placed over two different types and thicknesses of base course. The PPA mix study was done in conjunction with a study evaluating different base materials. The PPA Elvaloy sections were placed over 8 inches of either full depth reclamation or 8 inches of crushed aggregate base. The PPA, PPA + SBS and SBS sections were placed over 12 inches of crushed aggregate base. A graph of the materials and thicknesses of the individual sections is shown in Figure 2.

The same asphalt mix design was used for all six test sections. The HMA mix designation was SPWEB340C, which indicates a 12.5 mm Superpave wearing course mix, Traffic Level 3 (1-3 Million ESALs), 4.0% design air voids, and PG 58-34 binder. No RAP was used in any mixes and 1% hydrated lime was added at the drum plant. A liquid phosphate ester antistrip (Innovalt W) was added to each binder material at 0.5%. The cells include the following binder materials:

- 0.75% PPA only (Cell 33)
- 0.3% PPA + 1.0% SBS polymer (Cell 34)
- 2.0% SBS polymer only (Cell 35)
- 0.3% PPA + 1.1% Elvaloy polymer (Cells 77-79 – shared with Fly Ash Study)

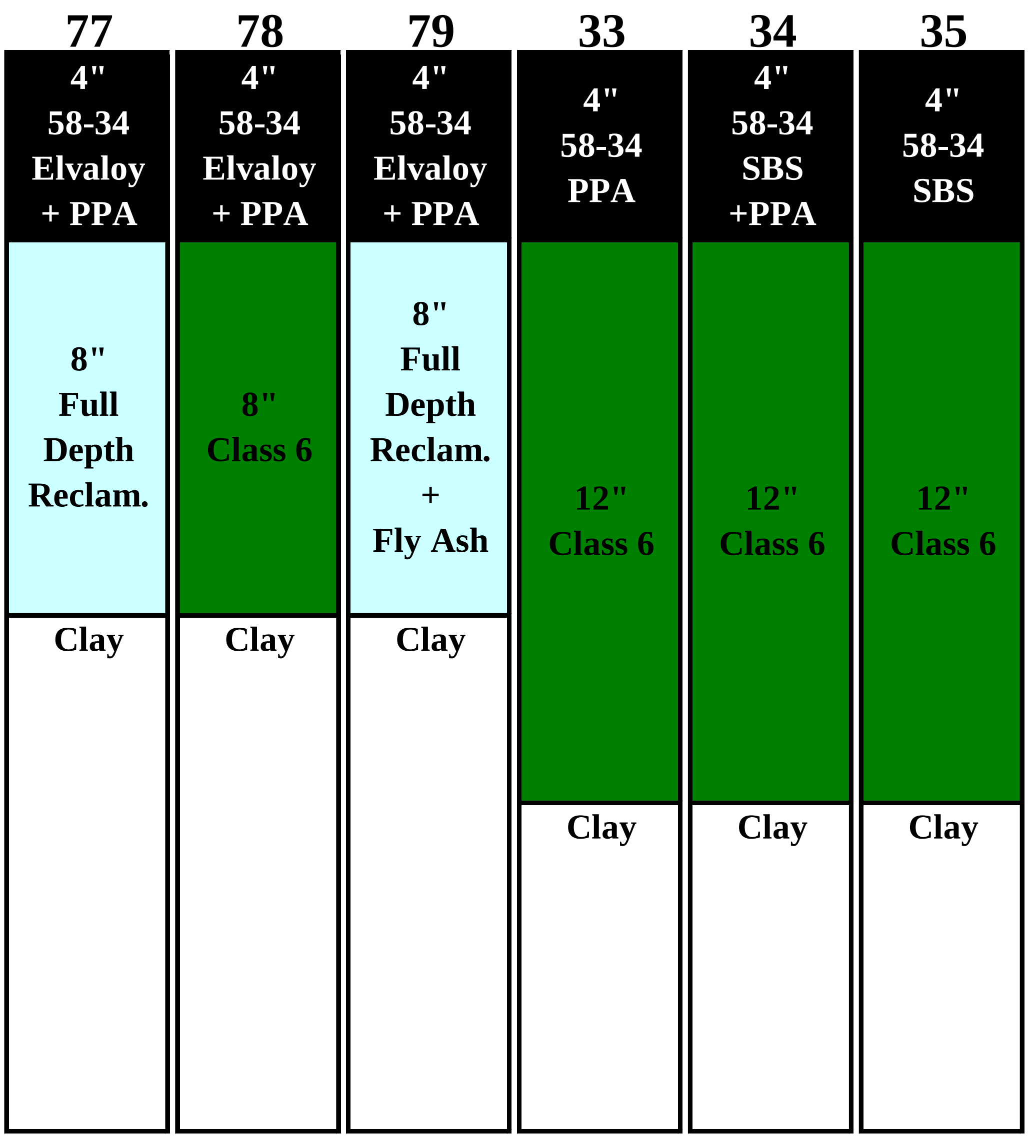

Figure 2. Structural sections for the PPA study cells.

Field Performance

During the five years of trafficking on the test sections approximately 90,000 Equivalent Single Axle Loads were applied to the roadway. Each of the sections has very little distress after five years of traffic and exposure to the environment. Falling Weight Deflectometer (FWD) testing shows two groupings for the test sections (see Figure 3). The PPA and PPA+SBS had a higher overall stiffness than the SSB and PPA+Elvaloy cells in October 2009. This can be attributed to the differences in the base thickness with the PPA+Elvaloy cells being placed on the thinner base layers. The SBS cell also had a lower stiffness even though it was placed on the thicker base. The FWD data from May 2011 shows a much lower stiffness which is likely due to spring thaw of the base. The overall ranking of the cells remained the same from season to season.

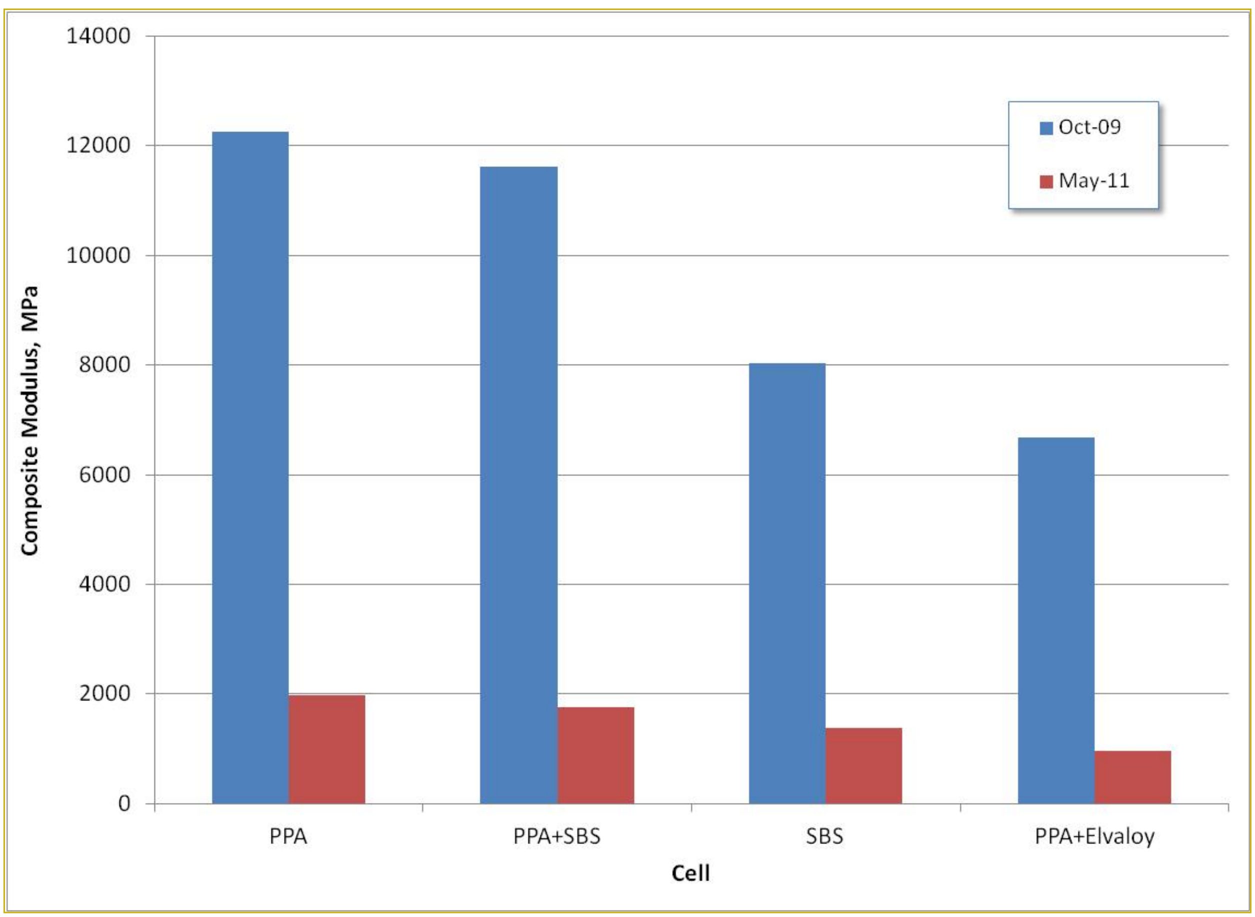

Figure 3. FWD back calculated modulus for the various cells in the study.

The rutting on each of the sections after 5 years and 90,000 ESALs is minimal. The maximum rutting on the sections is less than 0.25 inches and difference between the max rutting and the minimum rutting is 0.1 inches or 2.5 mm. Basically the sections all have equivalent rutting results. Rutting measurements from the initial construction until May 2012 are shown in Figure 4. From the plot it can be seen that the rutting on all the cells are basically equivalent until May 2010. There appears to be some minor change in rutting rate of the cells with the PPA + Elvaloy and SBS cells showing less rutting after the spring of 2010. However, it is unlikely that rutting would increase after 2.5 years of aging. It currently is not known if the rutting is the asphalt mixtures or in the base course.

There are currently only two transverse cracks in any of the cells. Both are in the PPA + Elvaloy cell. One crack is over a cable trench for the pavement sensors. The other is away from this location where it is believed the mix was overheated during production due to heavy rain just prior to paving.

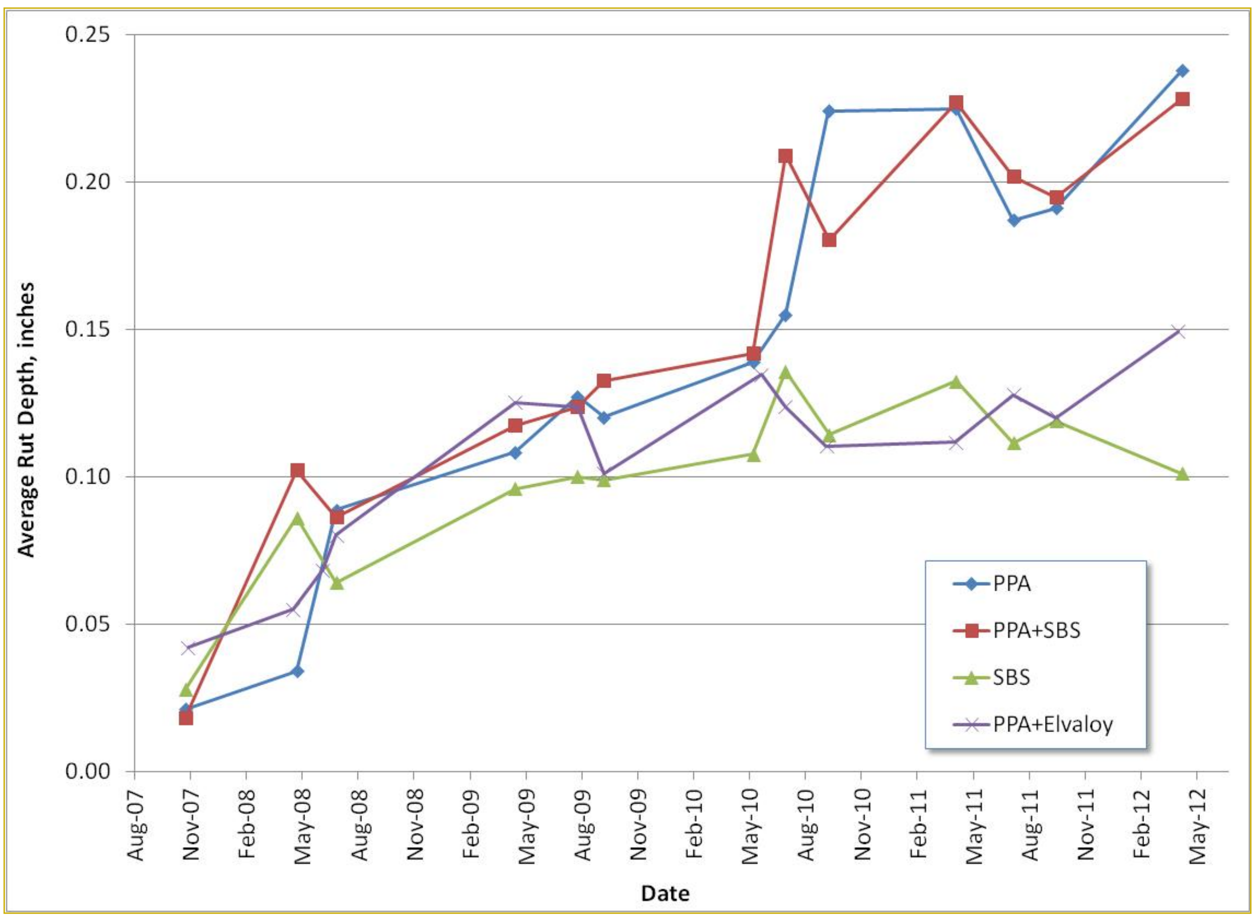

Figure 4. Plot of rutting for cells in the PPA study from initial traffic loading until May 2012.

Laboratory Mix Testing

Field samples of mixes placed for each of the cells, in the MnROAD PPA mix study, were tested for rutting and moisture damage. In addition, the binder was recovered from the field produced mix for comparison to the PG grading [1]. The Hamburg wheel tracking test was run wet to evaluate moisture damage and the test was run dry to evaluate rutting. The Hamburg wheel tracking test is considered a much more severe test than the indirect tensile test for the evaluation of moisture damage. Figure 5 presents a plot of the wheel tracking results. All the testing was done under water at 50°C. The field mix was reheated to 135°C prior to compaction in the gyratory compactor and the samples were made to 7% air voids. The data show that none of the mixes indicated any moisture damage problems. They all had minimal rutting with a maximum of 7mm for the Elvaloy mix. This is representative of field performance in that after five years there is no indication of any moisture damage in any of the cells.

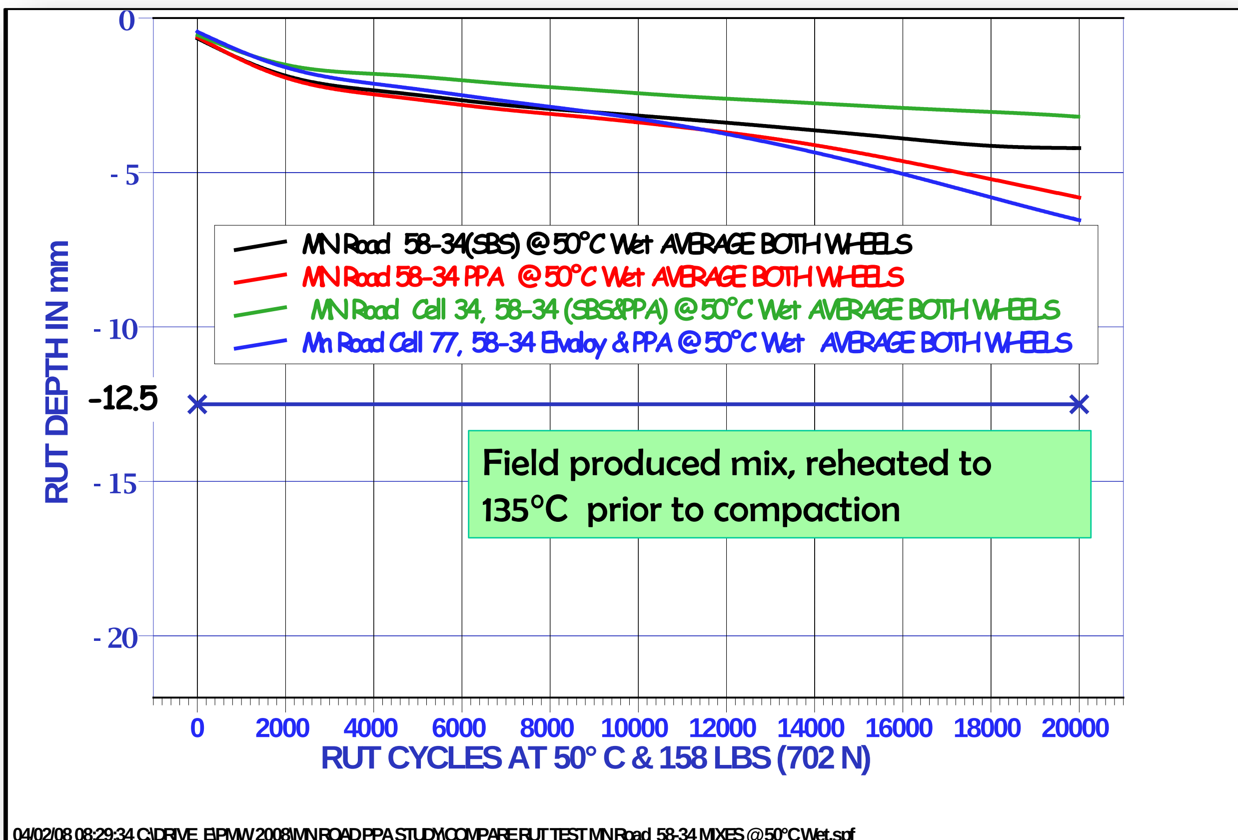

Figure 5. Plot of the Wet Hamburg tests at 50°C on field produced mix from each cell to evaluate moisture damage.

Rutting was evaluated with the dry Hamburg. The test is run just like the wet Hamburg except the sample temperature is controlled by hot air instead of water. This eliminates the issue of stripping from the rutting analysis. The test is also run hotter than the Hamburg moisture test. In this case the test was run at 58°C to represent the high climate temperature for the MnROAD location. Figure 6 shows a plot of the wheel tracking results for the dry Hamburg. The higher temperature of the dry Hamburg test produces higher rutting in the mixes and appears to spread the data out some. Overall the rutting is still low for a low traffic volume mix design. The larger spread in the data is likely due to causes other than mix type or binder differences. The binders were all formulated to produce a PG 58-34 with very similar high temperature properties.

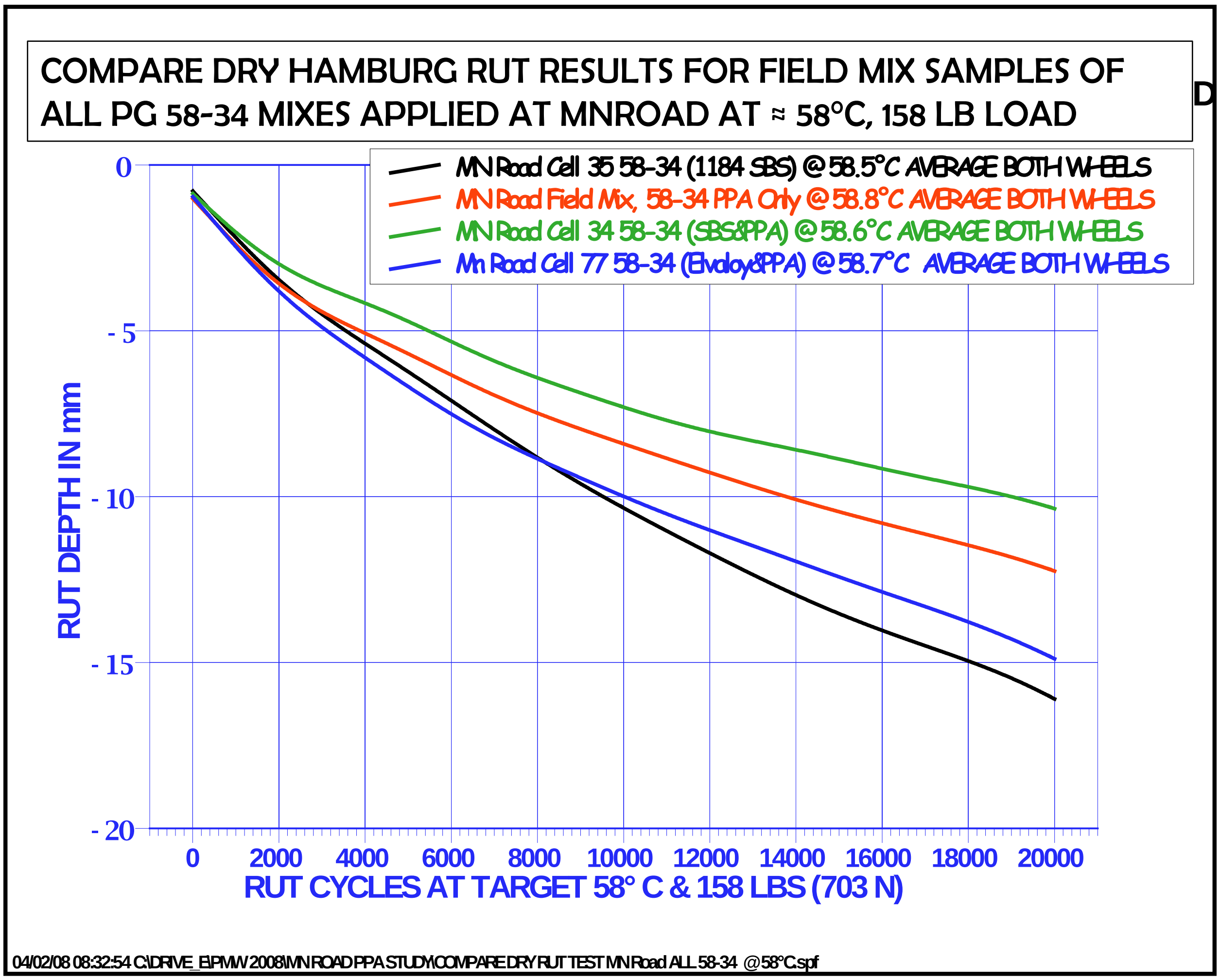

Figure 6. Plot of the wheel tracking results for the dry Hamburg mix tests for each cell at 58°C.

The binders were recovered from the mix and graded according to both the PG and Multi-Stress Creep and Recovery (MSCR) Specifictions. This data is provided in Table 1. The non-recoverable compliance of the recovered binder is significantly lower than the RTFOT aged binders. This would indicate that the field aging during production was much greater than the lab aging. The overall ranking based on the binder stiffness changes from the RTFOT to the recovered binders. This indicates that the aging of the individual mixes during production was not the same. This verifies that the mixes may have been produced at higher than typical temperatures due to heavy rain just before placement. Figure 7 shows a plot of the recovered J_{nr} values from the MSCR test compared to rutting in the dry Hamburg. The rutting correlates well with the MSCR data from the recovered binder.

Table 1. Comparison of RTFOT MSCR data to recovered binder from field mix MSCR data.

BINDER (RTFO)	Jnr @ 58°C @ 3.2 kPa	% RECOVERY @ 3.2 kPa	BINDER (RECOVERED FIELD MIX	Jnr @ 58°C @ 3.2 kPa	% RECOVERY @ 3.2 kPa
PG 58-34 SBS	1.27	19.3%	PG 58-34 SBS	0.636	25.9
PG 58-34 SBS + PPA	1.79	8.6%	PG 58-34 SBS + PPA	0.377	35.8%
PG 58-34 PPA	2.0	3%	PG 58-34 PPA	0.475	15.1%
PG 58-34 ELVALOY + PPA	0.95	25.6	PG 58-34 ELVALOY + PPA	0.795	26.7

General Field Performance

Arkansas DOT undertook a major reconstruction plan of their interstate system in 1999. Under the program 380 miles of interstate would be reconstructed over five years with 340 miles reconstructed using hot mix asphalt (HMA) [2]. The program included 7.4 million tons of mix produced with modified asphalt binder. Most of the binder included PPA. In 1999 37% of the system had a poor IRI (> 170 in/mi) and 33% had a moderate IRI (120 to 170 in/mi). As of 2006, after completion of the rehabilitation program, over 73% of the Arkansas interstate system is in good condition with an IRI (< 95 in/mi). There have been only very minor distresses on individual projects not related to the binder.

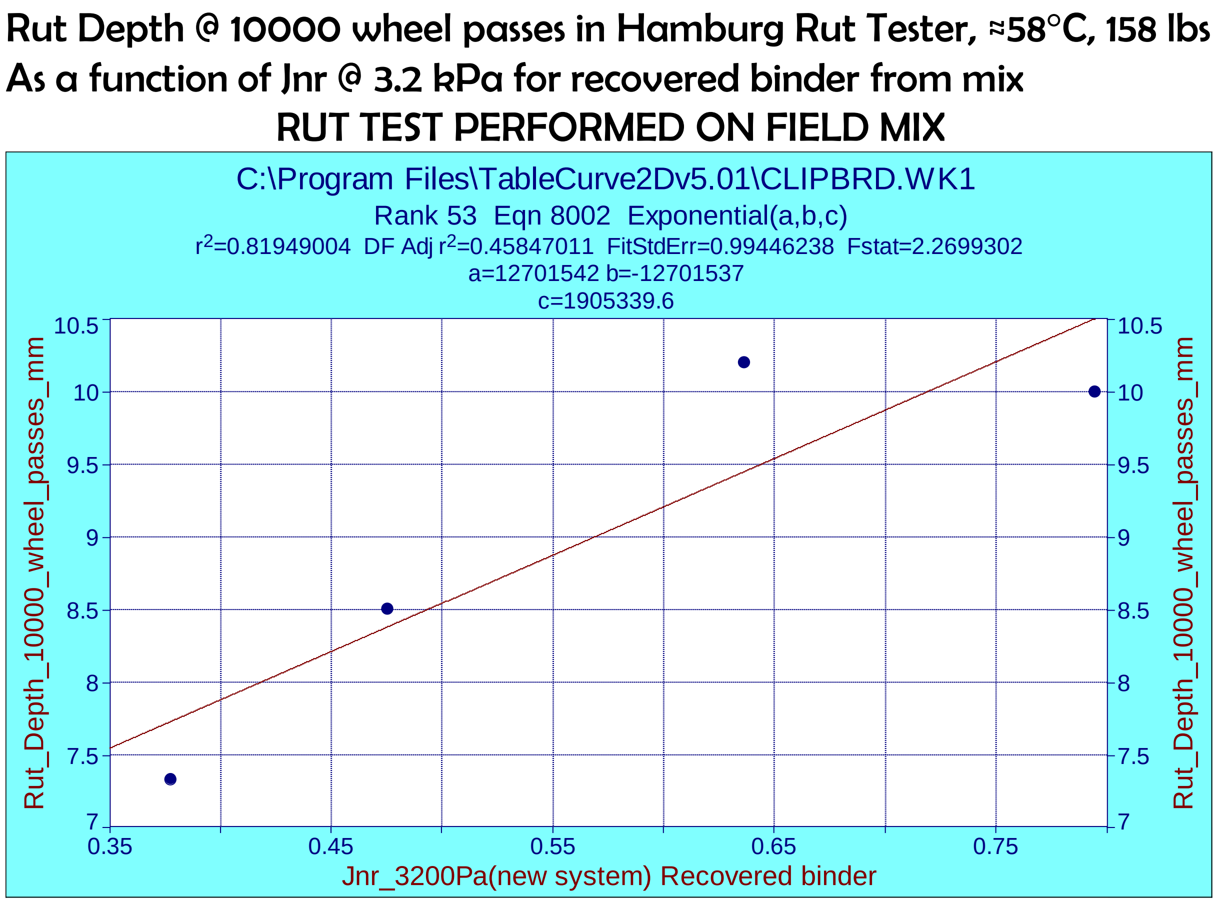

Figure 7. Plot of the dry Hamburg for field sampled mixes to MSCR data from the recovered binders.

The National Center for Asphalt Technology (NCAT) operates a test track in Opelika, Alabama. The track is used to evaluate various mixtures and pavement sections for performance. In 2000 18 SBS modified sections were placed to evaluate the performance of SBS modified asphalt binders compared to neat binders. All of the SBS modified binders also contained 0.25% PPA and the mixtures were produced with lime or liquid anti-stripping additives [3]. These sections received 10 million ESAL's during the first loading cycle with no indications of poor performance. The rutting for all test sections was less than 6mm. There was also no evidence of moisture damage. In 2003 a second cycle of the track was constructed where nine of the existing PPA/SBS sections were left in place and nine new PPA/SBS sections were constructed. Again after 10 million ESAL's (20 million for the original sections) rutting was less than 9mm on all the sections and there was no fatigue cracking attributable to the mixtures. After six years, with over 40 inches per year of rain, no moisture damage could be identified on the track sections.

Extended Aging Study

This study consisted of placing mixes produced with zero to two percent PPA in a Weatherometer for 3000 hours. The mixes were made with a 12.5 mm granite and a 5% binder content. The binder was a PG 64-22 control blended with 1, 1.5 and 2 percent PPA. A blend with 2% SBS and 0.5% PPA was also produced.

The Weatherometer is a device used mostly in the roofing industry to simulate aging of the shingles on a roof. It applies heat (for this study at60°C) plus UV light and moisture. The UV light and moisture are applied at various intervals during the aging process. Moisture conditioning and heat for oxidative aging are applied at the same time with this system. A picture of the slabs in the Weatherometer is shown in Figure 8.

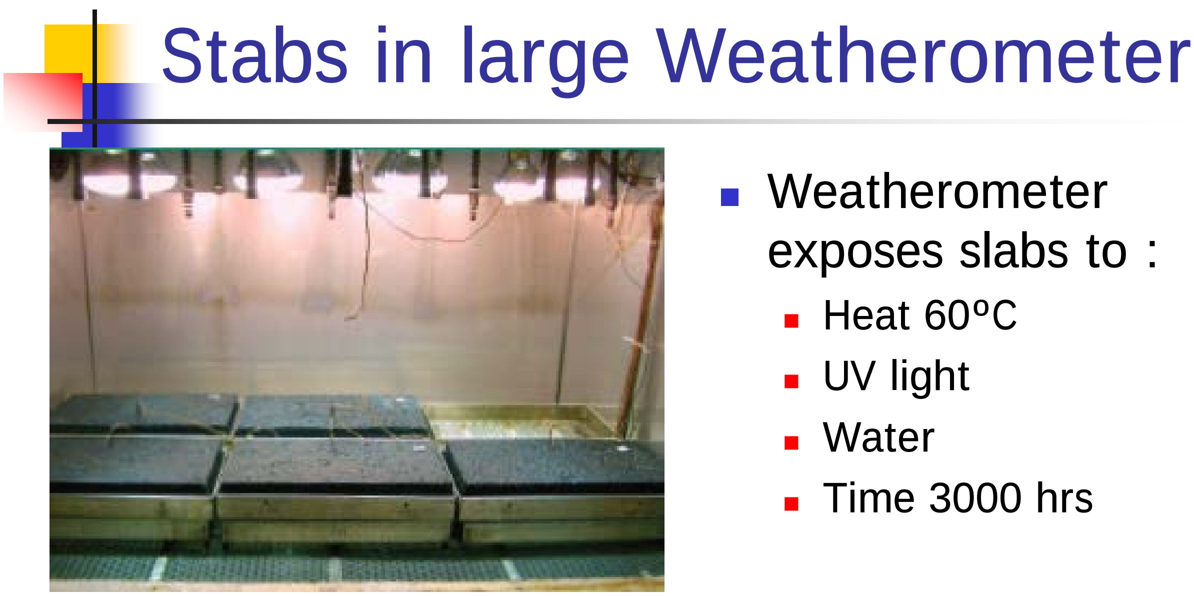

Figure 8. Picture of mix slabs in the Weatherometer showing UV lights and water nozzles used to spray the samples during aging.

The data in Table 2 shows the shows the original PG grading of the various PPA blends used in the aging study. This is compared to the recovered binder PG grading after 3000 hours in the Weatherometer. The data clearly shows that the addition of over 0.5% PPA reduces aging on the binders. The PG 64-22 control with no PPA increased in high temperature grade by 10°C, while the blends with 1% PPA or more increased by a maximum of 7.5°C. There was also a reduction in the loss of the low temperature grading.

Table 2. PG grading for the binder blends used in the long term aging experiment and PG grading of the recovered binders after 3000 hours of weatherometer aging.

Sample ID	**Description**	**Original Binder Continuous PG**	**Recovered Binder Continuous Grade**	**High-Temp Diff. (°C)**	**Low-Temp Diff.(°C) w/o PAV**
#1053-001-05	PG 64-22	69.5-26.2	79.7-25.1	10.2	1.1
#1053-001-15	Neat + 1% N200	72.9-24.1	78.7-24.3	5.8	0.2
#1053-001-20	Neat + 1.5% N200	75.2-24.7	81.5-24.2	6.3	0.5
#1053-001-25	Neat + 2% N200	81.0-23.5	88.5-23.0	7.5	0.5
#1057-017-05	Neat + 2% SBS + 0.1% S + 0.5% XL200	72.6-25.3	85.3-23.3	12.7	2.0

The various mixes were also tested in the Asphalt Pavement Analyzer (APA) before aging and after aging. A set of slabs were tested in the APA for rutting then the companion slabs were aged in the Weatherometer with exposure to UV, heat and moisture. The results are shown in Figure 8. All the samples had minimal rutting, less than 4 mm. The samples aged in the Weatherometer showed no indication of moisture damage even after being exposed to heat and moisture for 3000 hours.

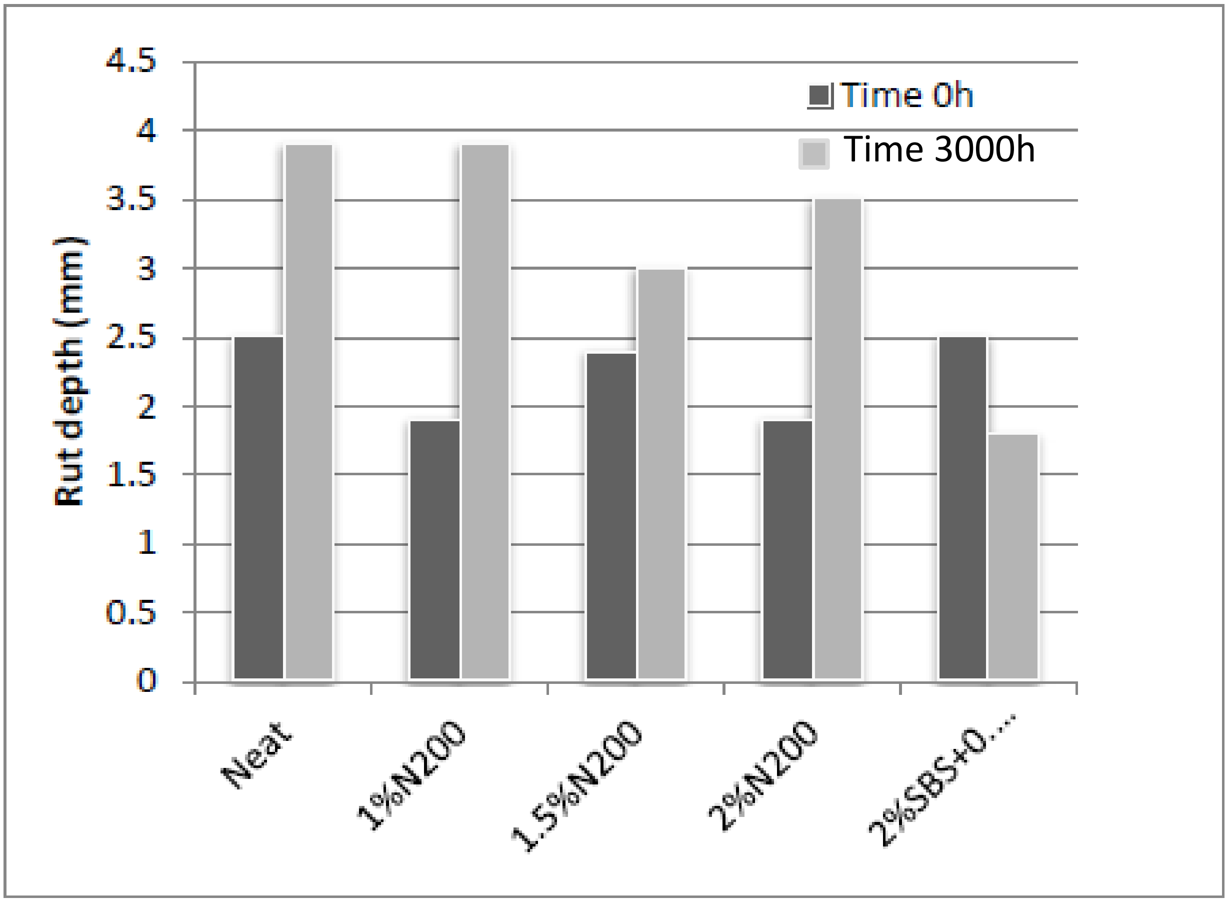

Figure 8. APA rutting results for the various mixes used in the long term aging experiment before and after aging.

Conclusions

In 2007 four different mixes were placed on the MinRoad test track to evaluate if there was any difference in performance of PPA modified binders and non-PPA modified binders. The sections included PG 58-34 binders produced using SBS, SBS + PPA, Elvaloy + PPA and PPA only. After five years of exposure to the weather and traffic the all cells in the PPA study at MnROAD are performing well. Various mixes placed with PPA modified asphalt binder are showing equal performance to strait SBS modified cells. Rutting is minimal on all the cells with a maximum of 0.25 inches (6mm) after five years of traffic. There are only two transverse cracks in any of the sections and one of those is over the cable trench for the pavement instrumentation. After the five years there are no signs of any moisture damage on any of the sections.

The results from MnROAD correlate well with results from previous studies in Arkansas and the NCAT track. After multiple years of service there are no indications that the PPA modified binders in Arkansas or at the NCAT track have caused any issues with cracking or moisture damage. Rutting has not been a problem.

The long term aging study using the Weatherometer has indicated that with the proper formulation even binders with higher percentages of PPA will provide long term performance in a mix.

References

1. Timothy R. Clyne, Eddie N. Johnson, James McGraw, and Gerald Reinke; "Field Investigation of Polyphosphoric Acid–Modified Binders at MnROAD," TRB E Circular E-C160 January 2012, pg. 115.
2. Gerry R. Westerman and John A. D'Angelo; "Modified Asphalt Cement Use in Arkansas," TRB E Circular E-C160 January 2012, pg. 108
3. Don Watson and John A. D'Angelo; "Binder Modification with Combination of Polyphosphoric Acid and Styrene-Butadiene-Styrene: National Center for Asphalt Technology Test Track Experience" TRB E Circular E-C160 January 2012, pg. 106
4. Laurand Lewandowski, Jean Valery Martin; "Effect of Accelerated Weathering on Polyphosphoric Acid Modified Binder," Euro Asphalt Euro Bitume Conference, Istanbul 2012, paper 434.