FINAL REPORT ON LONG TERM OUTDOOR AGING STUDY OF WARM MIX SAMPLES
MTE SERVICES, INC
& THREE YEAR COMPARISON OF PG 58-28 HMA & WMA

WARM MIX TECHNICAL WORKING GROUP MEETING
OCTOBER 27-28, 2010
OKLAHOMA CITY, OK

by
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BACKGROUND

WARM MIX PRODUCED USING PG 58-28 + 0.65% EVOTHERM 3G + 35% RAP 8/26/2008

PAVED ON COUNTY ROAD IN WISCONSIN with a 1 MILLION ESAL MIX

30 FIVE GALLON PAILS OF MIX TAKEN TO COMPACT RUT PILLS, AMPT PILLS, 95 mm PILLS

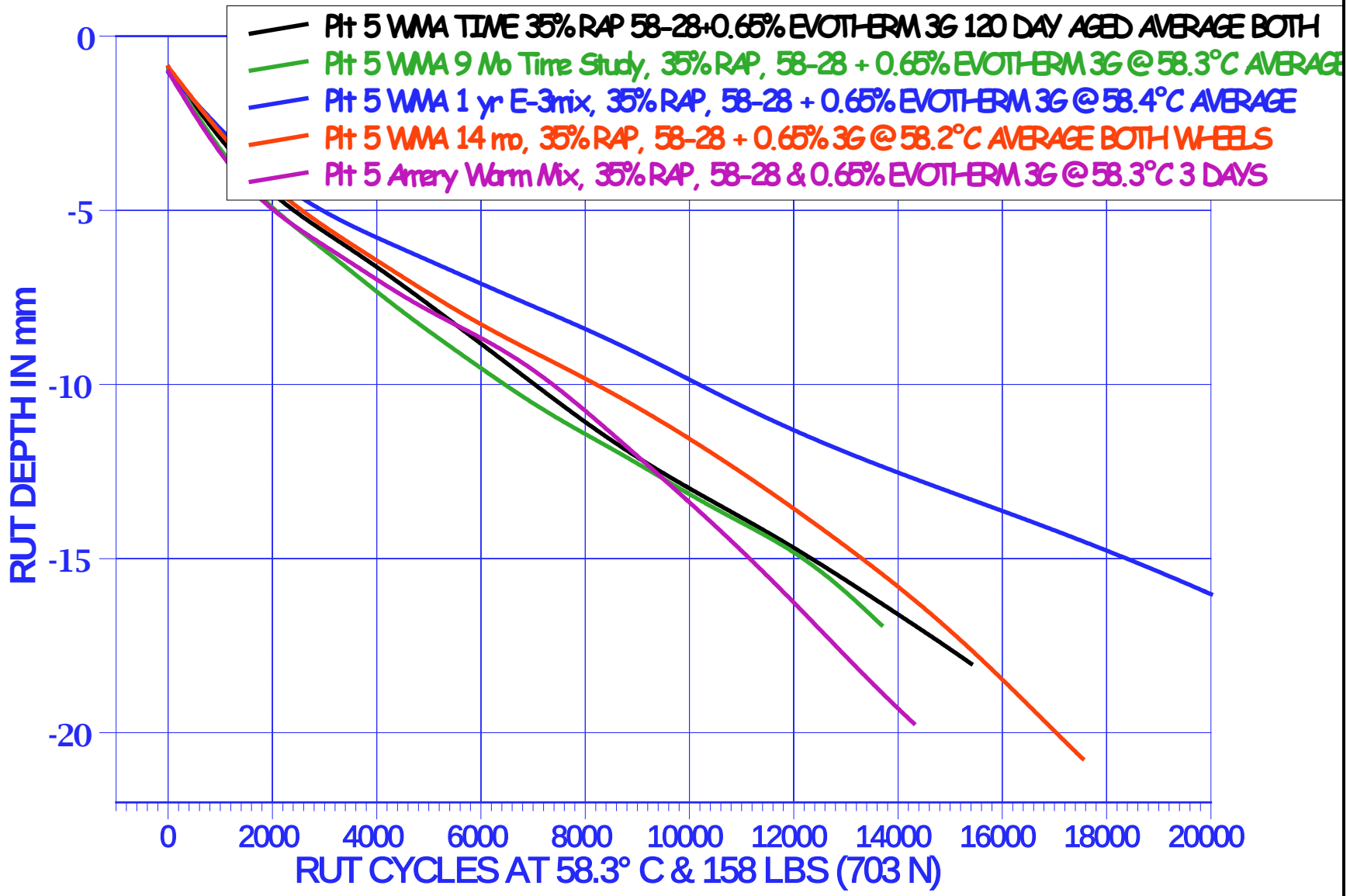
COMPACTED PILLS STORED OUTSIDE TO AGE

PERIODICALLY SAMPLES DRAWN AND TESTED

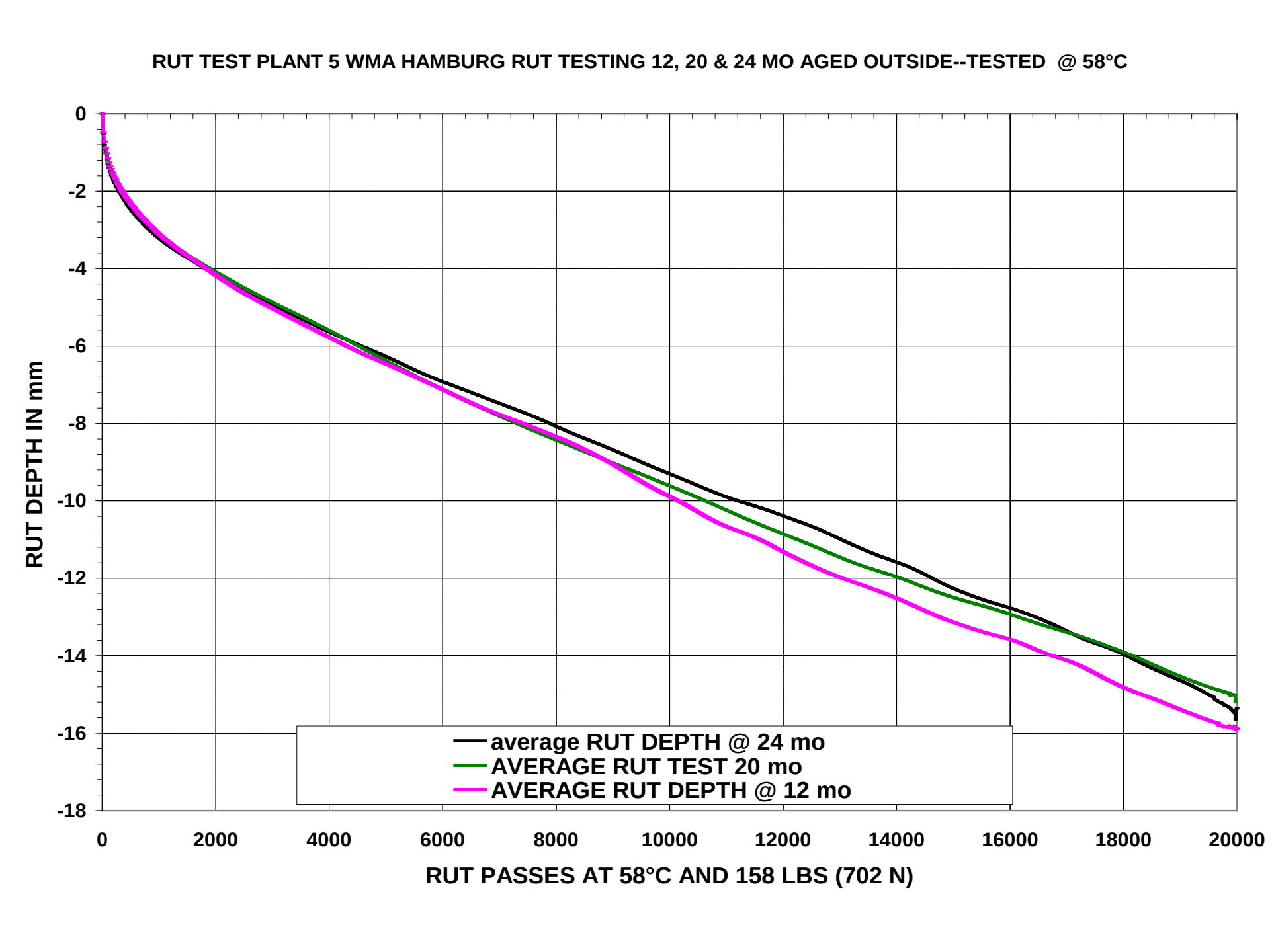
UNCOMPACTED MIX STORED AT 40°F FOR FUTURE WORK


DANGER

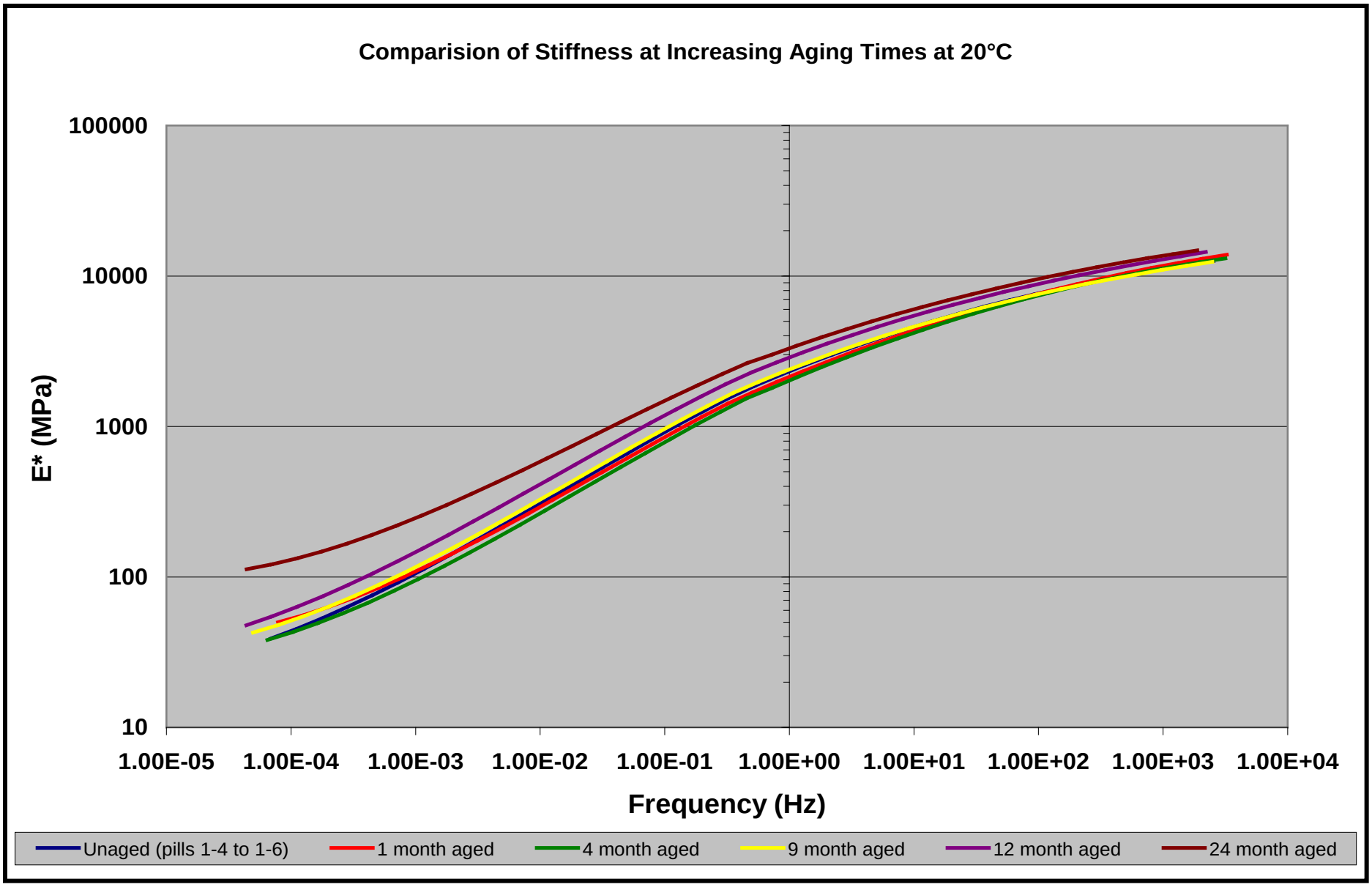
PLT 5 WARM MIX TIME STUDY PG 58-28 + 0.65% EVOTHERM 3G
TESTED IN HAMBURG DRY AT 58.3° C, 158# LOAD
PLANT MIX CONDITIONED OUTSIDE FROM 9/19/08 TO ONGOING

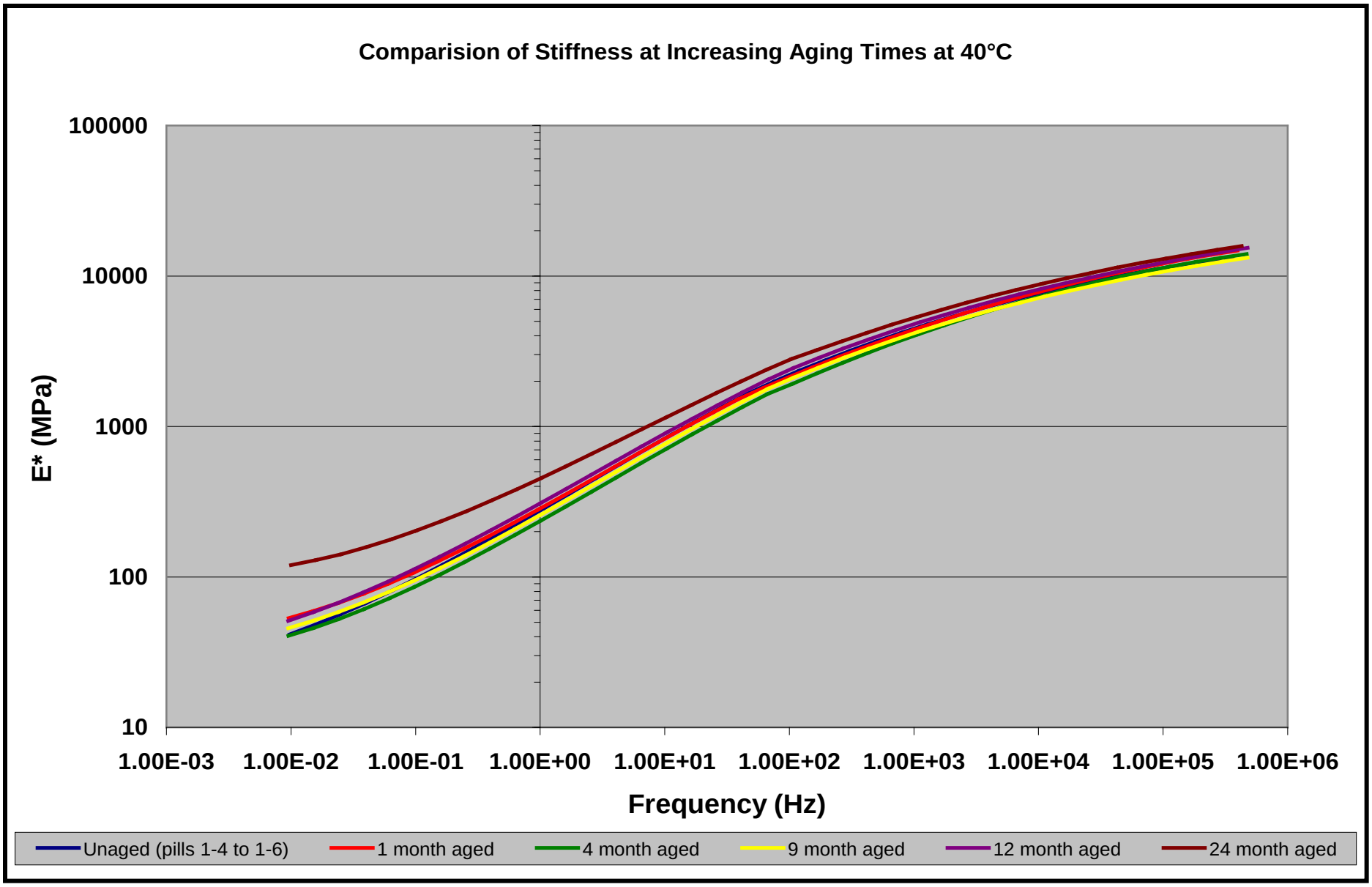


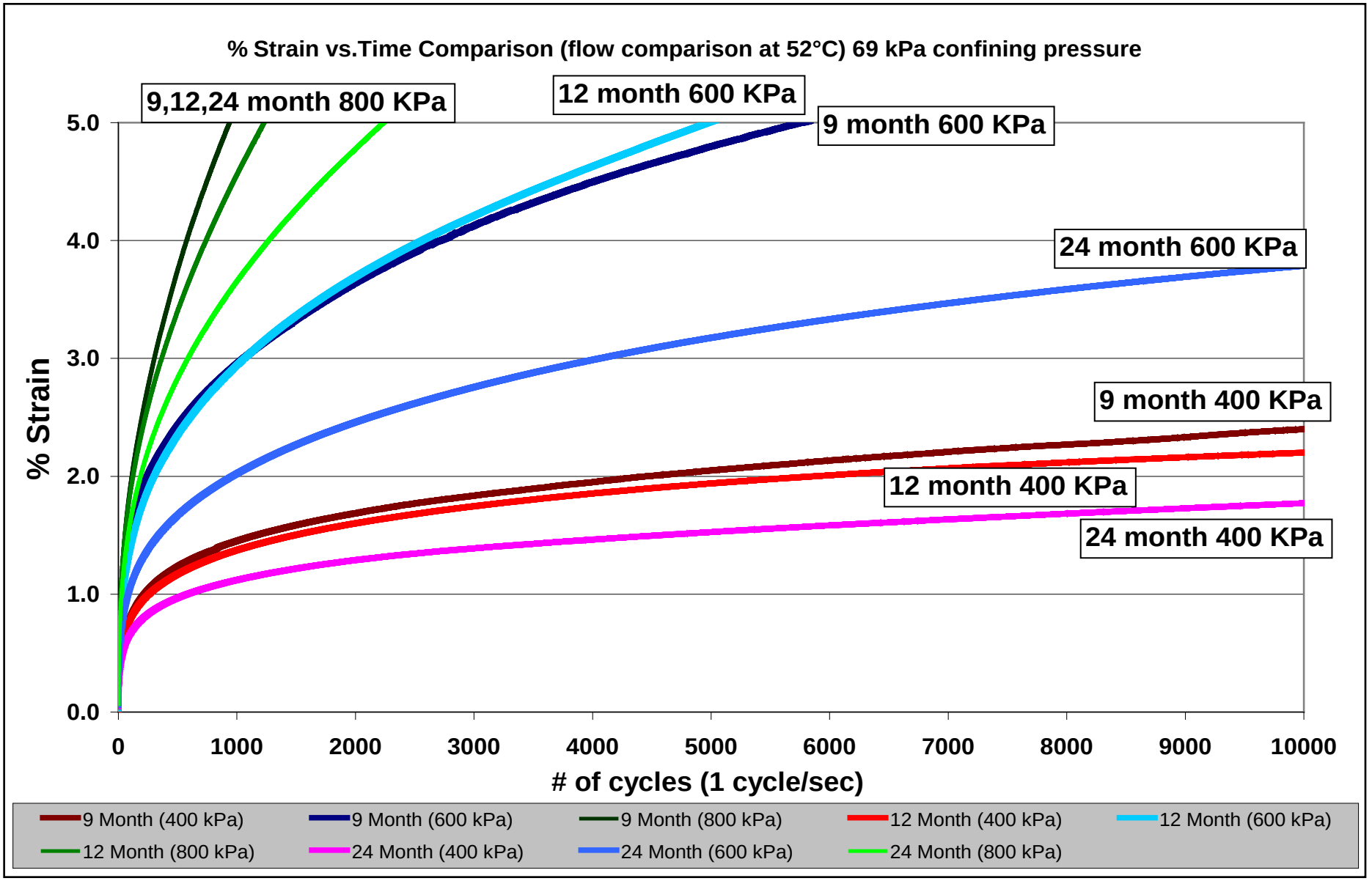
12/16/09 01:58:12 E:\DRIVE E\PMW 2009\WARM MIX 2009\COMPARE RUT PLT 5 WMA AT 4, 9 AND 12 MONTHS AGING.spf


RUT TEST PLANT 5 WMA HAMBURG RUT TESTING 12, 20 & 24 MO AGED OUTSIDE--TESTED @ 58°C
RUT DEPTH IN mm
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
RUT PASSES AT 58°C AND 158 LBS (702 N)
average RUT DEPTH @ 24 mo
AVERAGE RUT TEST 20 mo
AVERAGE RUT DEPTH @ 12 mo

PLANT 5 WARM MIX, 35% RAP, 0.65% EVOTHERM 3G			
AGE	PG GRADE RECOVERED AC	PG GRADE PAV OF REC AC	CHANGE IN LOW TEMP GRADE
ZERO DAY	65.1-33.4	65.1-30.4	3.0
ZERO DAY	66.2-33.0	66.2-29.9	3.1
2 WEEK	68.1-32.1	68.1-29.4	2.7
7 MONTH	68.8-32.1		
9 MONTH	69.5-31.9		
12 MONTH	69.5-31.6	69.5-28	3.6
14 MONTH	70.1-31.1	70.1-28.4	2.7
24 MONTH	**72.9-30.3**	**72.9-28.8**	**1.5**


Comparision of Stiffness at Increasing Aging Times at 20°C
100000
10000
1000
100
10
E* (MPa)
1.00E-05
1.00E-04
1.00E-03
1.00E-02
1.00E-01
1.00E+00
1.00E+01
1.00E+02
1.00E+03
1.00E+04
Frequency (Hz)
Unaged (pills 1-4 to 1-6)
1 month aged
4 month aged
9 month aged
12 month aged
24 month aged

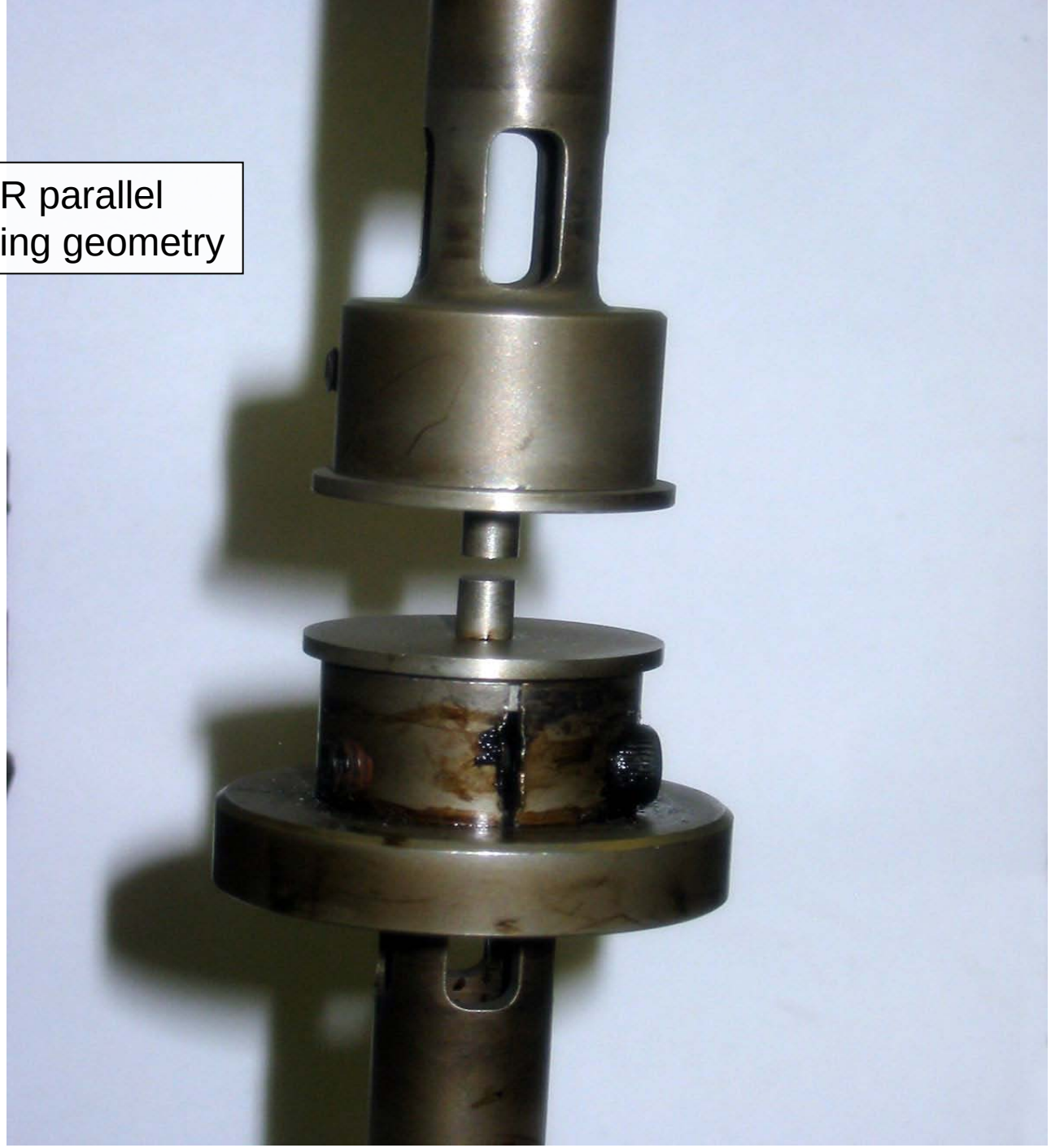

Comparision of Stiffness at Increasing Aging Times at 40°C
100000
10000
1000
100
10
E* (MPa)
1.00E-03
1.00E-02
1.00E-01
1.00E+00
1.00E+01
1.00E+02
1.00E+03
1.00E+04
1.00E+05
1.00E+06
Frequency (Hz)
Unaged (pills 1-4 to 1-6)
1 month aged
4 month aged
9 month aged
12 month aged
24 month aged

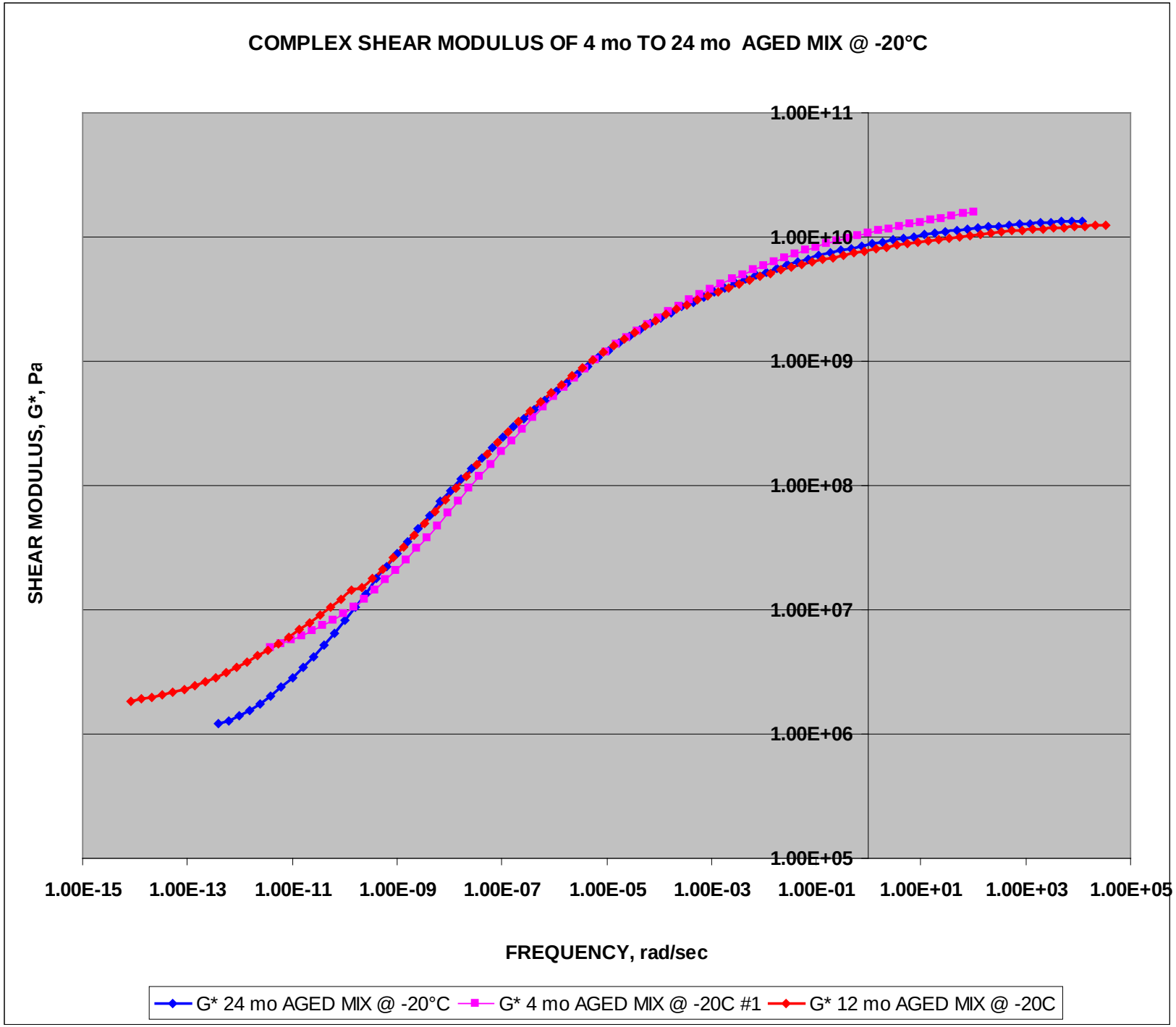

% Strain vs.Time Comparison (flow comparison at 52°C) 69 kPa confining pressure
9,12,24 month 800 KPa
12 month 600 KPa
9 month 600 KPa
24 month 600 KPa
9 month 400 KPa
12 month 400 KPa
24 month 400 KPa
% Strain
5.0
4.0
3.0
2.0
1.0
0.0
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
# of cycles (1 cycle/sec)
9 Month (400 kPa)
9 Month (600 kPa)
9 Month (800 kPa)
12 Month (400 kPa)
12 Month (600 kPa)
12 Month (800 kPa)
24 Month (400 kPa)
24 Month (600 kPa)
24 Month (800 kPa)

VECD ANALYSIS OF RECOVERED BINDER SAMPLES USING STRAIN SWEEP TEST AND ANALYSIS DEVELOPED BY BAHIA @ UW-MADISON

STRAIN LEVEL, %	*Nf @ 0*	*Nf @ 7 mo*	*Nf @ 9 mo*	*Nf @ 12 mo*	*Nf @ 22 mo*	*Nf @ 24 mo*
0.50	35,913	30,151	28,067	23,624	41,853	35,243
2.50	1,928	1,623	1,563	1,349	2,198	1,914
5.00	547	461	451	393	618	546

4 mm DSR parallel
Plate testing geometry




COMPLEX SHEAR MODULUS OF 4 mo TO 24 mo AGED MIX @ -20°C
SHEAR MODULUS, G*, Pa
1.00E+11
1.00E+10
1.00E+09
1.00E+08
1.00E+07
1.00E+06
1.00E+05
1.00E-15
1.00E-13
1.00E-11
1.00E-09
1.00E-07
1.00E-05
1.00E-03
1.00E-01
1.00E+01
1.00E+03
1.00E+05
FREQUENCY, rad/sec
G* 24 mo AGED MIX @ -20°C
G* 4 mo AGED MIX @ -20C #1
G* 12 mo AGED MIX @ -20C

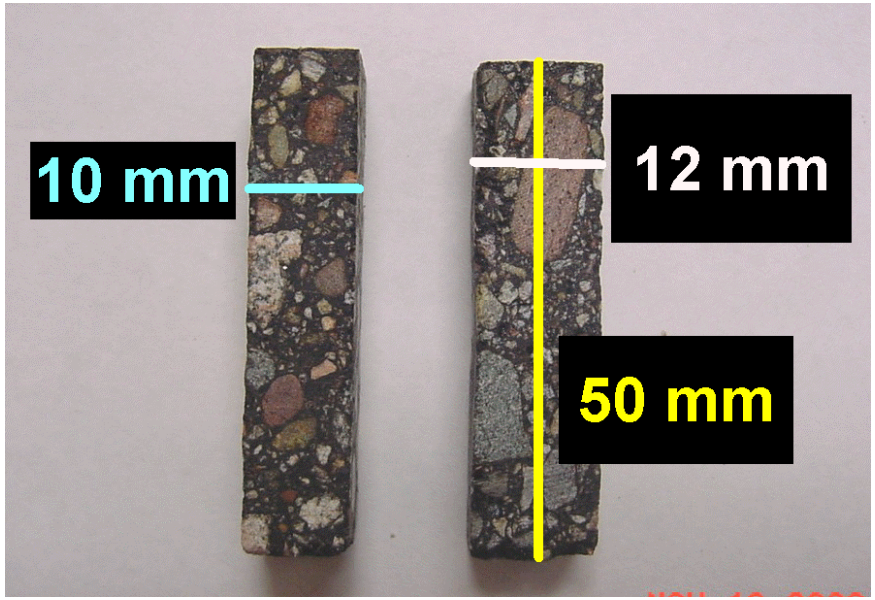
FINAL THOUGHTS

- After 2 years of outside aging there does appear to be an increase in mixture modulus and some reduction creep strain from flow number test
- Rut test results @ 58°C dry appear to have leveled off after 20 months
- High temp PG grade increased by ≅ 7°C
- Low temp PG grade increased by ≅ 2°C
- Recovered binder fatigue test properties @ 19°C have shown no trend


WI STATE Hwy 33, paved Sept 2007
58-28 warm mix
58-28 hot mix

Sample Preparation for DSR Creep Test

Final Size Target
50 mm x 12 mm x 10mm



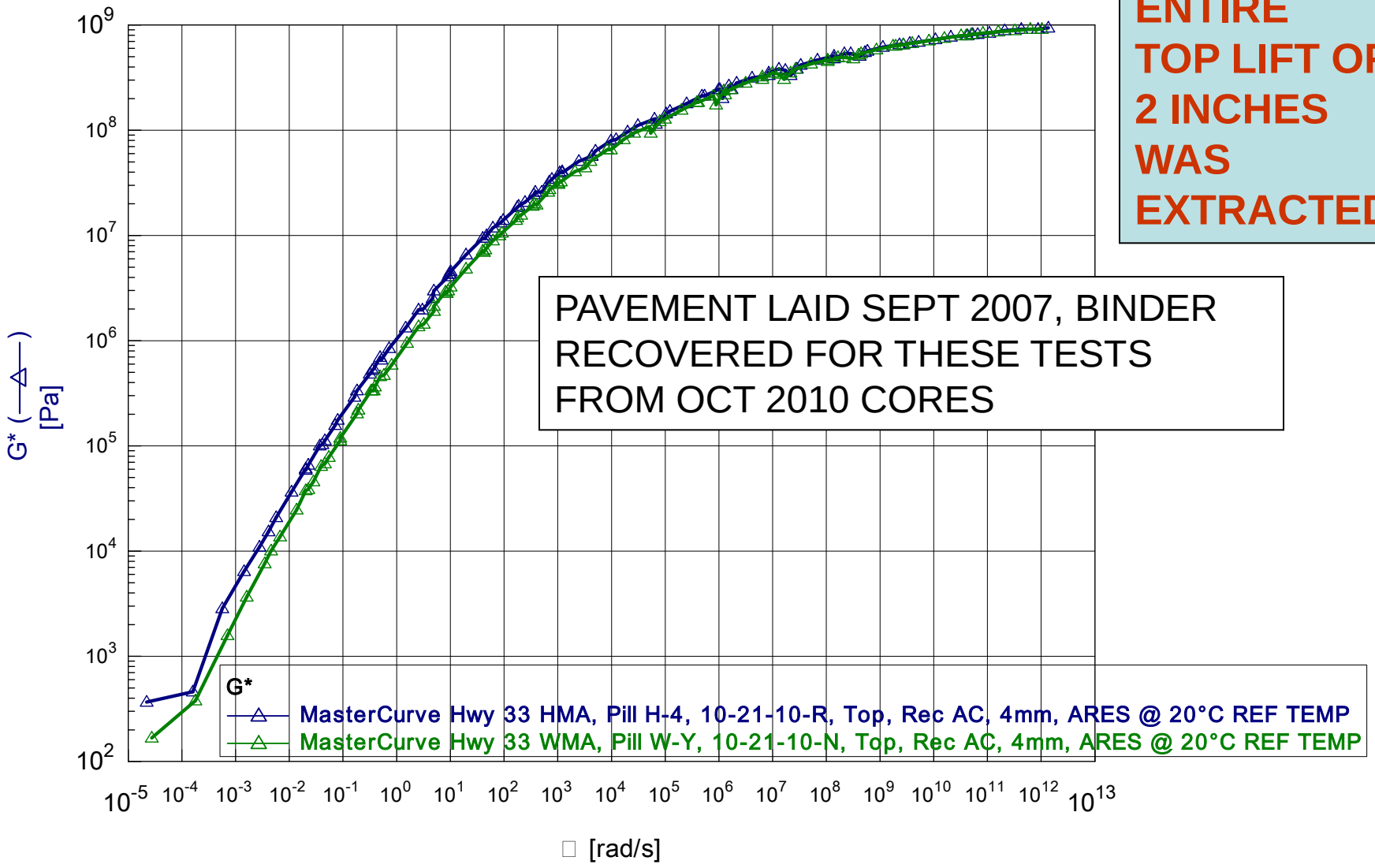
Temperature frequency

Sweeps performed to determine

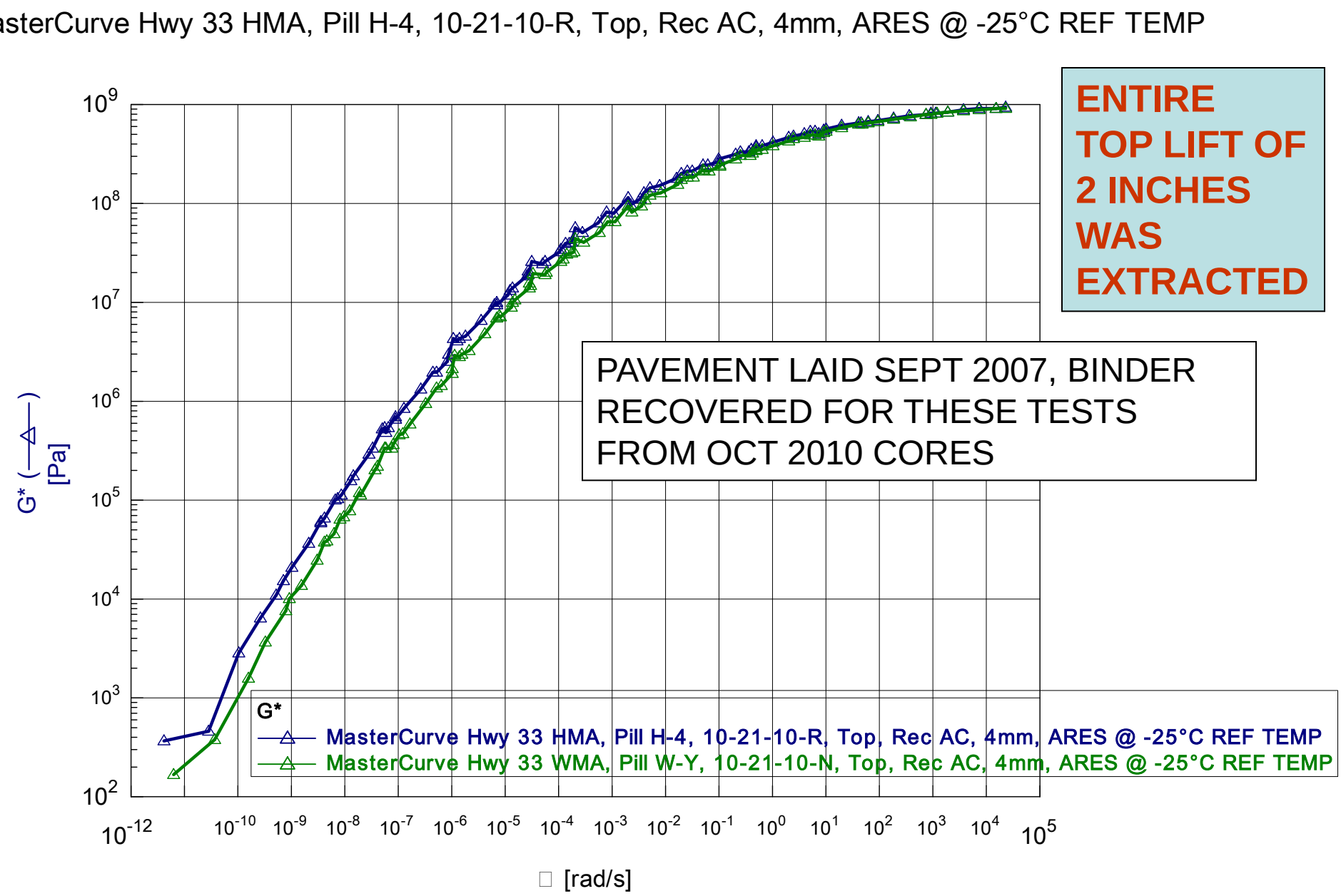
Complex modulus （G∗） of mix

RESULTS FROM 4 mm DSR TESTING @ +20°C REFERENCE TEMP

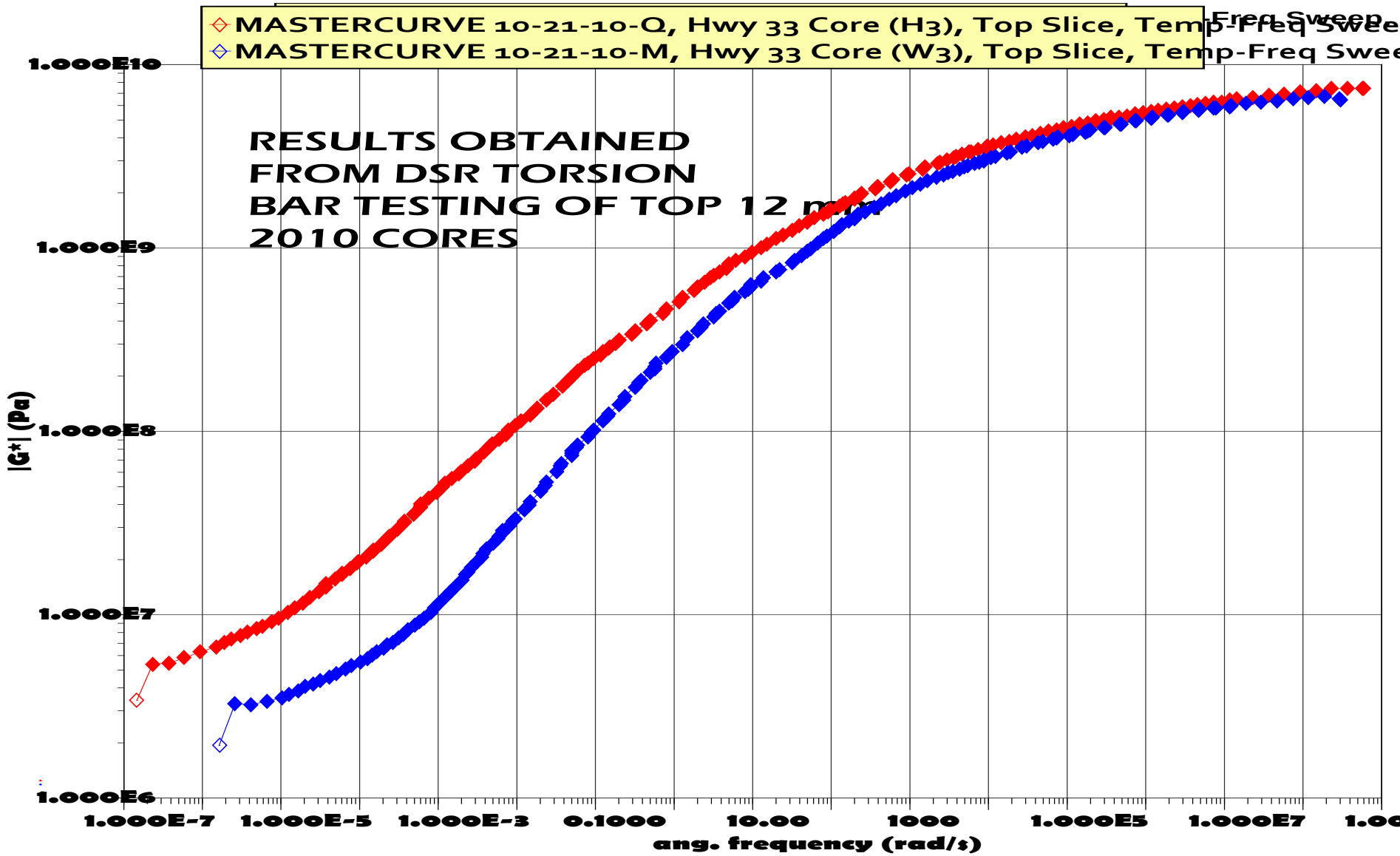
MasterCurve Hwy 33 HMA, Pill H-4, 10-21-10-R, Top, Rec AC, 4mm, ARES @ 20°C REF TEMP

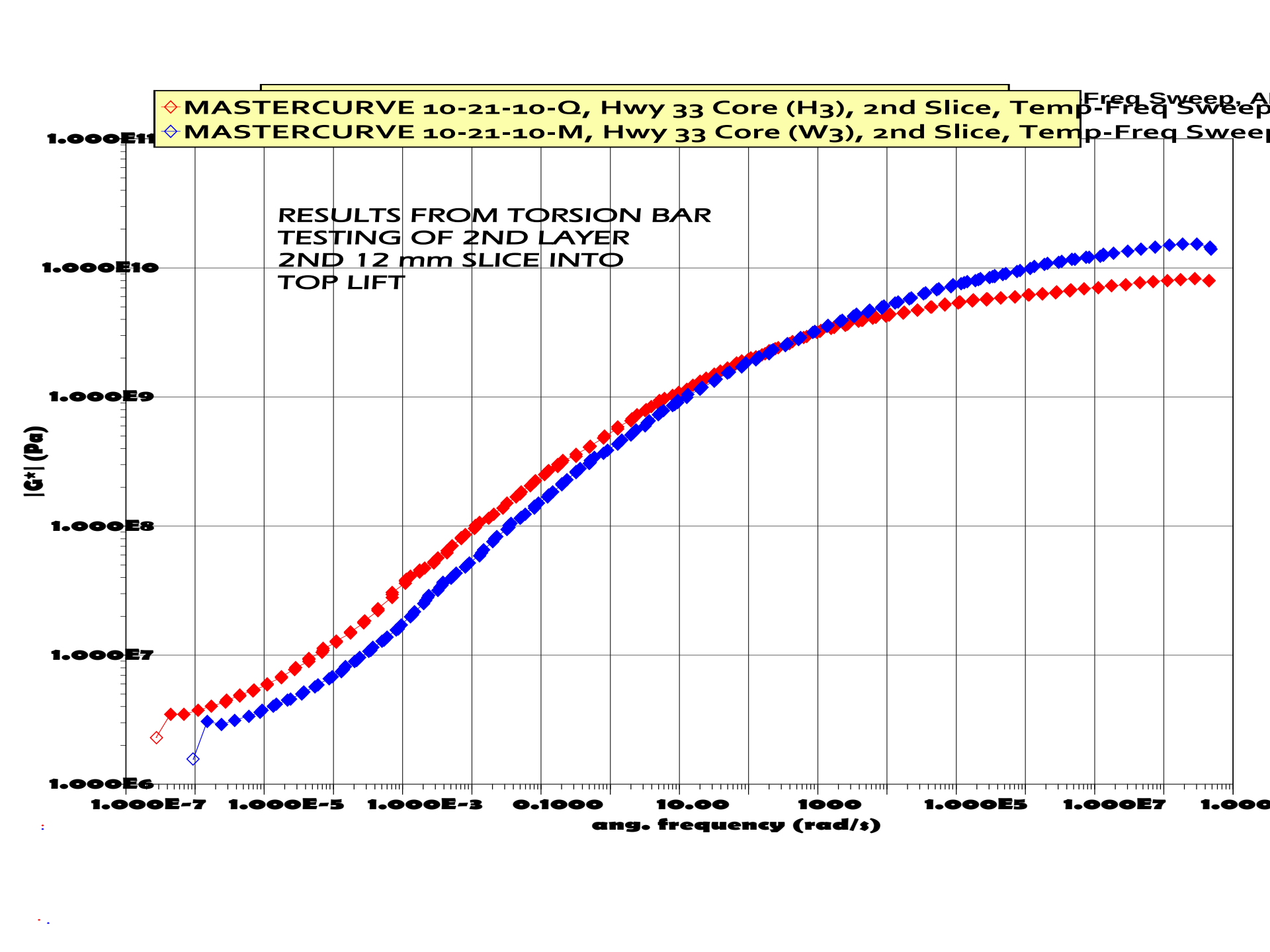


RESULTS FROM 4 mm DSR TESTING @ -25°C reference temp



TORSION BAR G* RESULTS AT 20°C REF TEMP ON 3 YEAR OLD MIX




MASTERCURVE 10-21-10-Q, Hwy 33 Core (H3), 2nd Slice, Temp-Freq Sweep
MASTERCURVE 10-21-10-M, Hwy 33 Core (W3), 2nd Slice, Temp-Freq Sweep
RESULTS FROM TORSION BAR
TESTING OF 2ND LAYER
2ND 12 mm SLICE INTO
TOP LIFT
1.000E11
1.000E10
1.000E9
1.000E8
1.000E7
1.000E6
|G*| (Pa)
1.000E-7
1.000E-5
1.000E-3
0.1000
10.00
1000
1.000E5
1.000E7
ang. frequency (rad/s)

MIX SOURCE	HIGH PG GRADE	LOW PG GRADE
WI HWY 33 HMA 1 YR	PG 60.5	PG -35.2
WI HWY 33 HMA 3 YR	PG 68.0	PG -31.4
WI HWY 33 WMA 1 YR	PG 58.9	PG -36.3
WI HWY 33 WMA 3 YR	PG 65.5	PG -32.6

ENTIRE TOP LIFT OF 2 INCHES WAS EXTRACTED

SOME FINAL THOUGHTS

- After 3 seasons the HMA and WMA recovered binders are 2°C apart at the high temp grade and 1.2°C apart at the low temp grade.
- 4 mm DSR binder testing supports this
- Torsion bar testing on DSR shows greater relative aging of HMA compared to WMA in top 12 mm compared to the 2nd 12 mm
- Additional cores need to be tested and micro extractions on these two layers


QUESTIONS
DISCUSSION