WEATHEROMETER AGING OF SCRUB SEAL EMULSIONS APPLIED TO CORES FROM A FIELD AGED PAVEMENT

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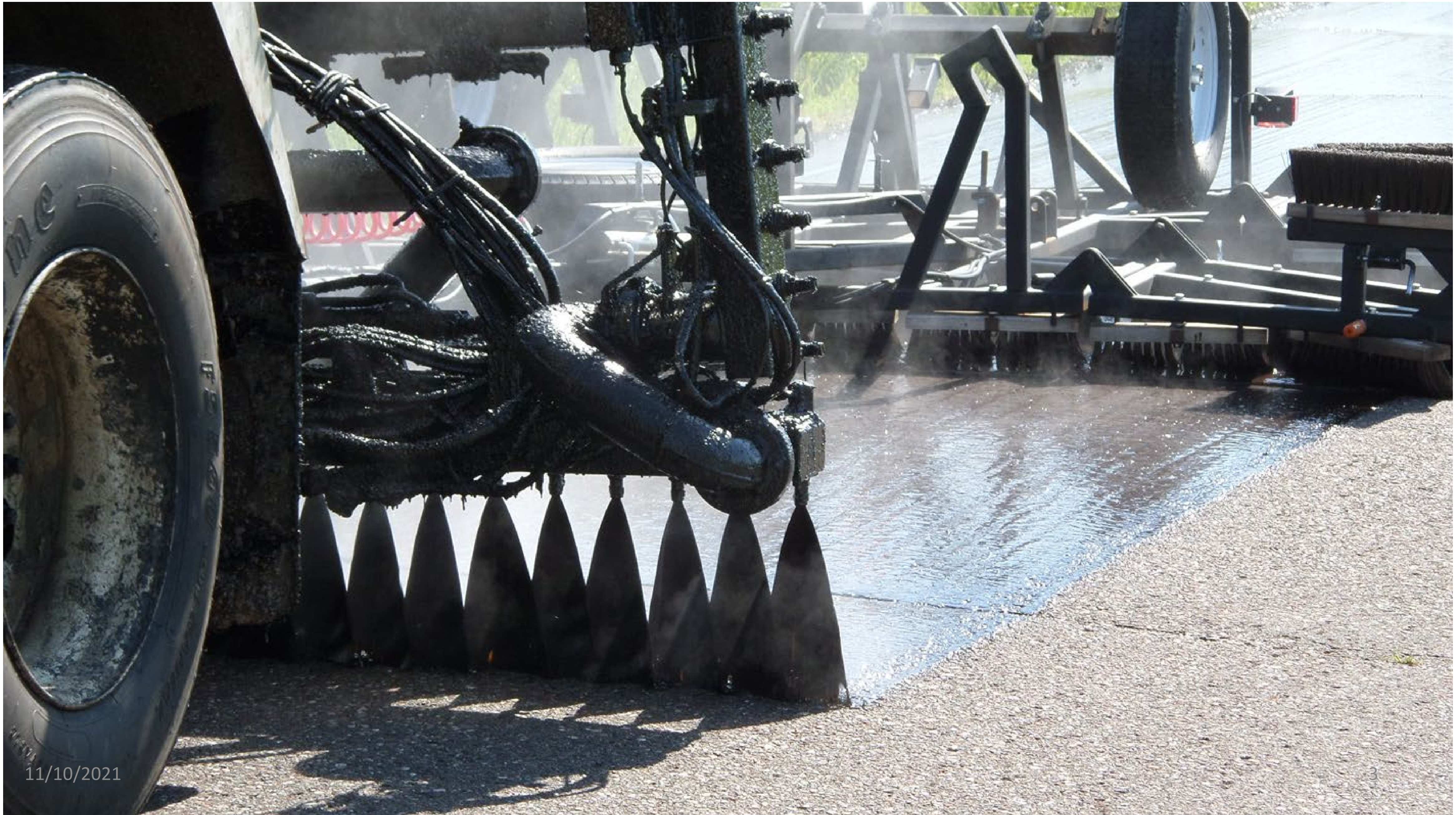
WHAT IS SCRUB SEAL

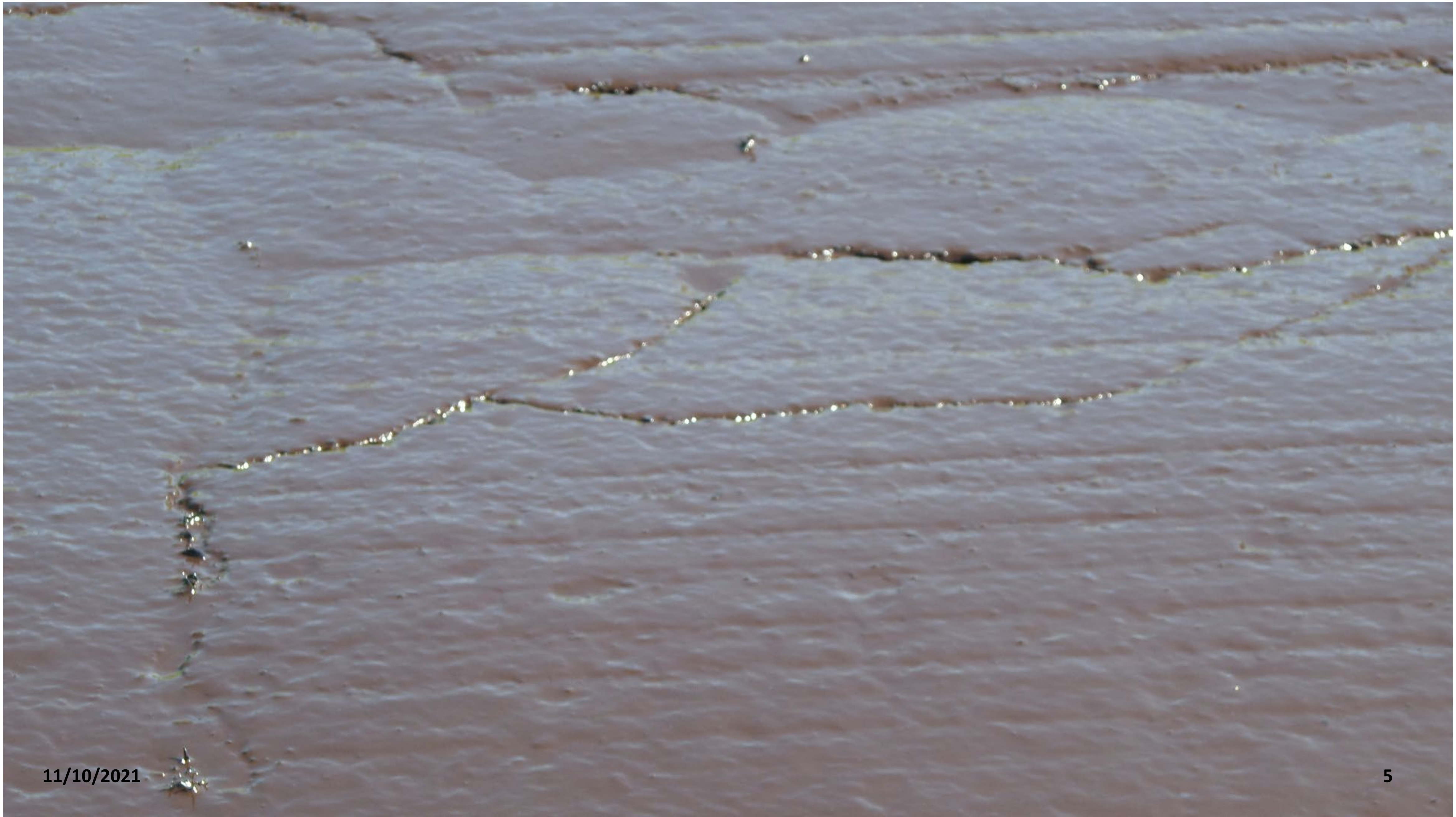
1. A scrub seal is a type of surface treatment somewhat similar to a chip seal, but with differences
   a. Rather than a typical rapid setting emulsion the scrub seal emulsion has a retarded break to allow for the “scrubbing” of the emulsion
   b. The cover aggregate is not a chip but a blend of chips and finer gradation aggregate as a typical scrub seal aggregate spec will show
   c. The binder typically contains a softening additive as a goal of the scrub seal is to fill cracks and the softening additives plus the fine aggregate is used to fill cracks to the point where moisture intrusion can be reduced and eliminated for small cracks.
   d. The scrubbing component of the scrub seal application is to force the emulsion into the cracks prior to aggregate application and rolling
   e. A few slides follow which show scrub seal material being applied

SCRUB SEAL EMULSION BEING APPLIED , FOLLOWED BY "SCRUBBING" BROOMS



ANOTHER VIEW OF THE SCRUBBING BROOMS WORKING THE EMULSION INTO THE SURFACE

SCRUB SEAL EMULSION FLOWING INTO CRACKS AFTER SCRUBBING ACTION



200 CORES WERE TAKEN FOR THE WEATHEROMETER STUDY FROM AN ABANDONED SECTION OF MISSISSIPPI HWY 45

PICTURE SHOWS WHERE CORES WERE REMOVED TO BE USED AS THE TREATEMENT SUBSTRATE FOR THE STUDY

CORES PREPARED WITH EMULSION AND AGGREGATE APPLIED READY FOR WEATHEOMETER CONDITIONING

STUDY DESIGN
FIVE GROUPS OF 18 CORES FOR EACH EMULSION TYPE
FOUR GROUPS TREATED WITH A SCRUB SEAL EMULSION
TYPE A-eScrub asphalt emulsion with acrylic latex with petroleum softening additive
TYPE B-Escrub G asphalt emulsion with acrylic latex and bio-oil
TYPE C-Scrub Seal asphalt emulsion with Neoprene latex and bio-oil
Type D-Elvaloy modified asphalt emulsion with bio-oil
TYPE E-CRS-2P SBS asphalt emulsion, not a scrub seal product

Weatherometer aging for 0, 100, 500, 1000, and 1500 cycles. Weatherometer aging cycles described in the paper. Zero cycle specimens were not weatherometer conditioned

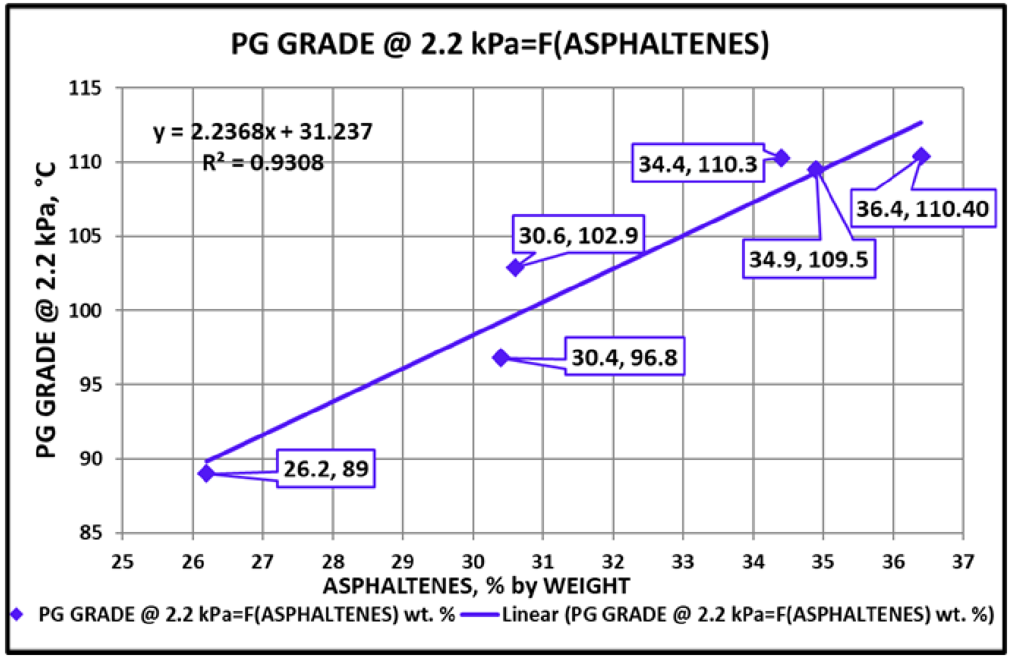
AGING VARIABILITY OF BITUMEN RECOVERED FROM TOP TWO 12-13 mm LAYERS OF THREE CONTROL CORES

Colloidal Index = (Resins + Cyclics)/(Asphaltenes + Saturates)

ALL LOW TEMPERATURE DATA FROM 4 mm DSR

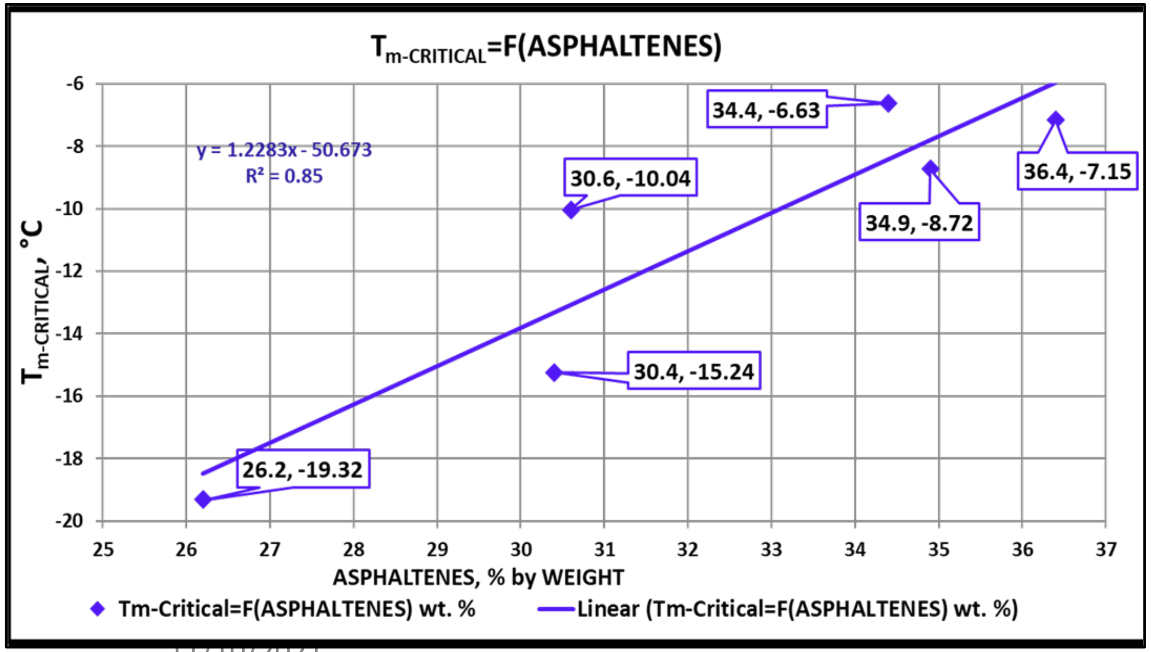
Lower CI values are evidence of greater levels of bitumen aging

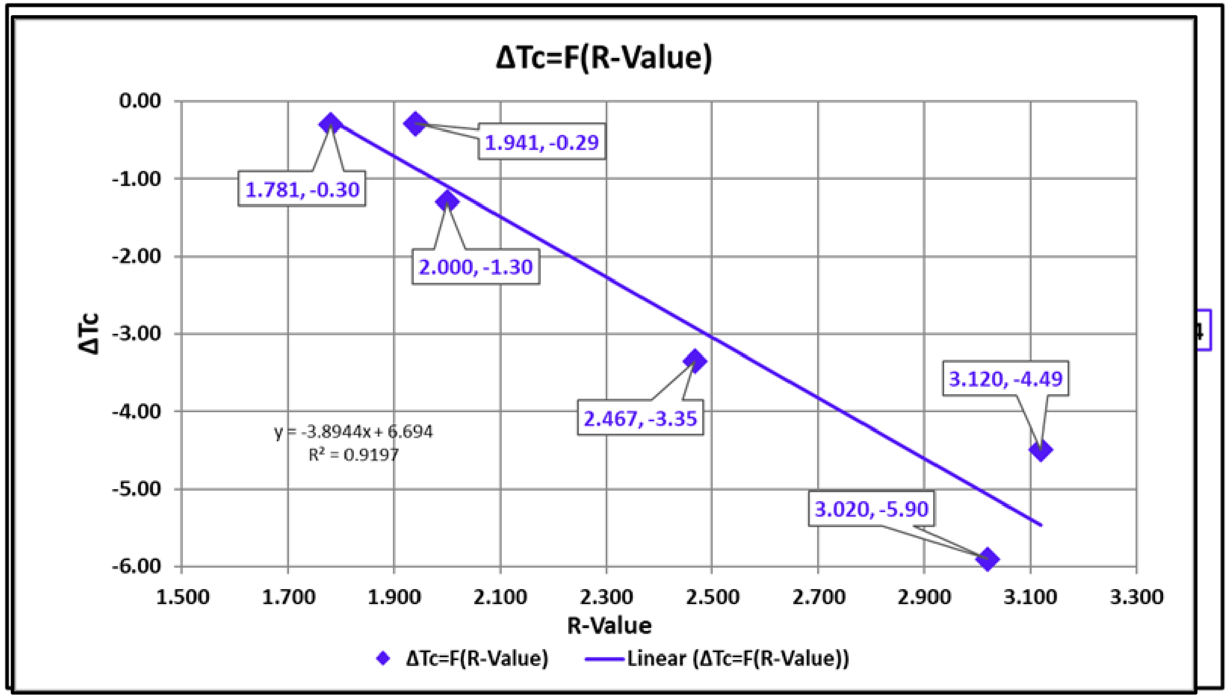
Properties of bitumen recovered from top 12-13 mm and second 12-13 mm of cores representing the existing pavement													
MTE sample ID	Core location #	Layer	Temp @ 2.2 kPa	$T_{S\text{-critical}}$	$T_{m\text{-critical}}$	ΔT_c°C	R-value	Original R-Values	Asphaltenes	Resins	Cyclics	Saturates	Colloidal Index CI
02-28-17-AD	#3	top 12 mm	109.5	-14.62	-8.72	-5.90	3.020	3.061	34.9	39.2	22.0	3.8	1.581
02-28-17-AG	#6	top 12 mm	110.40	-11.64	-7.15	-4.49	3.120	2.906	36.4	38.0	22.3	3.3	1.519
02-28-17-AB	#1	top 12 mm	110.3	-9.99	-6.63	-3.35	2.467	3.034	34.4	40.0	22.8	2.8	1.688
02-28-17-AD	#3	2nd 12 mm	96.8	-16.56	-15.24	-1.30	2.000	2.664	30.4	32.1	34.3	3.2	1.976
02-28-17-AG	#6	2nd 12 mm	102.9	-10.29	-10.04	-0.30	1.781	2.457	30.6	33.7	33.6	2.1	2.058
02-28-17-AB	#1	2nd 12 mm	89	-19.61	-19.32	-0.29	1.941	2.409	26.2	39.5	31.0	3.3	2.390
CI = (Resins + Cyclics)/(Asphaltenes + Saturates)													

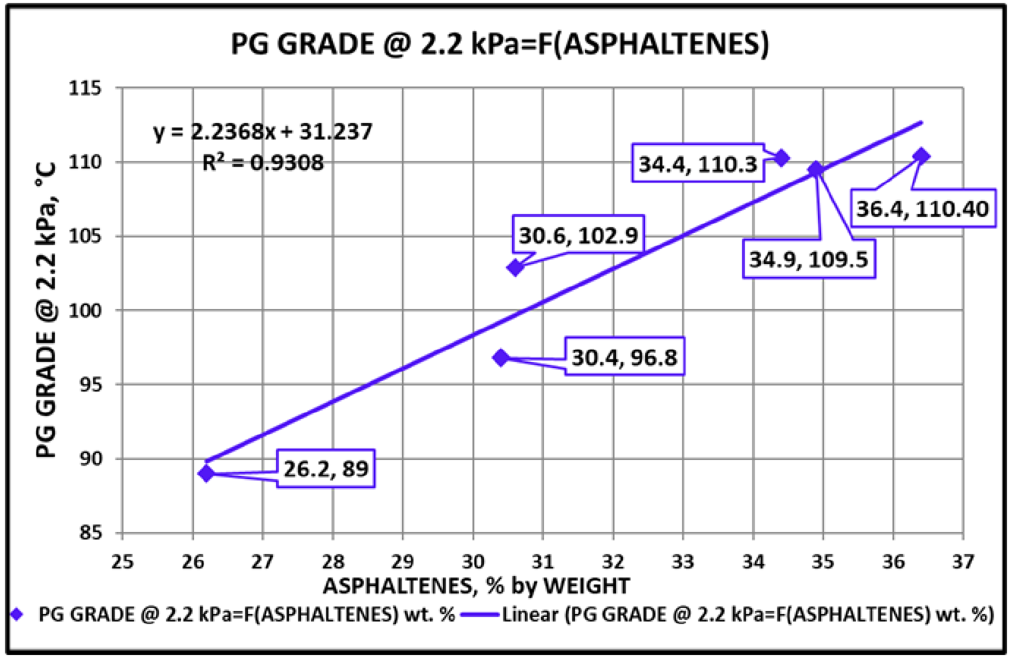


These plots show the distribution of some data from the previous slide. The distribution of asphaltenes in the two layers of the control cores show the top layer asphaltenes are more similar than the second layer asphaltenes and as a result $T_{m\text{-Critical}}$ is more variable.

However, ΔT_c is more variable for the top layer—that is because $T_{S\text{-Critical}}$ is more variable for the top layers recovered bitumen as is shown in the table of the previous slide and the plot in next slide







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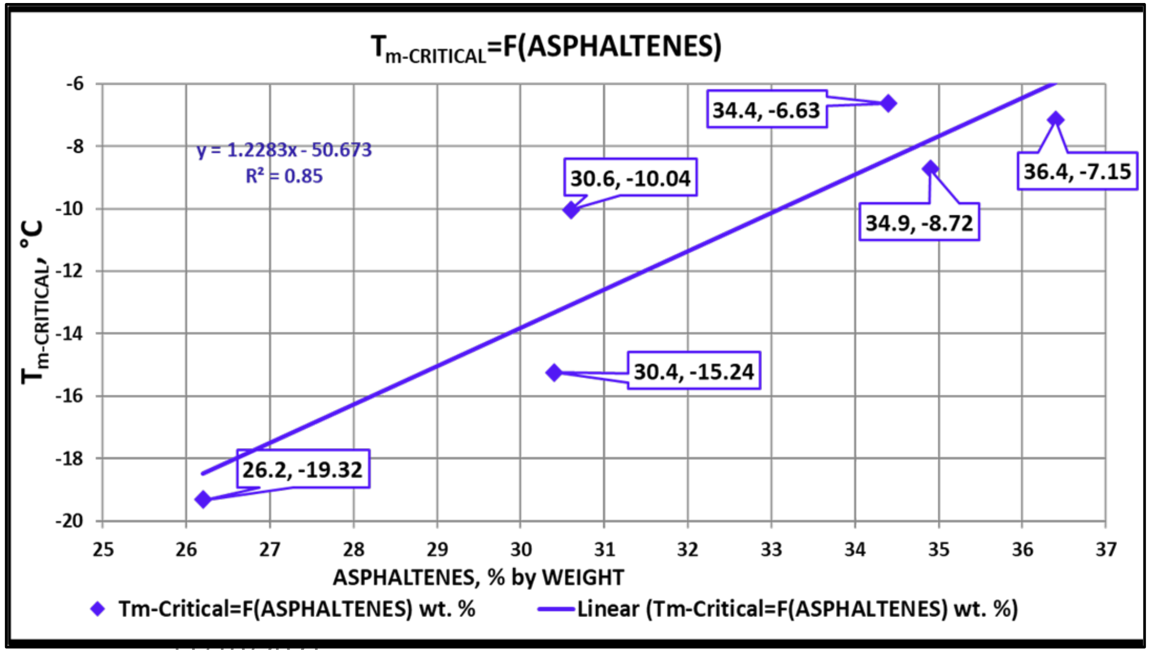
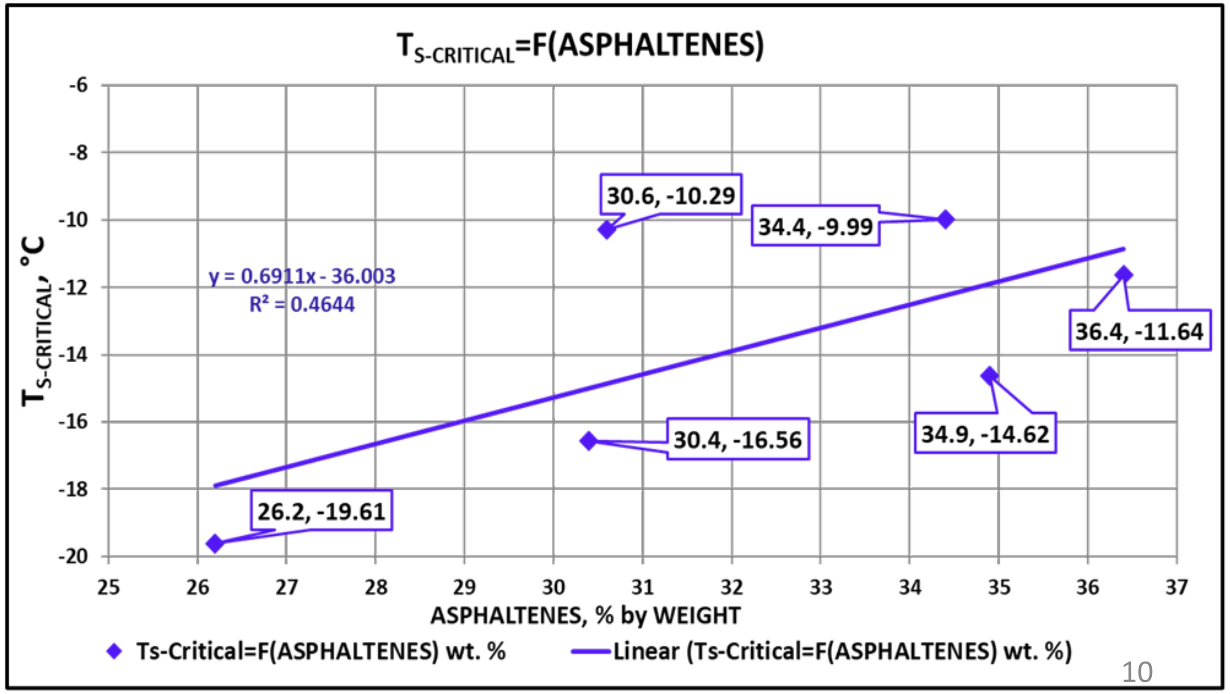
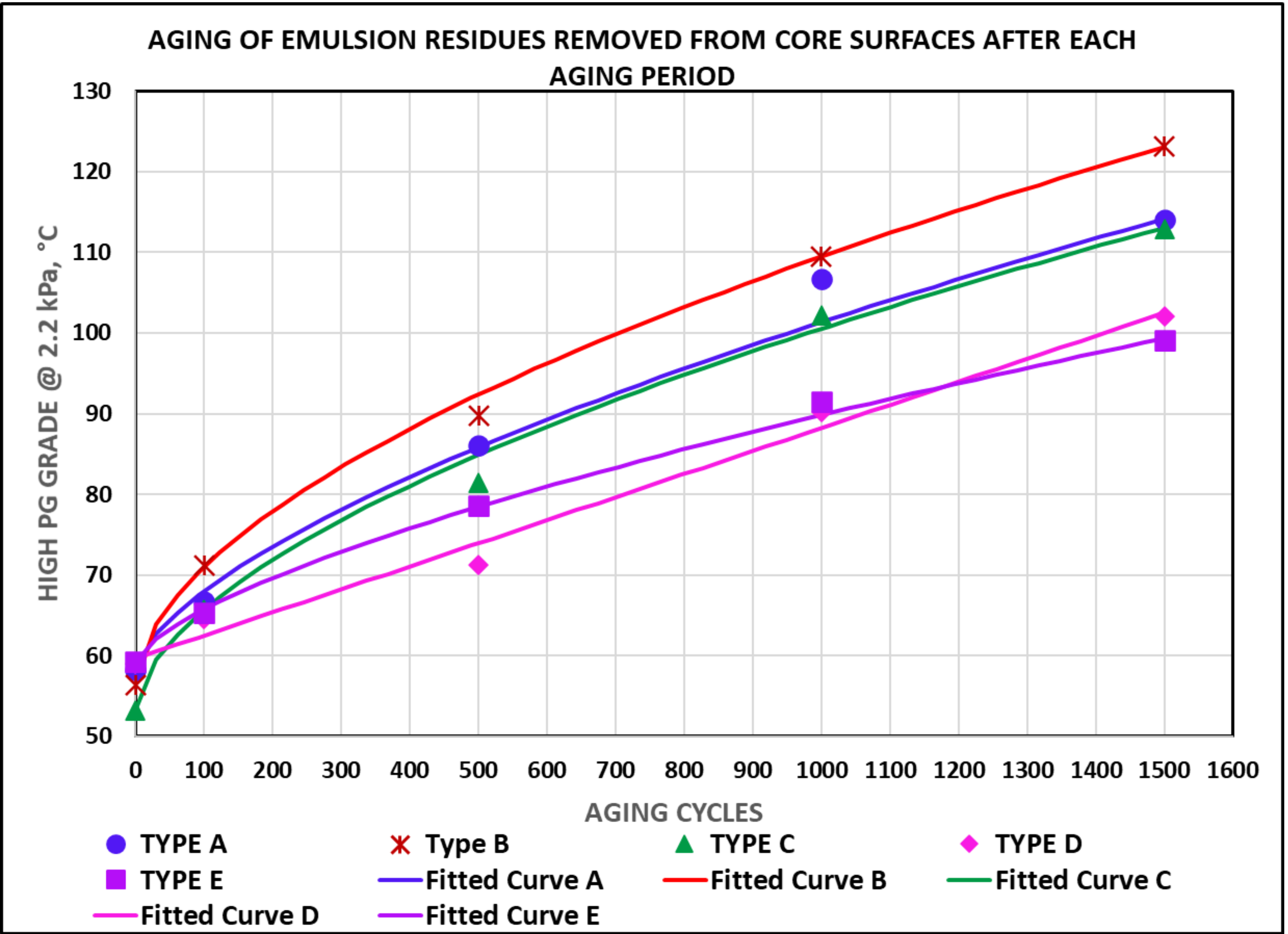




HIGH PG GRADE AGING VARIABILITY OF BITUMEN RECOVERED FROM EMULSION SCRUB SEAL REMOVED FROM CORE SURFACES



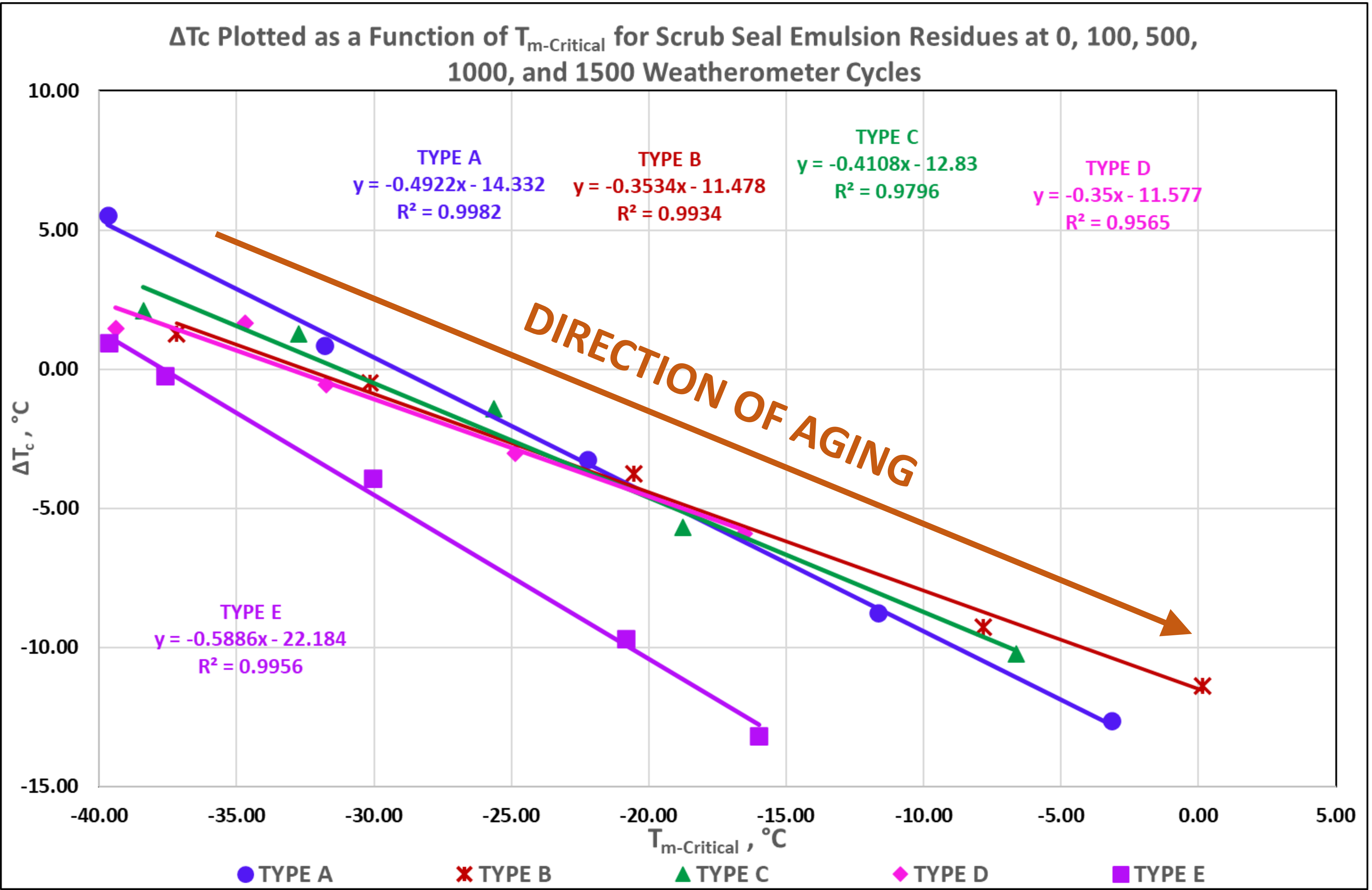
EMULSION AND AGGREGAGTE SCRAPED FROM 3 TREATED CORES FOR EACH SCRUB SEAL TREATMENT AFTER EACH AGING PERIOD

REMOVED MATERIAL FROM 3 CORES COMBINED, EXTRACTED AND RECOVERED FOLLOWED BY RHEOLOGICAL TESTING

ALL OF THE EMULSION RESIDUES EXCEPT FOR THE TYPE D FOLLOWED A POWER LAW AGING PATH

WE HAVE NO EXPLANATION FOR THIS OTHER THAN THE BASE ASPHALT FOR TYPE D WAS A PG 52-34

LOW TEMPERATURE AGING VARIABILITY OF BITUMEN RECOVERED FROM EMULSION SCRUB SEAL REMOVED FROM CORE SURFACES

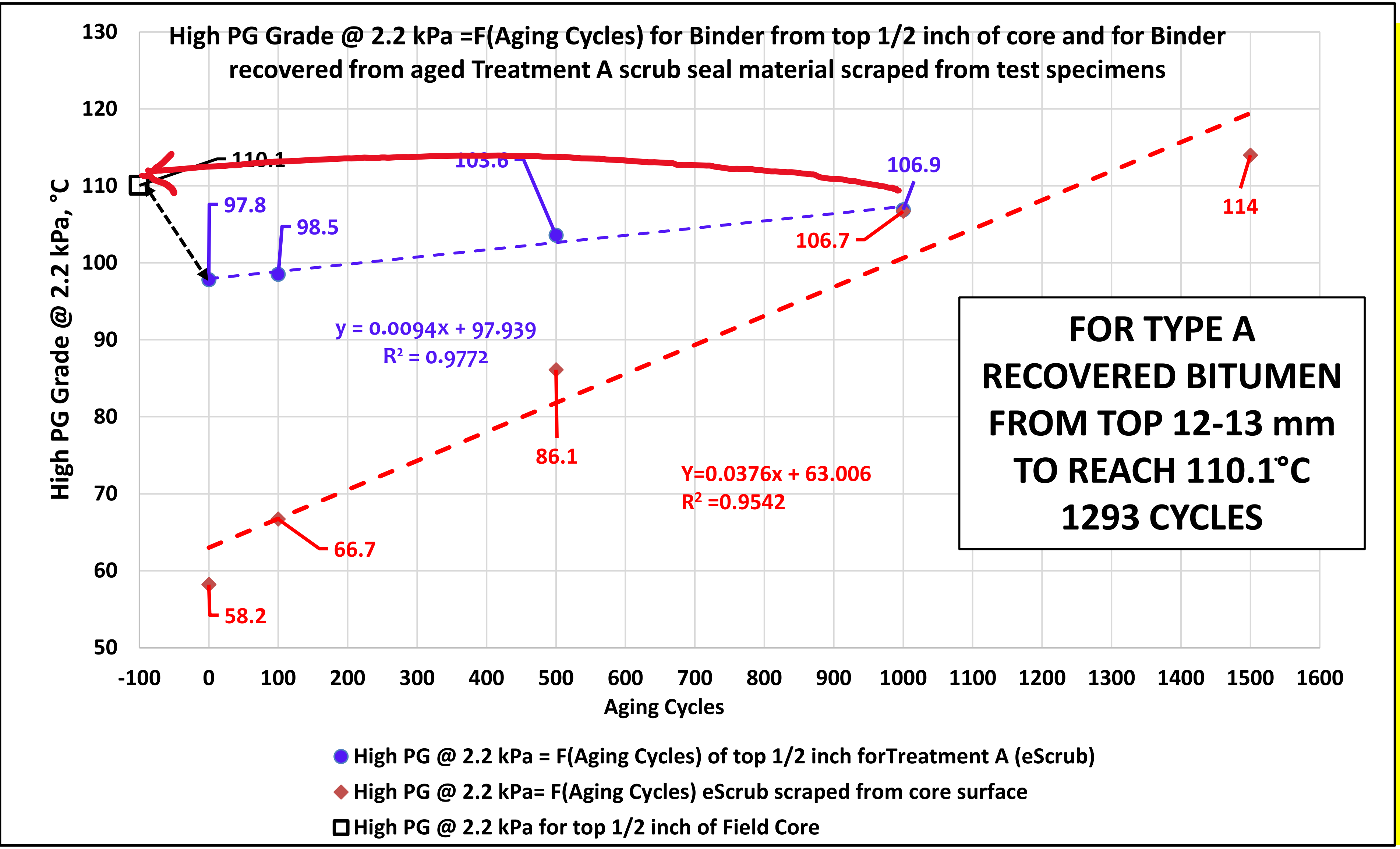


ΔT_C is generally well correlated to $T_{m\text{-}Critical}$ as shown in these plots

ΔT_C for all scrub seal emulsion residues age a slower rate (slope values) as a function of $T_{m\text{-}Critical}$ compared to the CRS-2P.

Although all emulsion residues have similar properties at zero aging cycles, Types A, B, and C residues have ΔT_C values more negative and $T_{m\text{-}Critical}$ values warmer than Type D residue after 1000 cycles. This is most likely due to the PG 52-34 bitumen base for the Type D emulsion

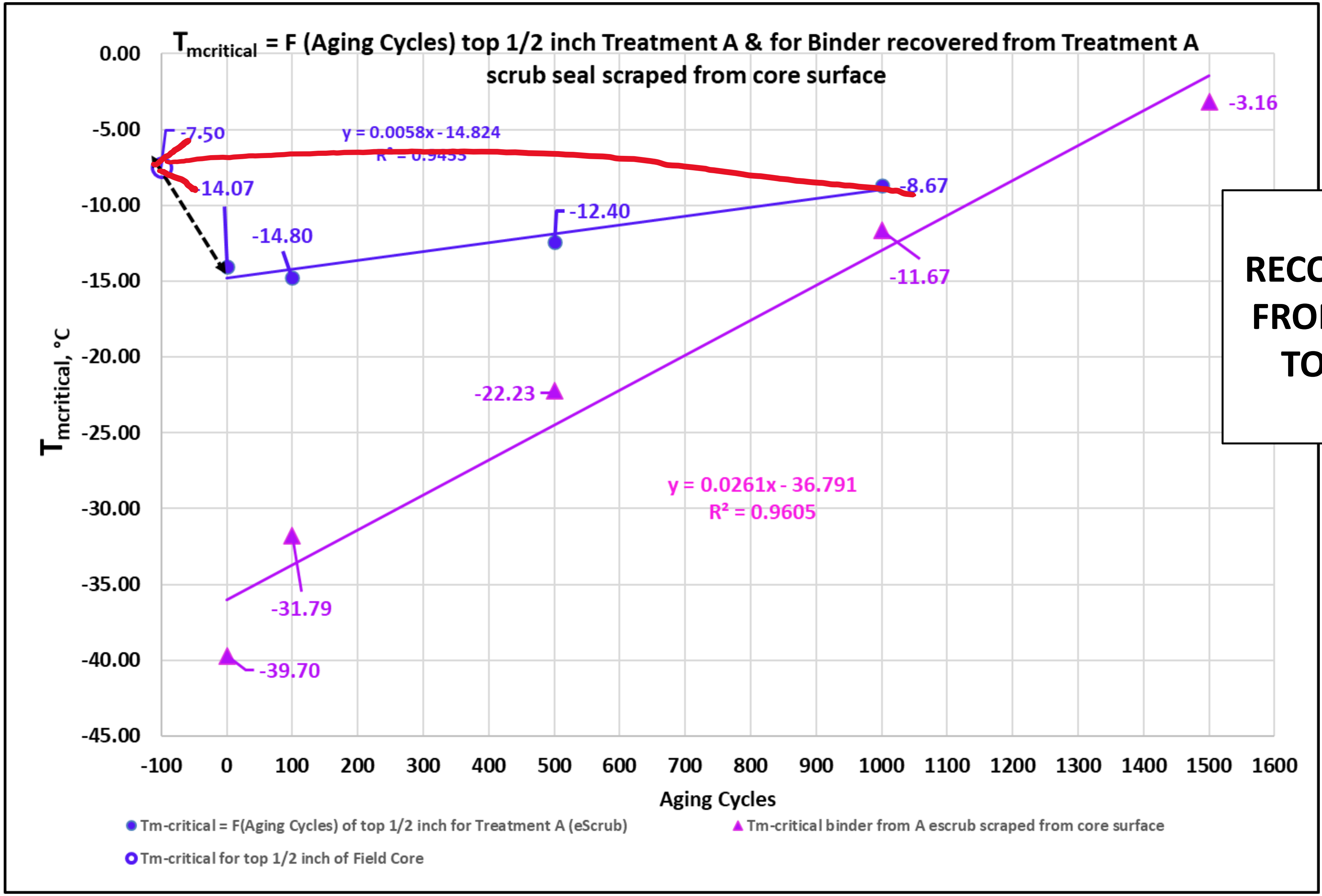
COMPARATIVE AGING OF BITUMEN FROM TOP 12-13 mm AND BITUMEN RECOVERED EMULSION REMOVED FROM CORE SURFACES—TYPE A SCRUB SEAL



For the following six slides a mathematical function was fit to the 0, 100, 500, and 1000 cycle data from top 12-13 mm and used to calculate how many cycles would be required to reach the average starting property of the bitumen recovered from the top 12-13 mm of the control cores.

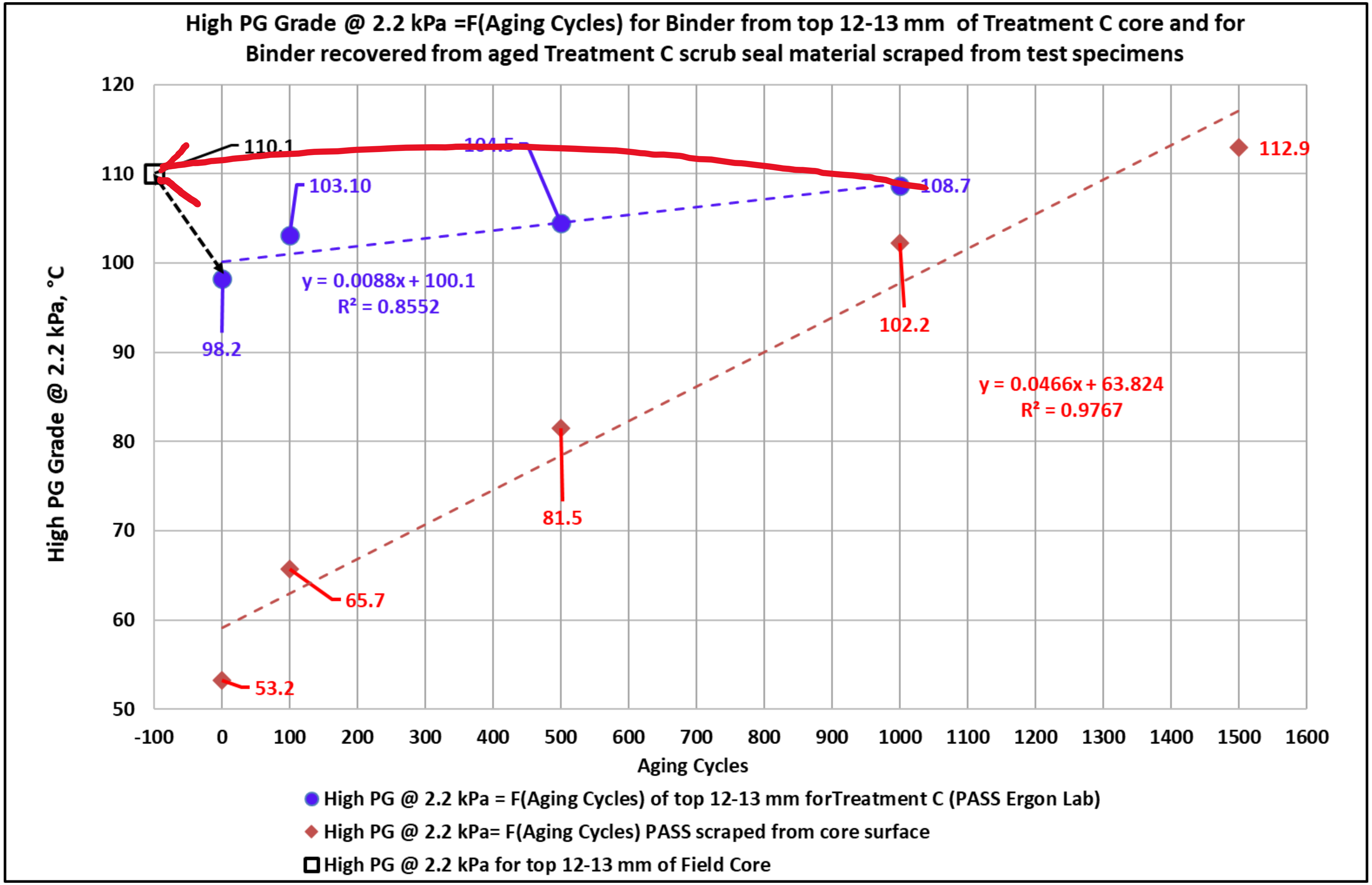
For most samples not much extrapolation was required, and the predicted equations had good R^2 results

COMPARATIVE AGING OF BITUMEN FROM TOP 12-13 mm AND BITUMEN RECOVERED EMULSION REMOVED FROM CORE SURFACES—TYPE A SCRUB SEAL



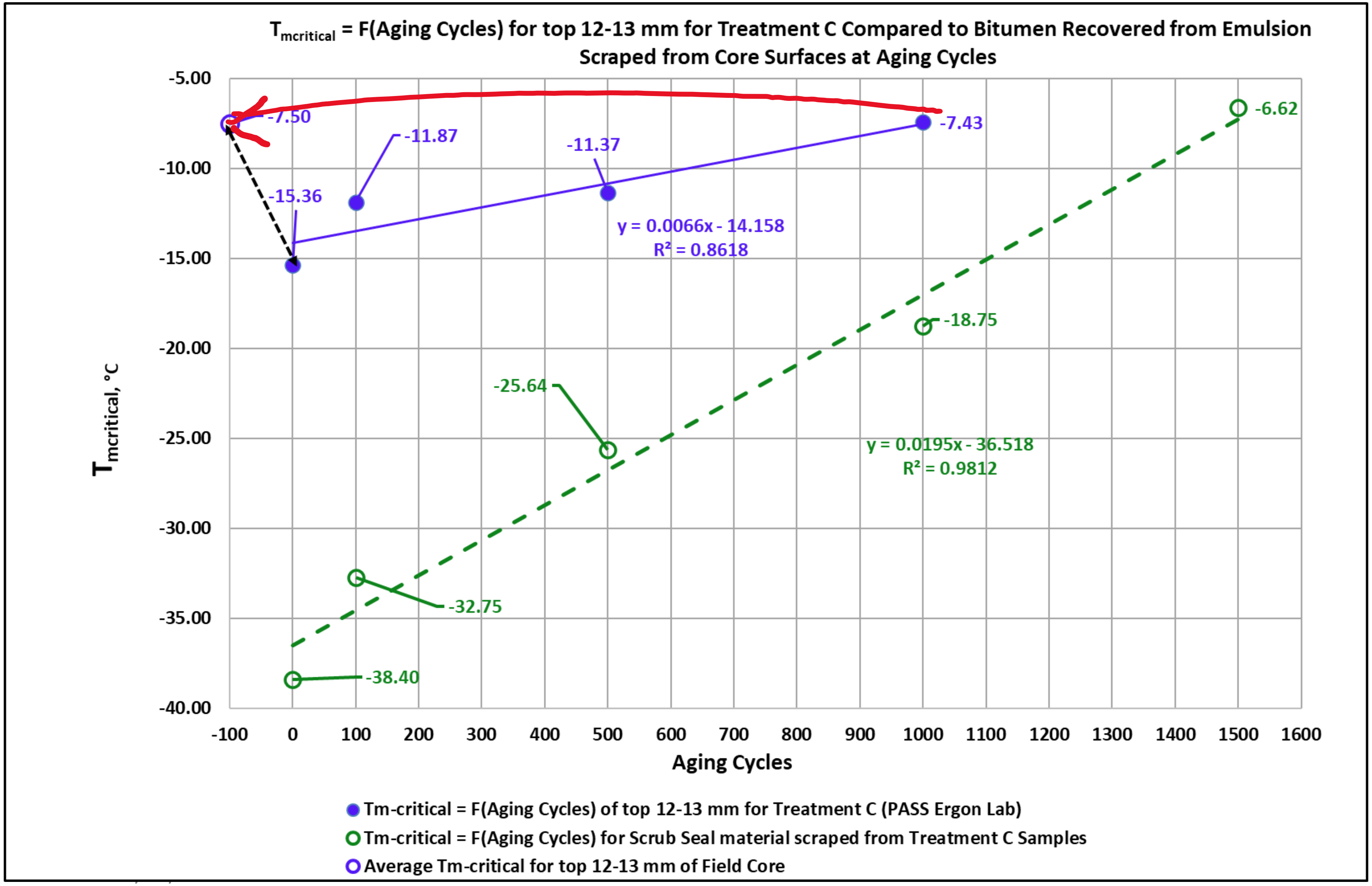
FOR TYPE A RECOVERED BITUMEN FROM TOP 12-13 mm TO REACH -7.50°C 1263 CYCLES

COMPARATIVE AGING OF BITUMEN FROM TOP 12-13 mm AND BITUMEN RECOVERED EMULSION REMOVED FROM CORE SURFACES—TYPE C SCRUB SEAL



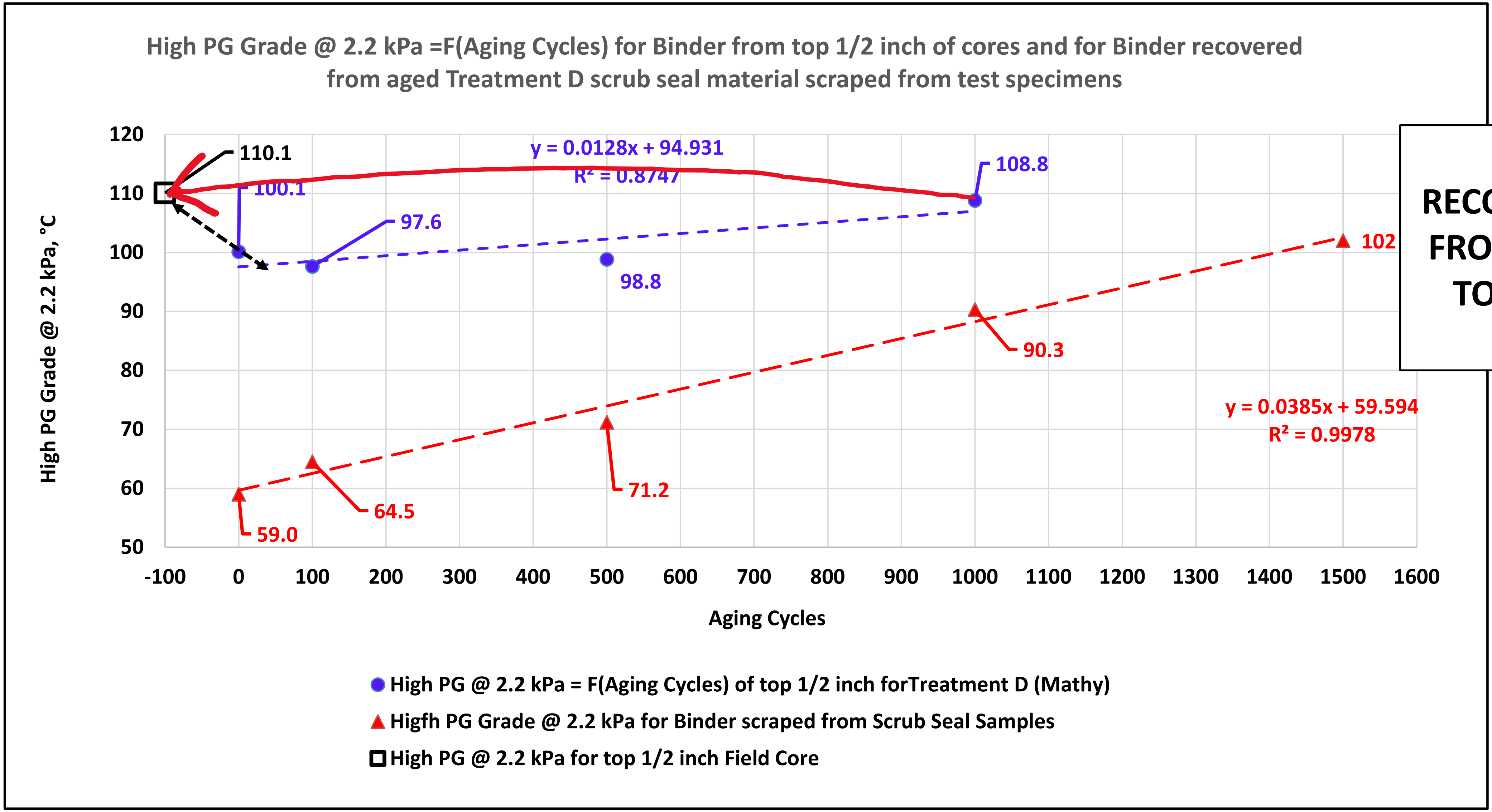
FOR TYPE C RECOVERED BITUMEN FROM TOP 12-13 mm TO REACH 110.1°C 1136 CYCLES

COMPARATIVE AGING OF BITUMEN FROM TOP 12-13 mm AND BITUMEN RECOVERED EMULSION REMOVED FROM CORE SURFACES—TYPE C SCRUB SEAL



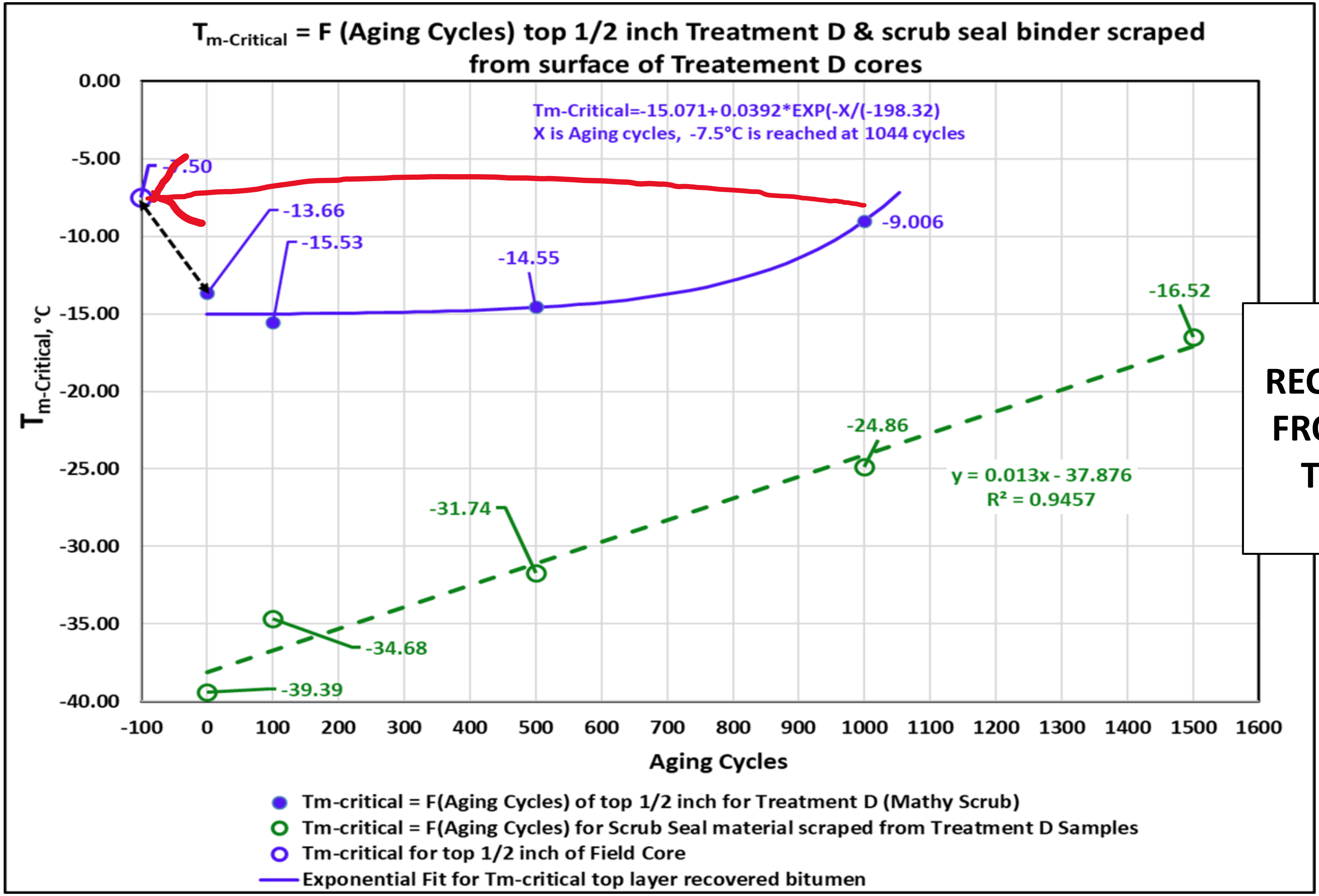
FOR TYPE C RECOVERED BITUMEN FROM TOP 12-13 mm TO REACH -7.50°C 1008 CYCLES

COMPARATIVE AGING OF BITUMEN FROM TOP 12-13 mm AND BITUMEN RECOVERED EMULSION REMOVED FROM CORE SURFACES—TYPE D SCRUB SEAL



FOR TYPE D RECOVERED BITUMEN FROM TOP 12-13 mm TO REACH 110.1°C 1185 CYCLES

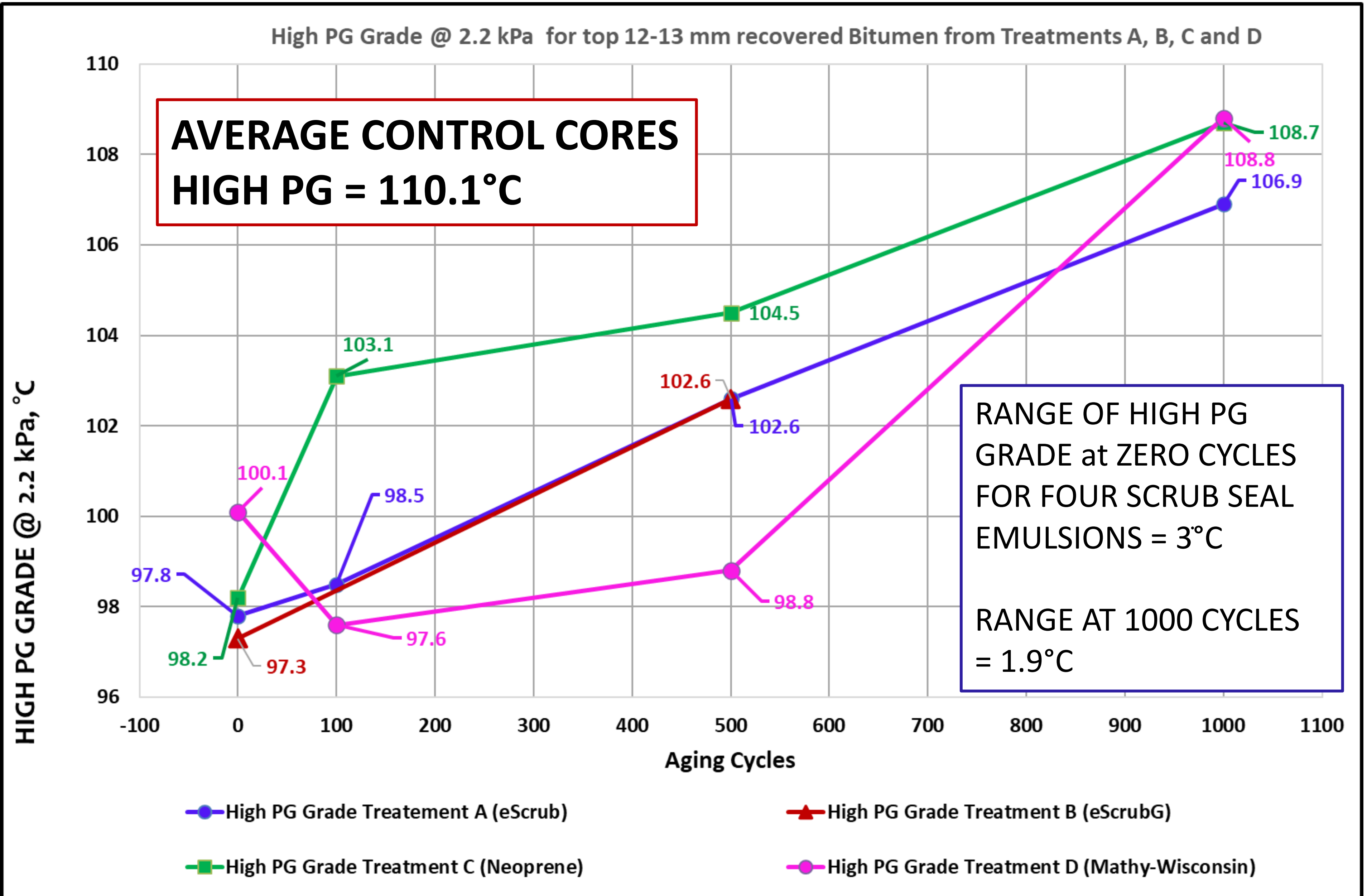
COMPARATIVE AGING OF BITUMEN FROM TOP 12-13 mm AND BITUMEN RECOVERED EMULSION REMOVED FROM CORE SURFACES—TYPE D SCRUB SEAL



TYPE D $T_{m\text{-Critical}}$ REQUIRED an EXPONENTIAL FIT DUE TO THE DATA SCATTER. A LINEAR FIT HAD R^2 =0.68, WHEREAS THE EXPONENTIAL FIT R^2 =0.91.

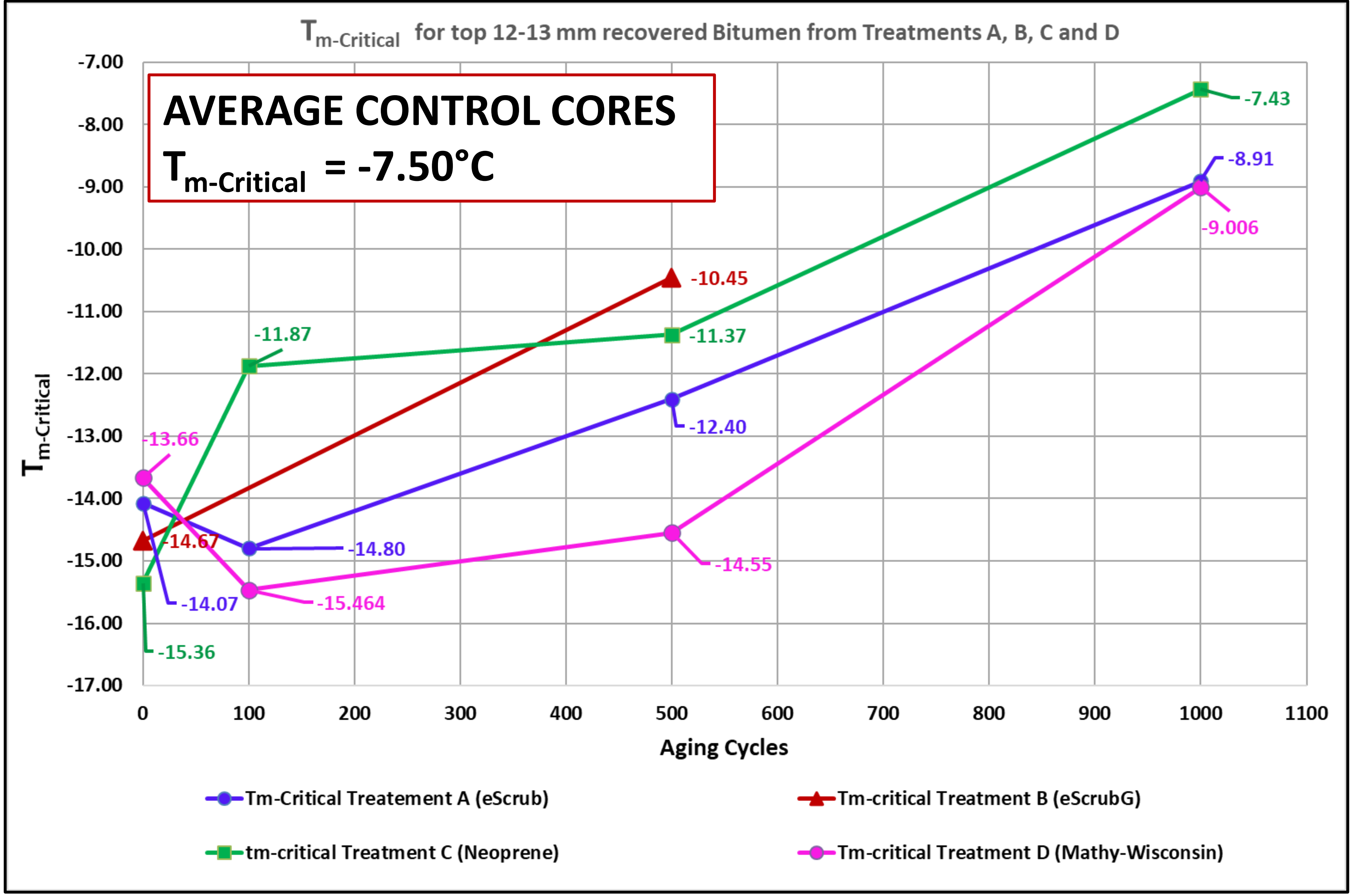
FOR TYPE D RECOVERED BITUMEN FROM TOP 12-13 mm TO REACH -7.50°C 1043 CYCLES

COMPARISON OF HIGH PG GRADE AGING OF BITUMEN FROM TOP 12-13 mm FOR SCRUB SEAL TYPES A, B, C, & D



FOR HIGH PG GRADE DATA (this slide) and $T_{m\text{-}Critical}$, next slide and ΔT_C third slide the data for each parameter tends toward a common value at 1000 cycles.
As seen from the previous six slides high PG Grades and low $T_{m\text{-}Critical}$ values trended toward the region of 1000 cycles to a maximum value 1293 cycles.
One could judge that these scrub seal emulsions had reached a near end of functionality by 1000 cycles.

COMPARISON OF $T_{m\text{-CRITICAL}}$ AGING OF BITUMEN FROM TOP 12-13 mm FOR SCRUB SEAL TYPES A, B, C, & D



RANGE OF $T_{m\text{-Critical}}$ at ZERO CYCLES FOR FOUR SCRUB SEAL EMULSIONS = 2°C

RANGE AT 1000 CYCLES = 1.6°C

DISCUSSION & COMMENTS 1

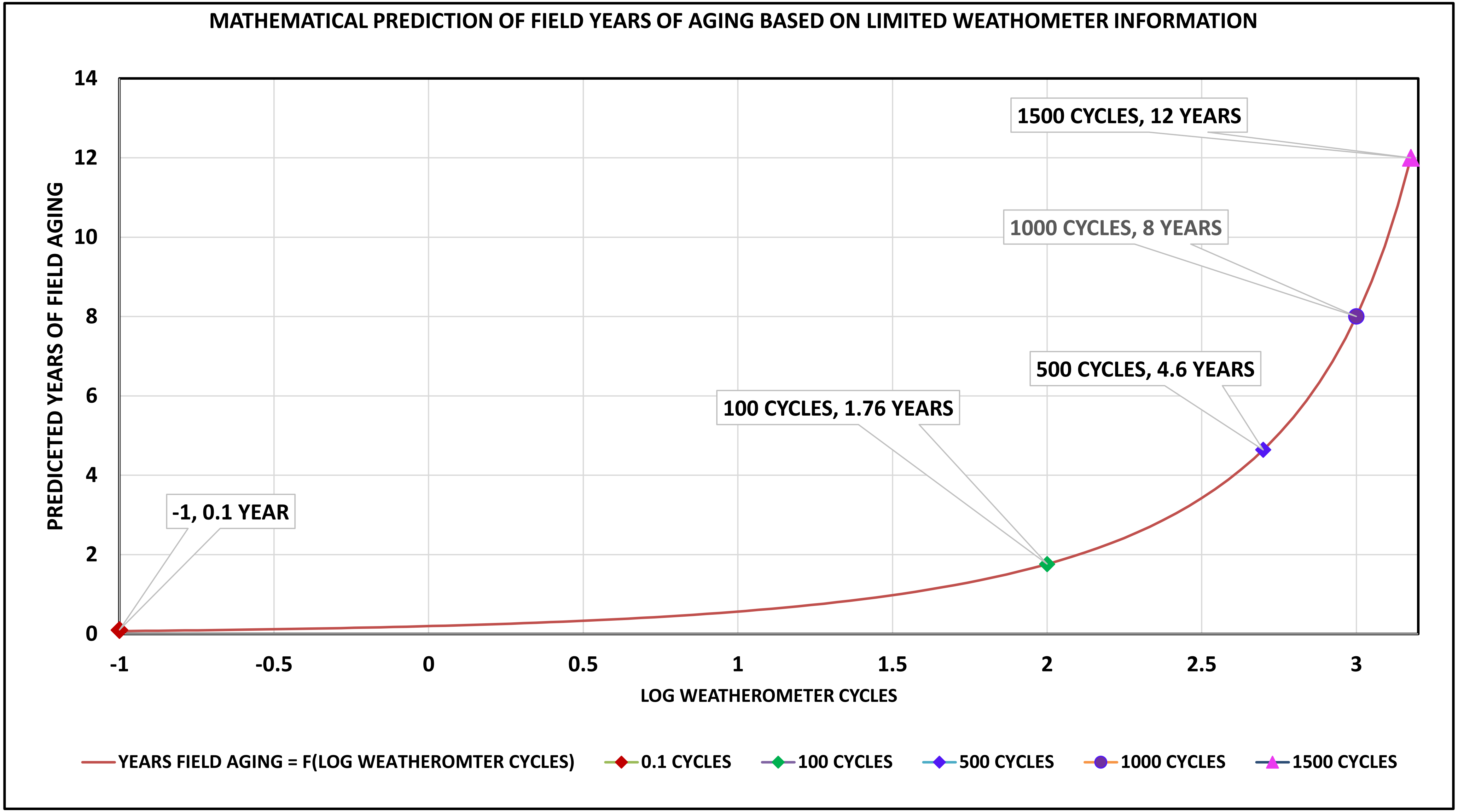
A. **Results of bitumen recovered from top 12-13 mm layers showed scrub seal emulsion treatments have a softening impact in the short term (≈ 1 month) and after 100 cycles of weatherometer conditioning based on comparison to the average results from control cores**

B. **Based on Aging Slopes High PG Grade of bitumen Recovered from top 12-13 mm stiffened at a slightly faster rate than did $T_{m\text{-}Critical}$ with aging time (see slides 12-17)**

C. **Based on Aging Slopes High PG Grade of Bitumen Recovered from Emulsion Layers Scraped from Core Surfaces Increased at a Faster Rate than the Rate at Which $T_{m\text{-}Critical}$ Increased with aging time (see slides 12-17)**

D. **By 500 cycles of conditioning both high and low temperature results show evidence of aging**
   a. Using zero cycles as zero time and the PRI estimate of 1000 cycles being 8 years of service and 1500 cycles being 12 of service, we have arrived at an estimate of 100 cycles approximating 1.8 years of field aging and 500 cycles approximating 4.7 years of field aging. Theses are mathematical estimates, but the 100-cycle data is consistent with the one-year aged data presented in the 2016 Hanz paper. ***[see next slide for graph]***

E. **The weatherometer conditioning procedure has been shown to accelerate aging of the scrub seal treated aged pavement cores and the applied emulsion, which is the purpose of the equipment**
   a. Bitumen recovered from emulsion treatments scraped from core surfaces at increased times showed evidence of both high and low temperature aging
   b. Bitumen recovered from top 12-13 mm of treated cores shows evidence of stiffening at both high and low temperatures
   c. Bitumen recovered from the applied emulsion aged more rapidly than did the bitumen recovered from the top 12-13 mm layer of treated cores (shown in slides 12-17)


MATHEMATICAL PREDICTION OF FIELD YEARS OF AGING BASED ON LIMITED WEATHOMETER INFORMATION
PREDICETED YEARS OF FIELD AGING
LOG WEATHEROMETER CYCLES
1500 CYCLES, 12 YEARS
1000 CYCLES, 8 YEARS
500 CYCLES, 4.6 YEARS
100 CYCLES, 1.76 YEARS
-1, 0.1 YEAR
YEARS FIELD AGING = F(LOG WEATHEROMTER CYCLES)
0.1 CYCLES
100 CYCLES
500 CYCLES
1000 CYCLES
1500 CYCLES

DISCUSSION & COMMENTS 2

E. CONTINUED

d) Data from the **second 12-13 mm layers** for the three control cores (data in paper) exhibited substantially better properties than the bitumen from the top layer. For this reason, we did not pursue data for the second layers of the treated core

e) Pavements treated with scrub seal emulsions under real world traffic may show some benefit at depths below 13 mm that were not identified in the weatherometer study which is a passive conditioning procedure (NO TRAFFIC ACTION TO FORCE EMULSION RESIDUE INTO PAVEMENT BEING TREATED)

f) The data in this weatherometer study show that by an estimated time of 2 to 4 years (100 to 500 cycles) high and low temperature trends show signs of aging.

g) It appears from the lab-based data the main improvement in the surface mix occurs rapidly (within a month in this study) and up to two years and then gradually begins to decline

h) Based on the data shown in slides 12-17 after 1000 cycles (estimated to be 8 years in service) high and low PG bitumen properties have not reached the starting values of the control cores prior to application **but are very close**. Based on these data 8 years appears beyond the useful life of the scrub seal

i) This point should be further explored and in so doing a second scrub seal or fog seal treatment should be applied after 4 to 5 years.

THANK YOU FOR TIME AND ATTENTION
I CAN BE REACHED AT
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THOSE GUYS ON TOP OF THE HILL ALL HAD QUESTIONS ABOUT WHETHER SCRUB SEALS WOULD WORK

NOW IT IS YOUR TURN TO ASK QUESTIONS

We acknowledge the hard work of those that performed the testing of these materials, as the amount of data shows this was no small effort
Doug Herlitzka, Steve Engber, and Mary Ryan

Special acknowledgement to Dr. Isaac Howard of Mississippi State University for identifying the abandoned pavement from which we obtained the aged cores for this investigation and to his students who cut and cleaned the cores for our use.