BINDER SPECIFICATION ISSUES

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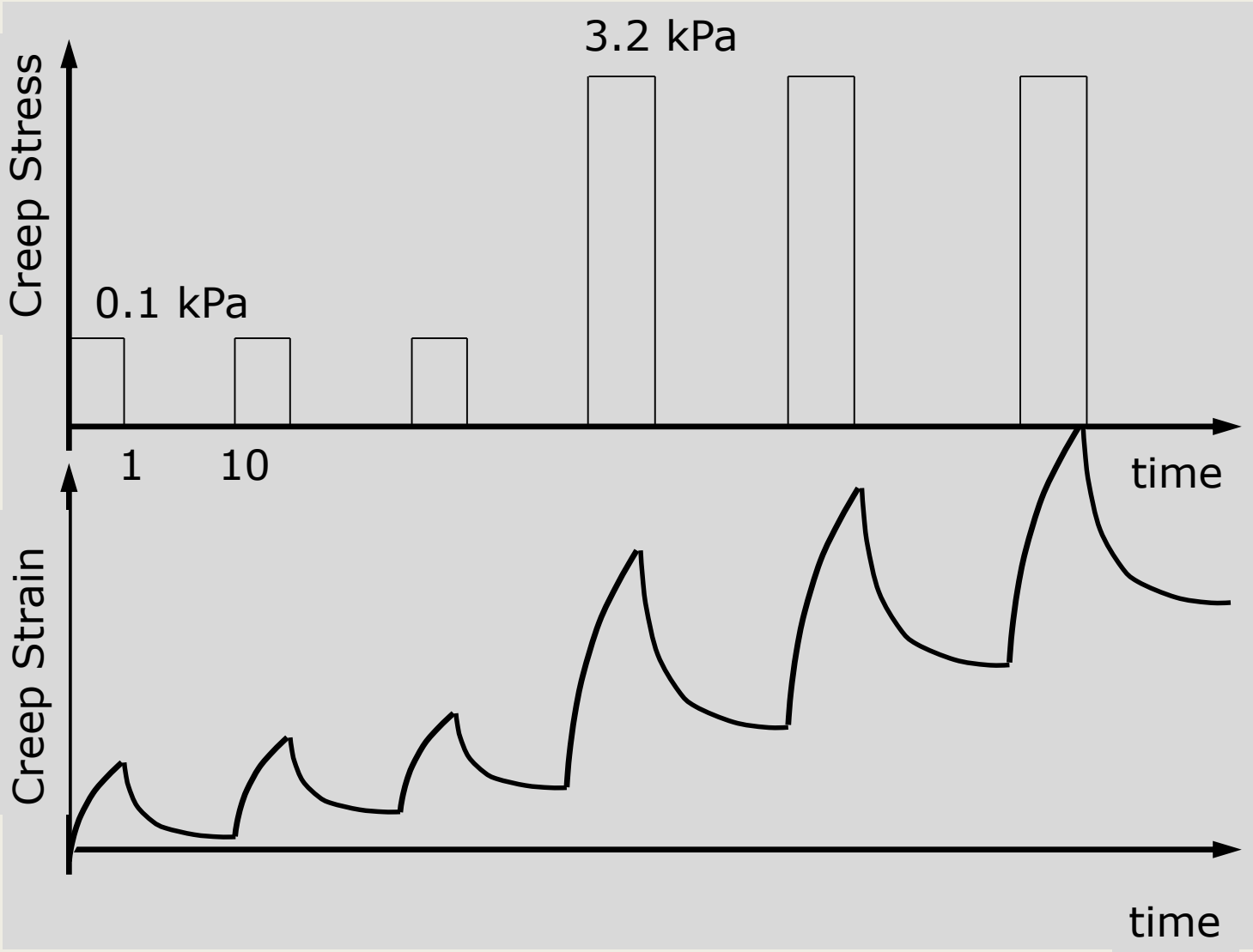
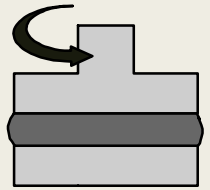
Outline

- Issues in Asphalt Binder Specifications
  - *MSCR*
  - *REOB*
    - Binder Aging
    - Binder Fatigue
- Impact on Binder Formulation and Grading
  - *Polymer Modification*
  - *Crumb Rubber Modification*
- My Take on Binder Specifications
  - *Wrap Up*

Multi Stress Creep and Recovery MSCR





Test using the DSR applying a 1 sec creep stress followed by 9 sec recovery.

MSCR Test
AASHTO T 350-14 and M 332-14

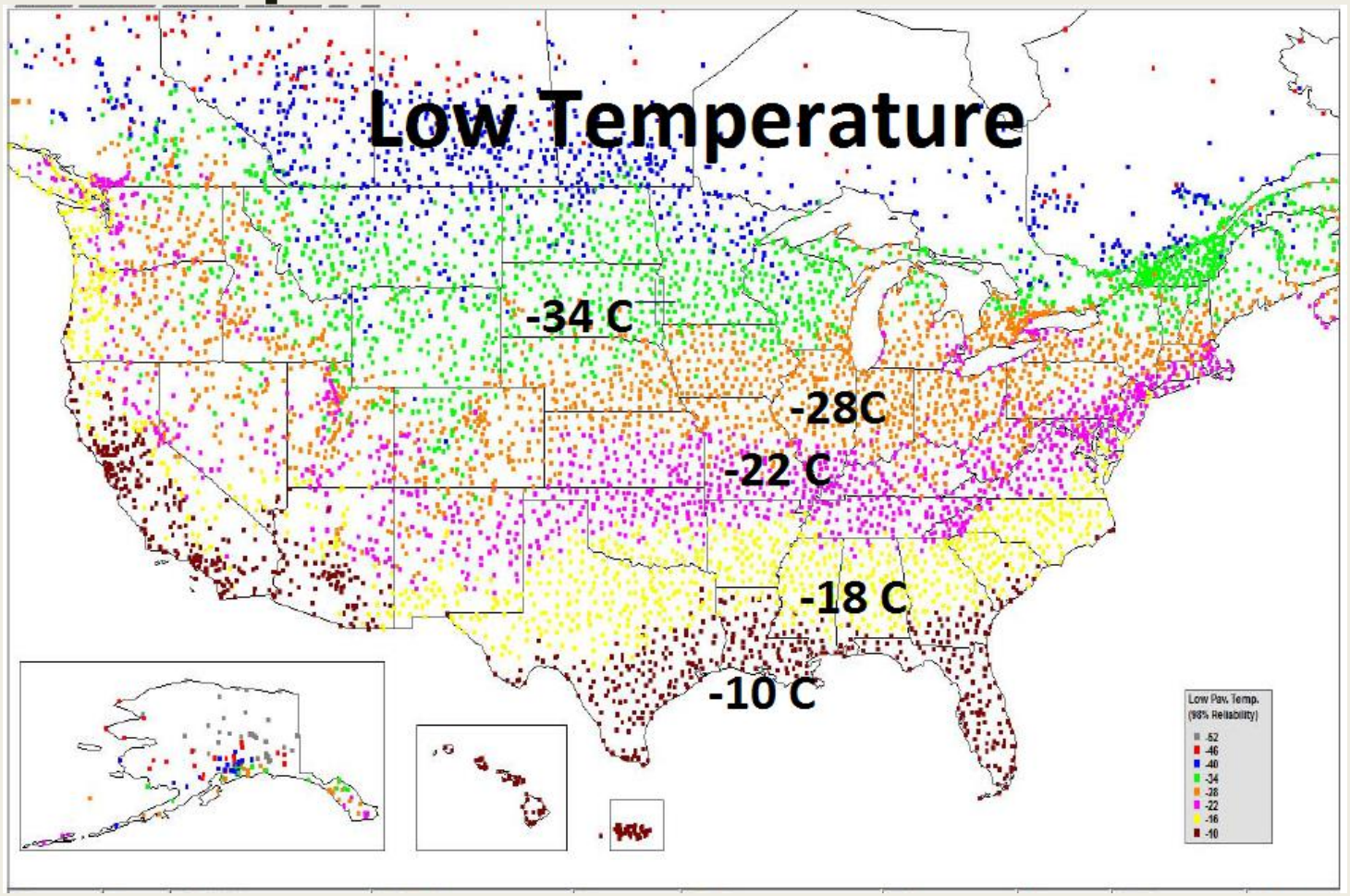
- Two key values for the MSCR test
- These will determine the binder grade and whether it can be called a PMA binder.
  - *Jnr*
  - *% Recovery*

So how do you grade a binder?

Effect of J_{nr} on Lab and Field Rutting

- Reducing J_{nr} by half typically reduced rutting by half.
- This effect is seen on ALF sections and Hamburg Rut Testing
- This is also seen on the Mississippi I 55 sections.

Like PG System, Grade Based on LTPP Climate Temperature



Grade Bumping - NO

- Right now it now it looks like the PG System
- The **BIG** change is that everything is based on the **LOCAL high temperature** environment.
- If environment is 64C
  - *the standard grade, like the PG system is PG 64-22.*
- Other grades, PG 70, and PG 76 will be tested at 64C as PG 64(something), based on the Jnr.
- Binder name becomes state/region dependent.

MSCR and Low Temperature

- The low temperature tests and nomenclature will not change with MSCR.
- It still uses the BBR results.
- The mid temperature criteria, the 8 mm DSR test, will have 6000 kPa as a cutoff for the stiffer grades, since for DelDOT the test temp will be 25C.

M - 332 Grades at 64C

- Jnr = 2.0 – 4.5 = PG 64S-22 “Standard” = PG 64-22
- Jnr = 1.0 – 2.0 = PG 64H-22 “Heavy” = PG 70-22
- Jnr = 0.5 – 1.0 = PG 64V-22 “Very Heavy” = PG 76-22
- Jnr = 0.25 – 0.5 = PG 64E-22 “Extreme” = PG 76-22
- Note M - 332 uses “High” & “Heavy” interchangeably
- Standard “S” = traffic < 10 million ESALs, > 70 km/h
- Heavy “H” = traffic 10-30 million ESALs, 20-70 km/h
- Very Heavy “V” = traffic > 30 million ESALs, < 20km/h
- Extreme “E” > 30 million ESALs, < 20km/h, toll plazas

M-320 vs M-332 Grades

- PG 58-28 = PG 58S-28, Jnr 2.0 – 4.5 58C
- PG 64-22 = PG 64S-22, Jnr 2.0 - 4.5 64C
- PG 64-28 = PG 64S-28, Jnr 2.0 – 4.5 64C
- PG 70-22 = PG 64H-22, Jnr 1.0 – 2.0 64C
- No Grade = PG 64V-22, Jnr 0.5 – 1.0 64C
- PG 76-22 = PG 64E-22, Jnr < 0.5 64C and meet polymer elasticity curve.

State DOT Survey - Summary

- Repeatability and Reproducibility
- Jnr Diff. – Not passing for stiff binders
- Nomenclature
  - *S, H, V, E for example PG 64-22V*
- Polymer Dosage
  - *Polymer Curve*
- Quick QC Test during construction
  - *No RTFO*
  - *Able to provide info similar to MSCR RTFO-aged*

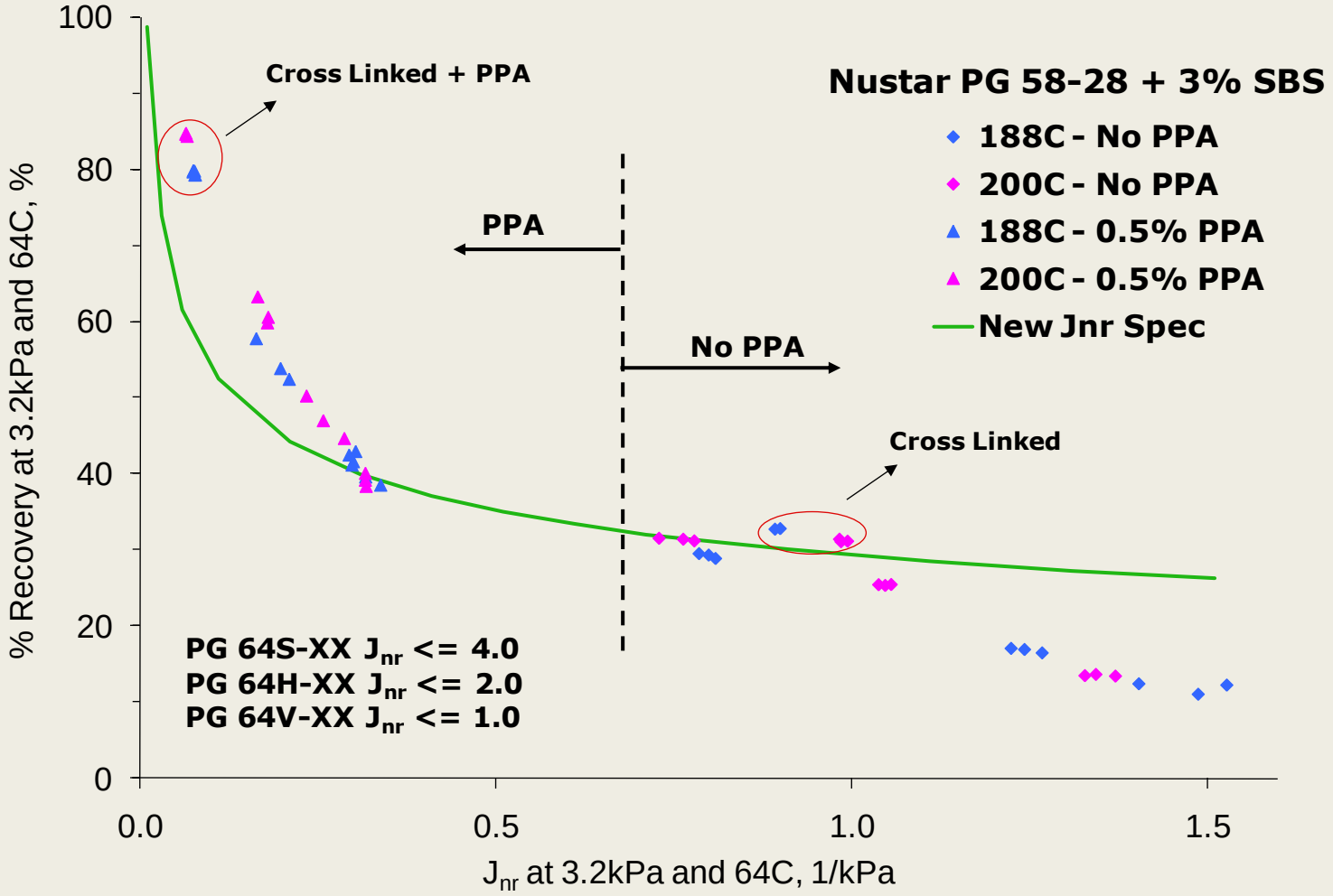
Nomenclature in AASHTO M332-14

- Problem:
  - *Correct grades are not being delivered due to the new names*
  - *Truck drivers are confused!!*
- My suggestion:
  - *Change names as follows:*
  - *PG 64-22S → SG 64-22*
  - *PG 64-22H → HG 64-22*
  - *PG 64-22V → VG 64-22*
  - *PG 64-22E → Too Expensive!!*

Binder Formulation Challenges Polymer Modification

- VH and E grades require satisfying the MSCR %Recovery Curve
- MSCR % Recovery Curve Requires that Jnr value has an associated % recovery value
  - *$\%R = 29.37*(J_{nr})^{0.263}$ at 3.2 kPa loading*
- % Recovery is affected by
  - *Cross-link efficiency*
    - Let downs from concentrates require less polymer to meet % Recovery
    - In earlier PG specification of G*/sin d, phase angle d was not as sensitive
  - *PPA*
  - *Base Binder Source*

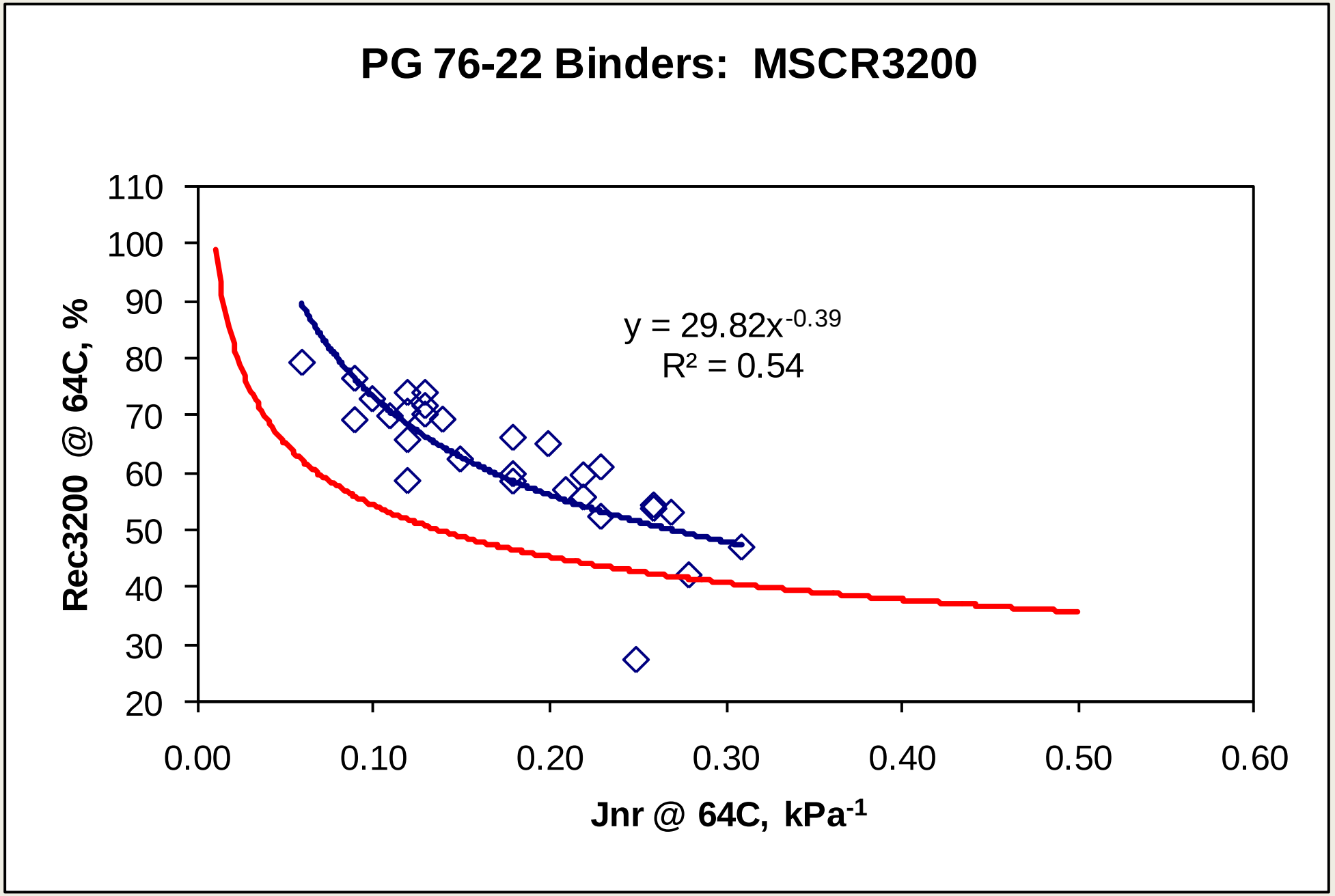
SBS/PPA Asphalt Modification Polymer Constant



MSCR shows PPA + Polymer is better than either alone.

Binder Formulation Challenges Crumb Rubber Modification

- Crumb Rubber Modified grades require satisfying the MSCR %Recovery Curve and m-value
  - *FL, GA, LA, NY*
- MSCR % Recovery Curve Requires that Jnr value has an associated % recovery value
  - *$\%R = 29.37*(J_{nr})^{0.263}$ at 3.2 kPa loading*
- % Recovery and m-value are affected by
  - *Polymer + Crumb Rubber Hybrid*
    - Made by adding crumb rubber to polymer modified binders
    - Use of ECR – crumb rubber pre coated by elastomers
  - *Crumb Rubber Type – Truck Tire Rubber is better*
  - *Base Binder Source*


PG 76-22 Binders: MSCR3200
Rec3200 @ 64C, %
110
100
90
80
70
60
50
40
30
20
y = 29.82x-0.39
R² = 0.54
0.00
0.10
0.20
0.30
0.40
0.50
0.60
Jnr @ 64C, kPa-1

WHAT IS engineered crumb rubber (ECR)?

- ASTM minus #30 crumb rubber (Truck Tire)
- Rubber Coated with Polymer to meet specific performance criteria:
  - *MSCR – Jnr and % Recovery, BBR - m-value, DSR - Phase Angle*
  - *PG adjustment: upper and lower temperatures*
  - *Penetration, SP, ER, etc.*
  - *Mix Fatigue and Rutting Performance similar to PMB (SBS modified)*

ECR Types

- Standard ECR
  - *30 mesh, 40 mesh with Elastomer coating*
  - *Typical ECR content in CRMB - 10% or less*
- ECR-WMA
  - *Standard ECR with WMA additive coating*
- ECR-MD (moisture damage)
  - *Standard ECR with Anti-strip coating*

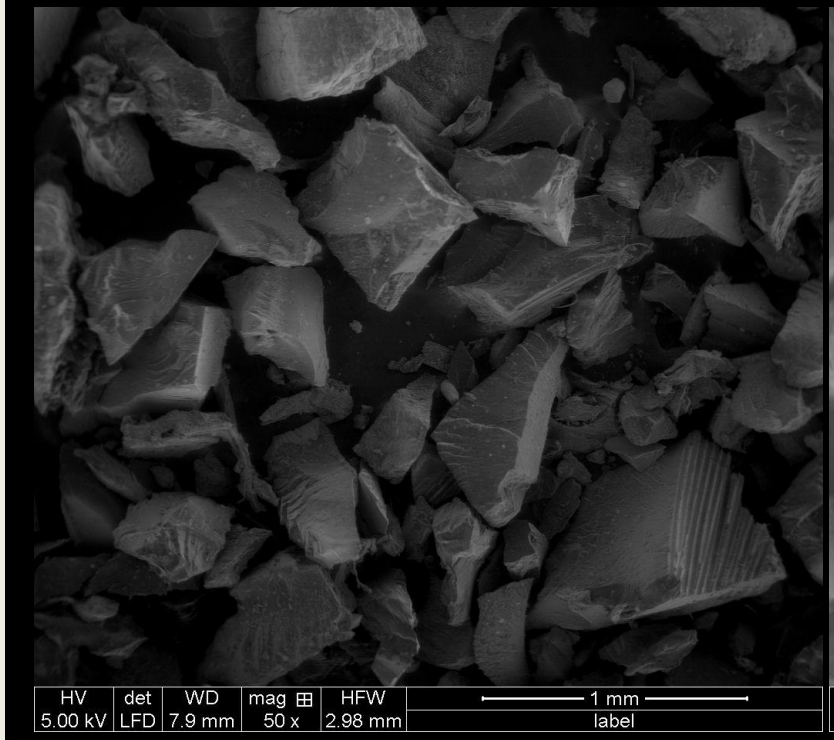
ECR Types.....

- ECR-PPA
  - *Standard ECR with PPA coating*
- ECR-HM (High Modulus Mix)
  - *ECR with higher elastomer coating*
  - *DRY MIX method – used with standard PMA*

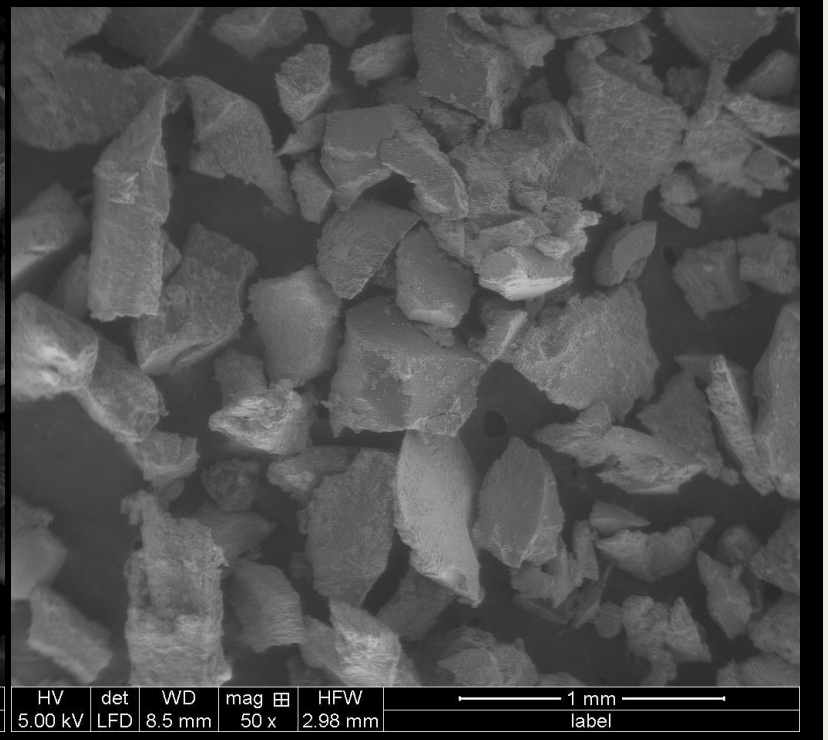
WHAT IS ENGINEERED CRUMB RUBBER (ECR)?

- Polymer Coated Crumb Rubber with a Patented Coating Process - - #30 mesh CRM (0.2 to 0.4 mm)

Normal Crumb Rubber



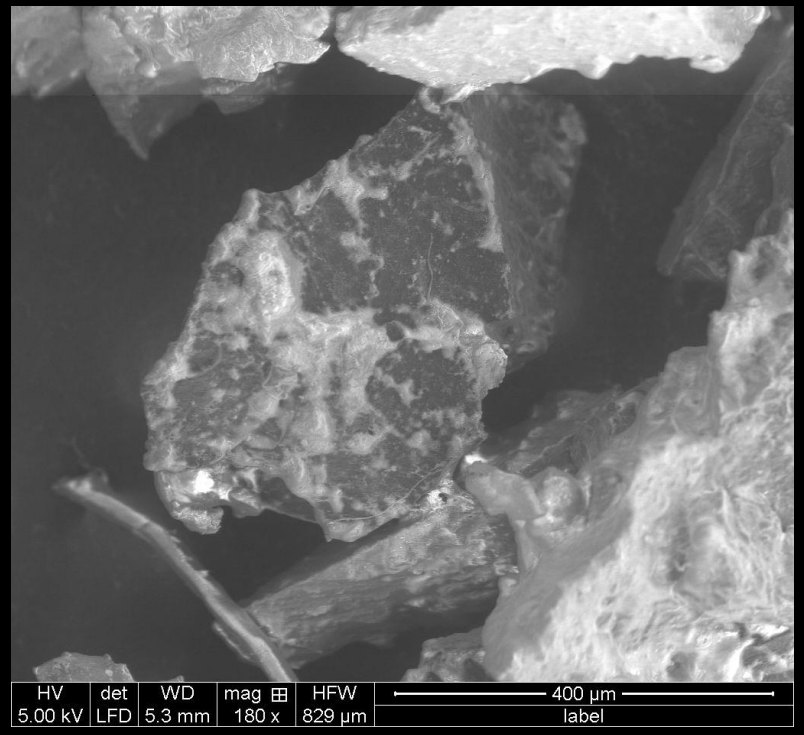
Engineered Crumb Rubber



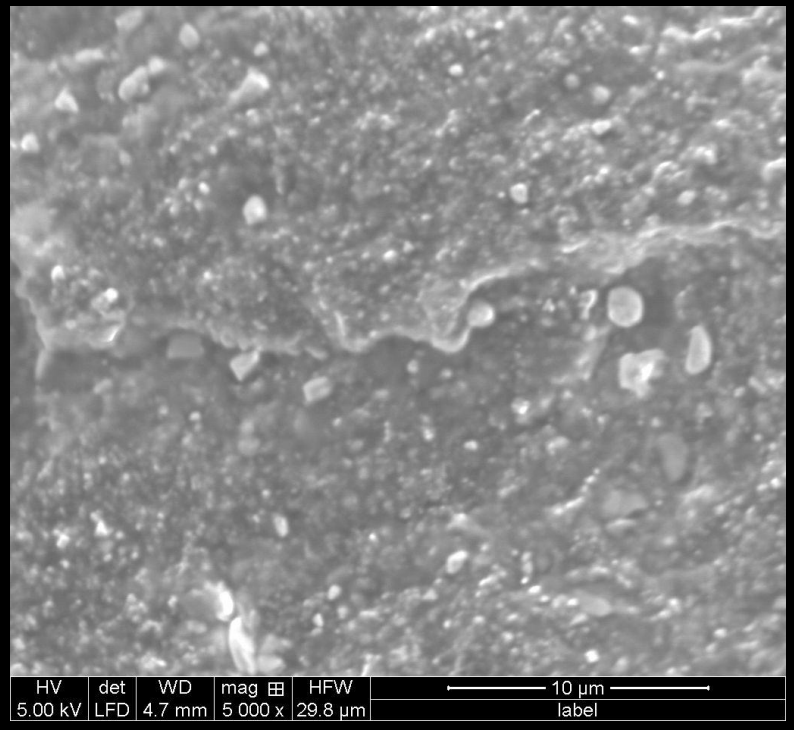
WHAT IS ENGINEERED CRUMB RUBBER (ECR)?

- Polymer Coated Crumb Rubber with a Patented Coating Process - - #30 mesh CRM (0.2 to 0.4 mm)

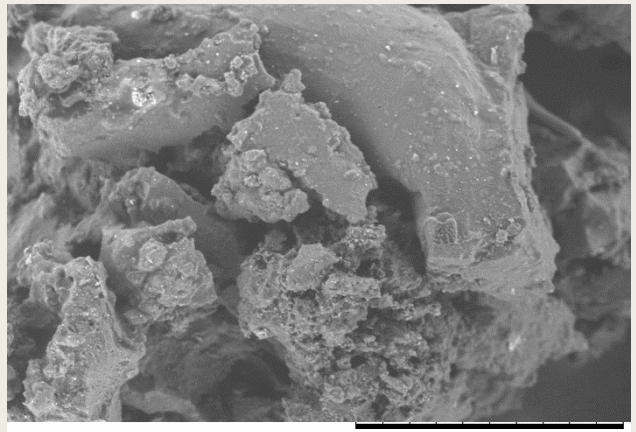
ECR at 180x mag.

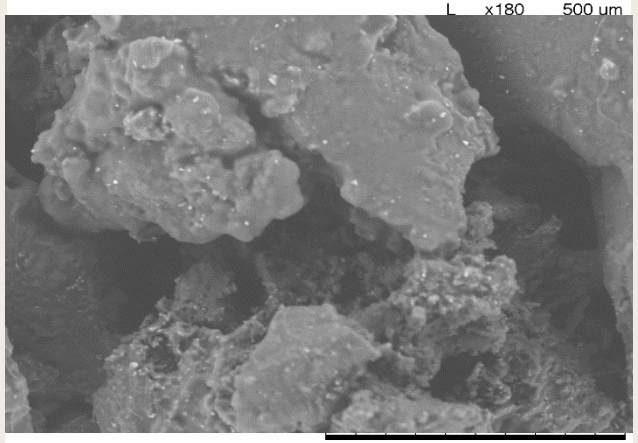


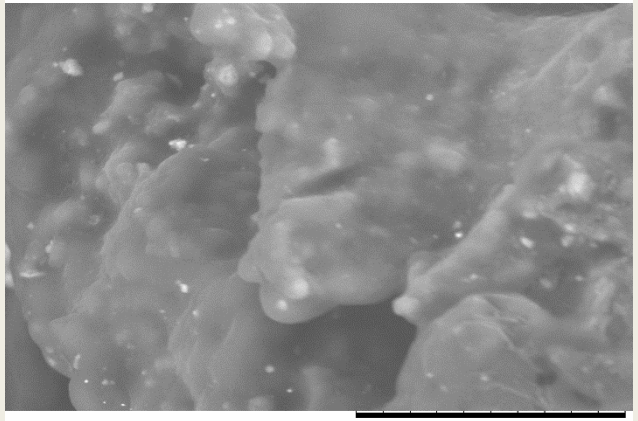
ECR at 5000x mag.



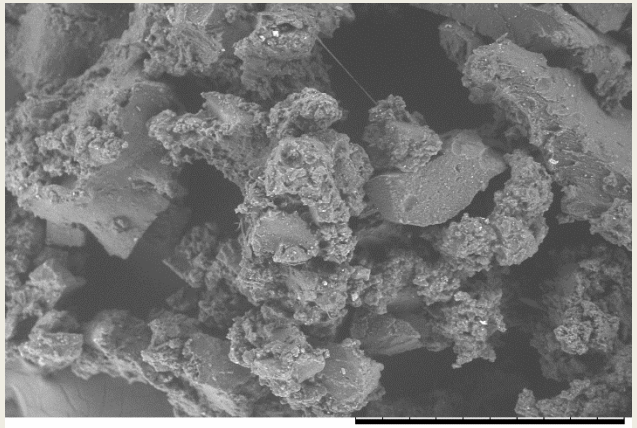
-30 mesh

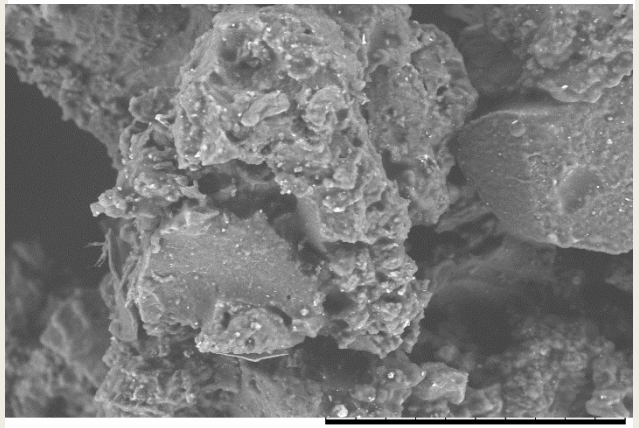


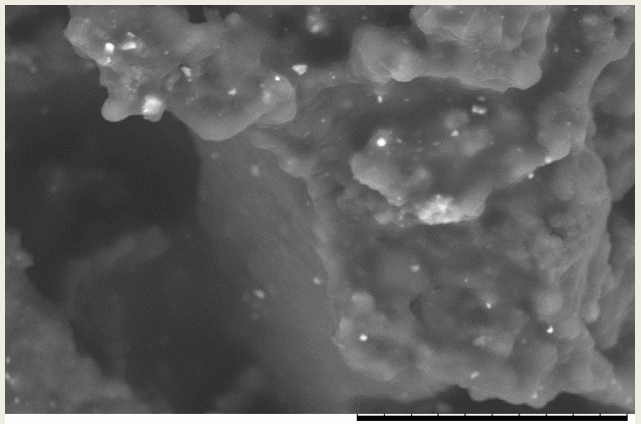




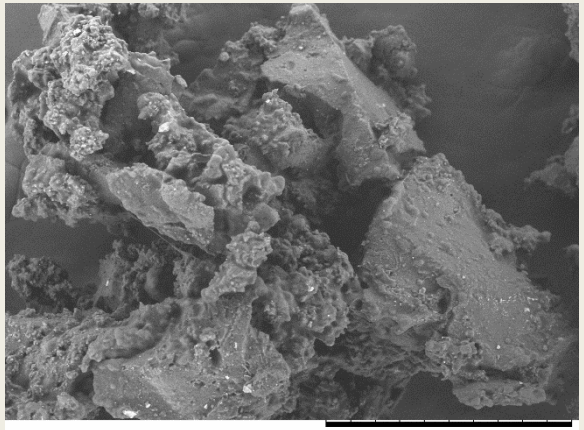
-40 mesh

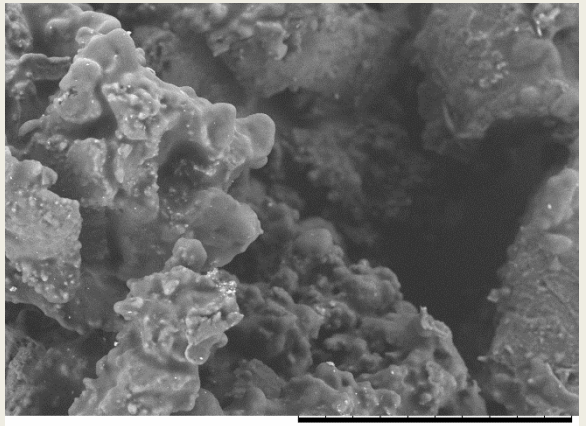


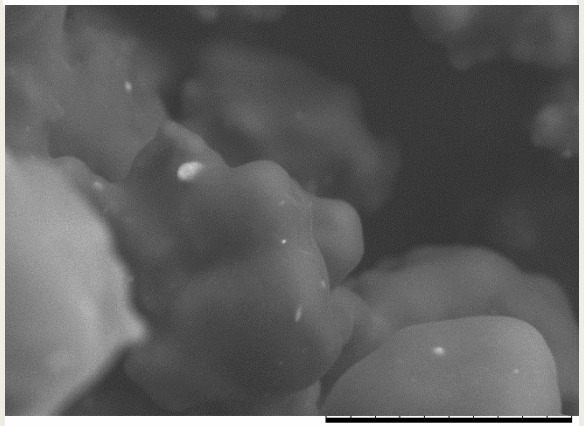




-30 mesh – Dual Polymer

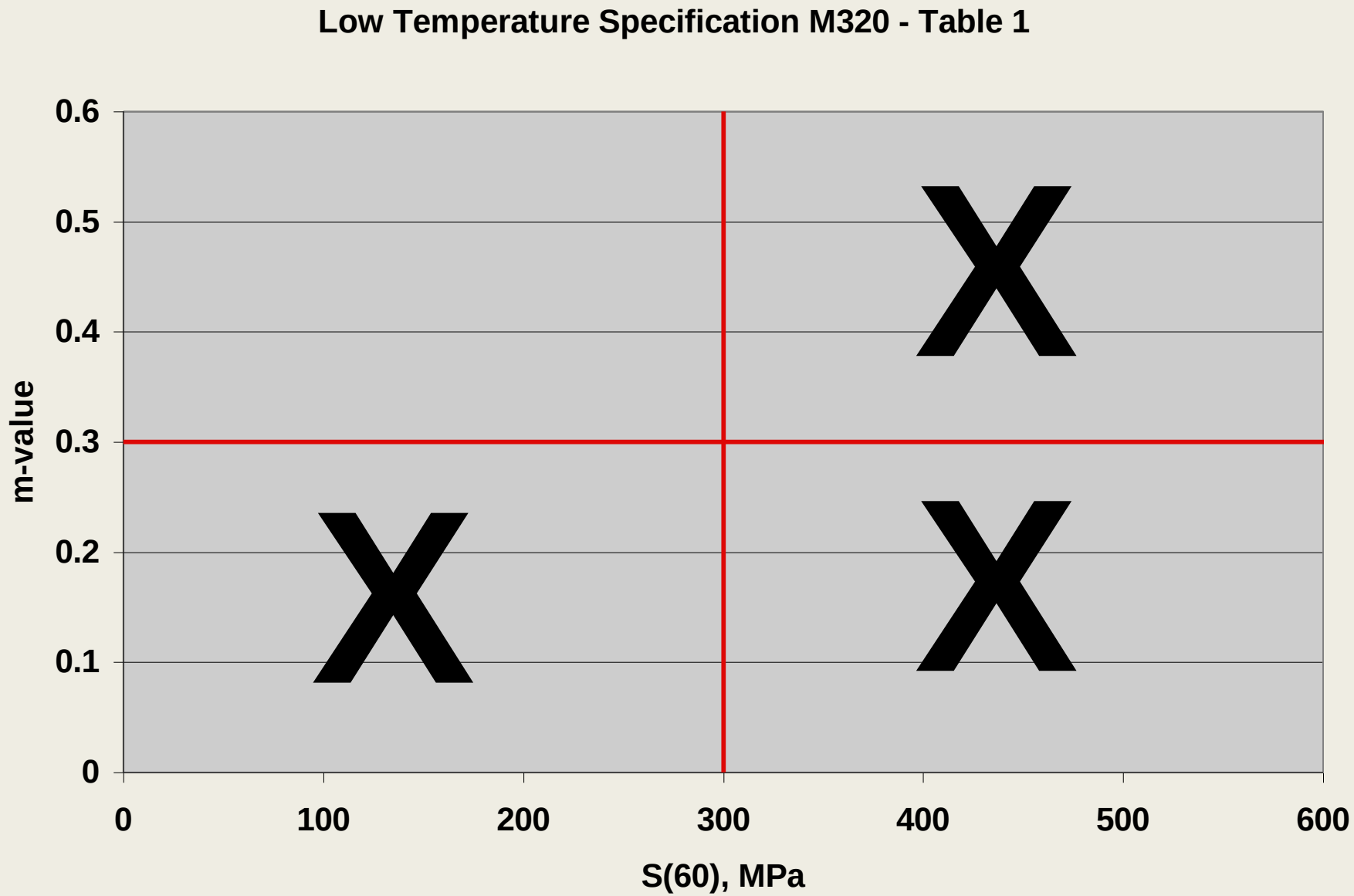


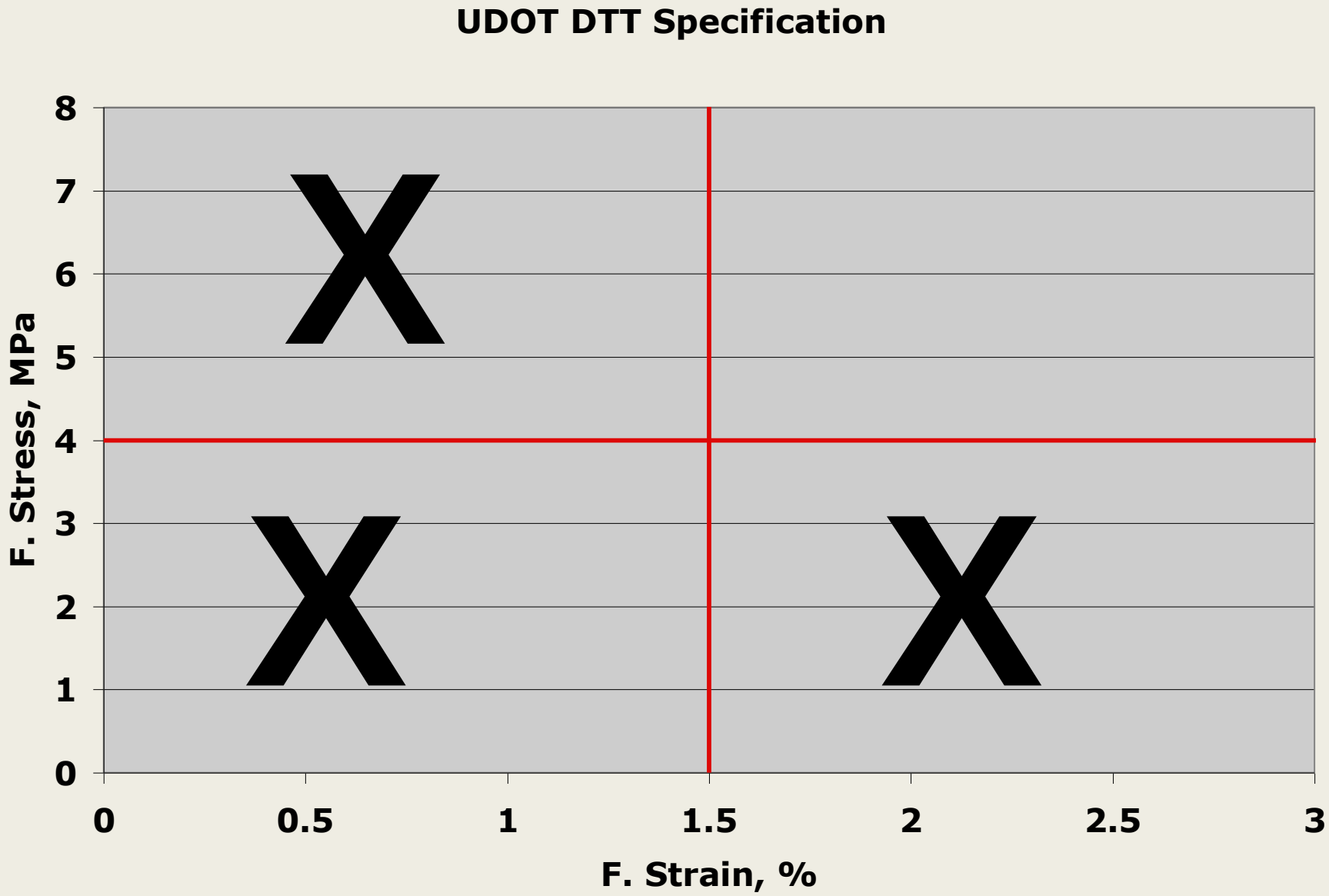


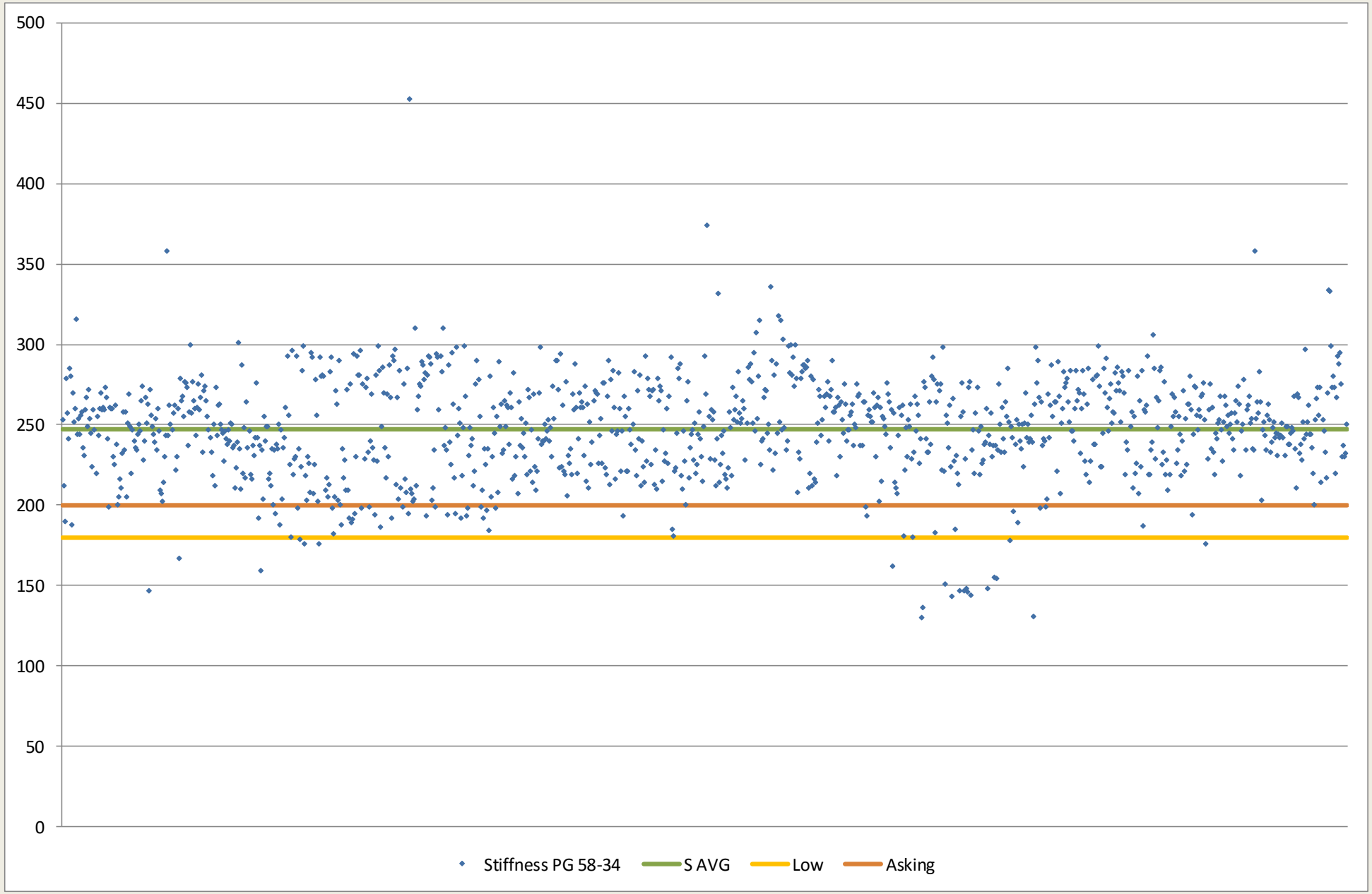


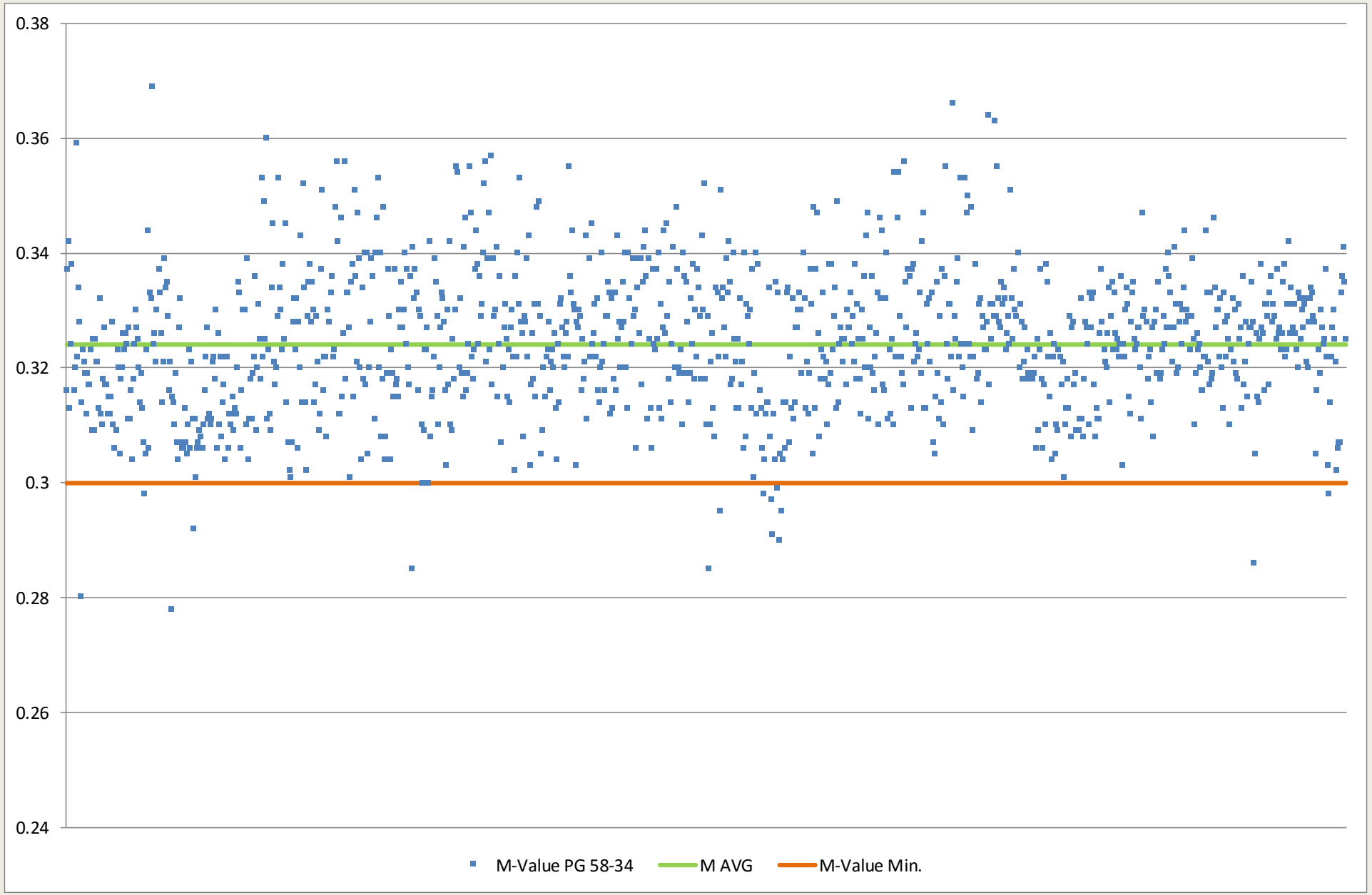
REOB – Recycled Engine Oil Bottoms

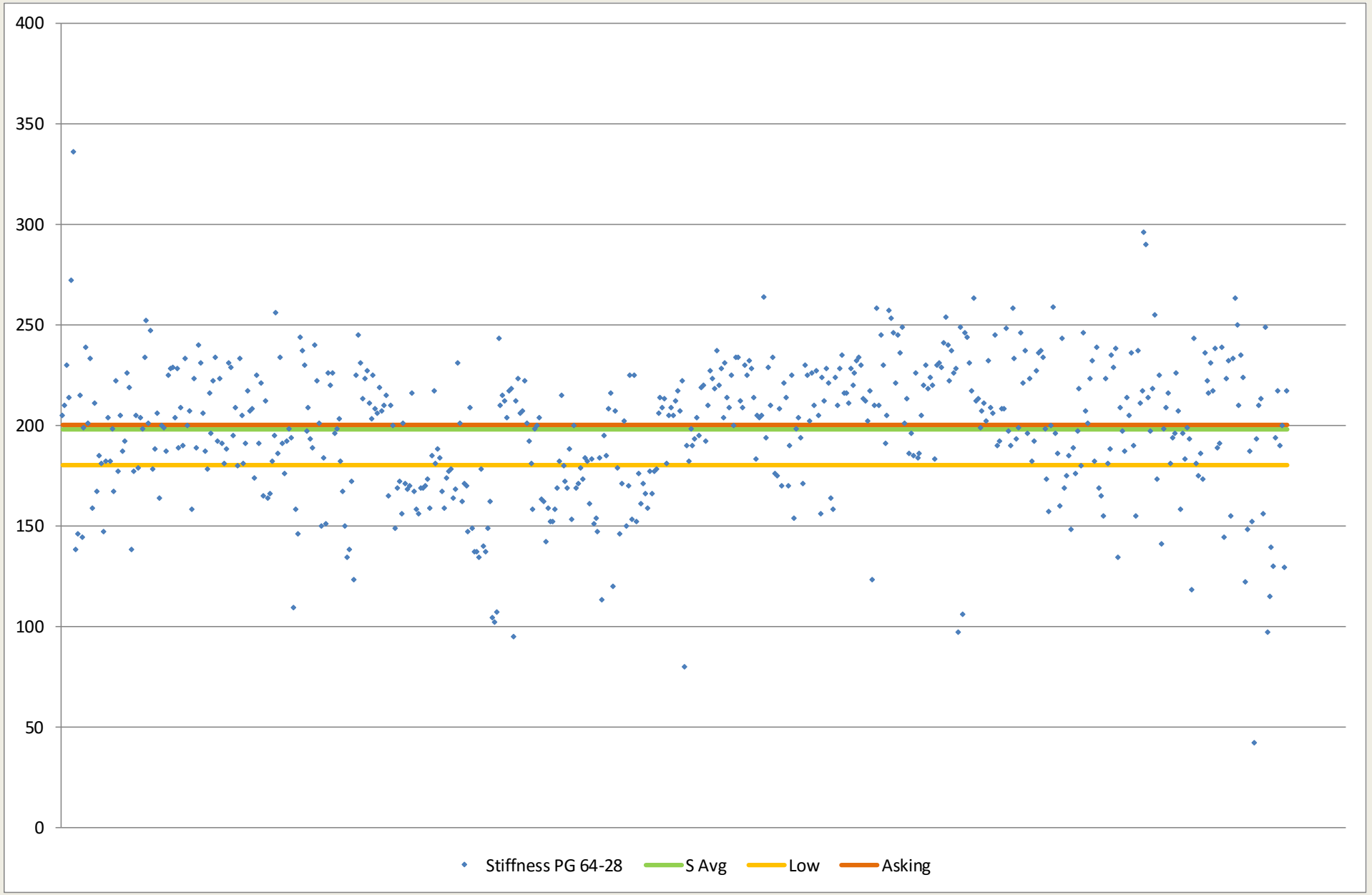
- What is the Issue? (pre Crude Oil price drop)
  - *I don't know!!*
    - I have not seen any field data showing effect of REOB on performance
    - The PG grading system forces use of soft base binders
    - There is a perception out there that excessive use of REOB is bad
- How is the Issue being addressed?
  - *Mix testing to show that either REOB is good or bad to performance*
    - The problem is most mix tests are strain controlled!!
    - So softer binders always look good!
- S and m-value based approach
  - *Specify that m-value is met at a certain S value*
- Double PAV – Embrittlement!

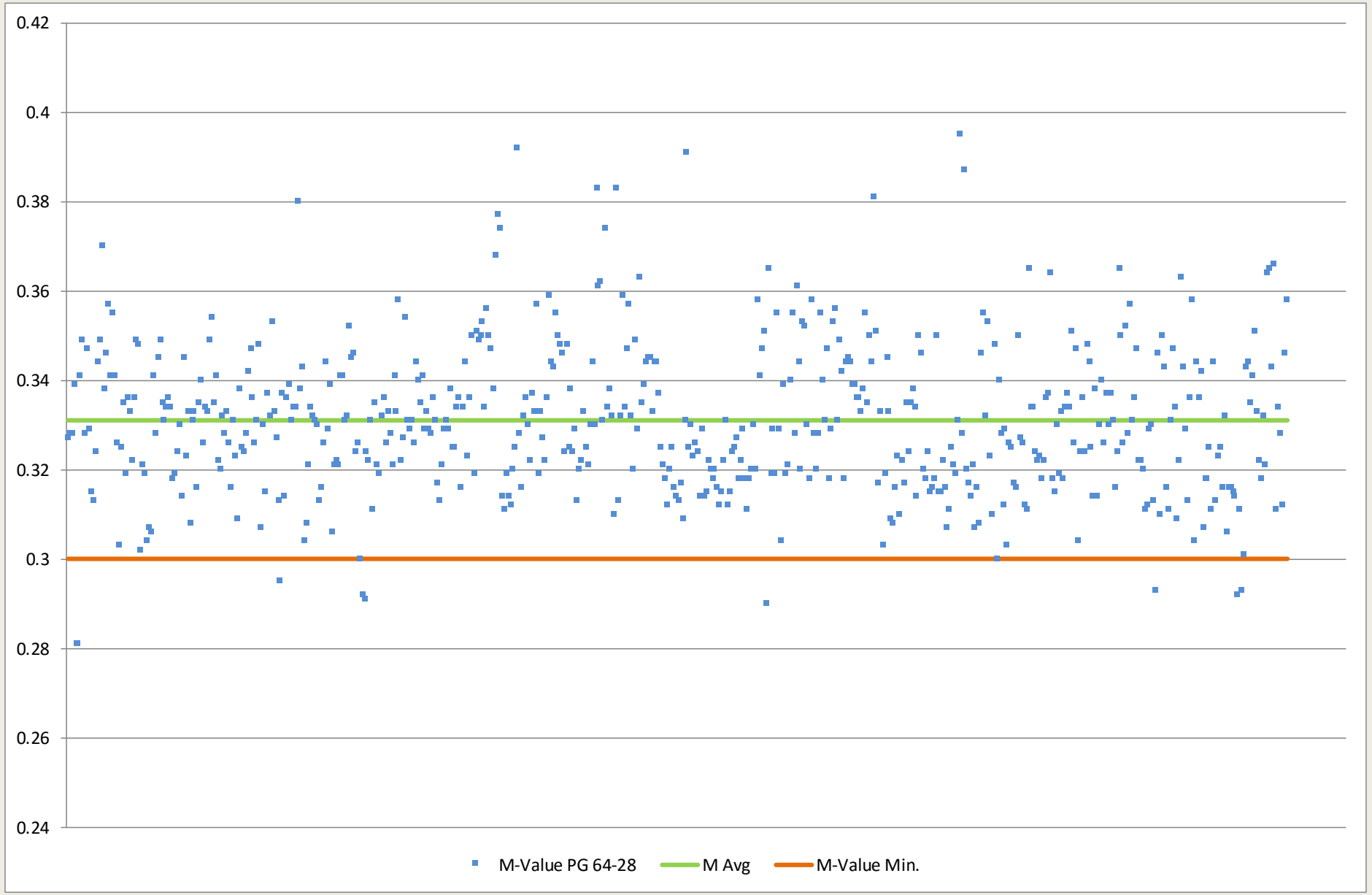

Low Temperature Specification M320 - Table 1
m-value
0.6
0.5
0.4
0.3
0.2
0.1
0
0
100
200
300
400
500
600
S(60), MPa
X
X
X

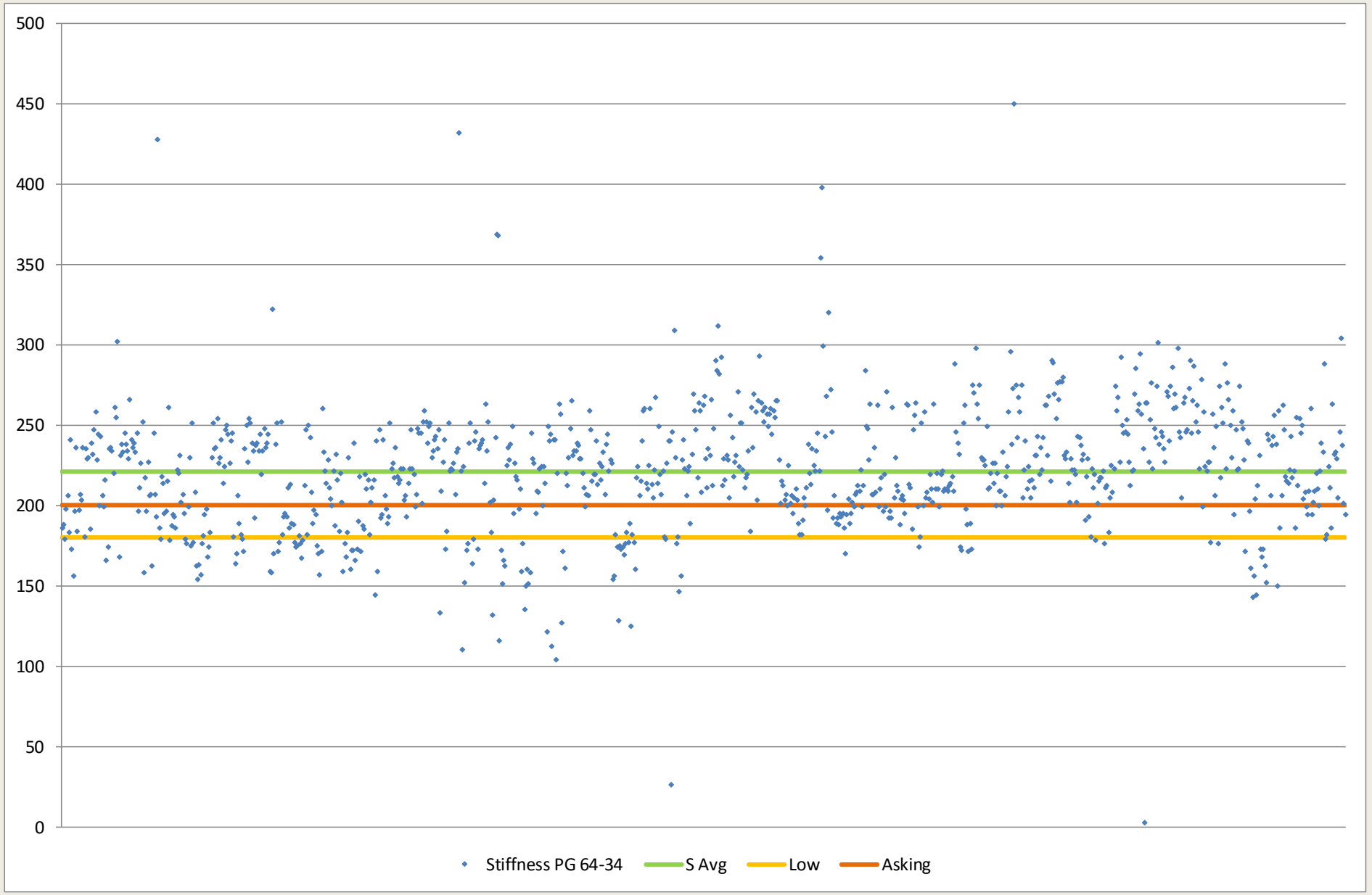

UDOT DTT Specification
F. Stress, MPa
8
7
6
5
4
3
2
1
0
0
0.5
1
1.5
2
2.5
3
F. Strain, %
X
X
X

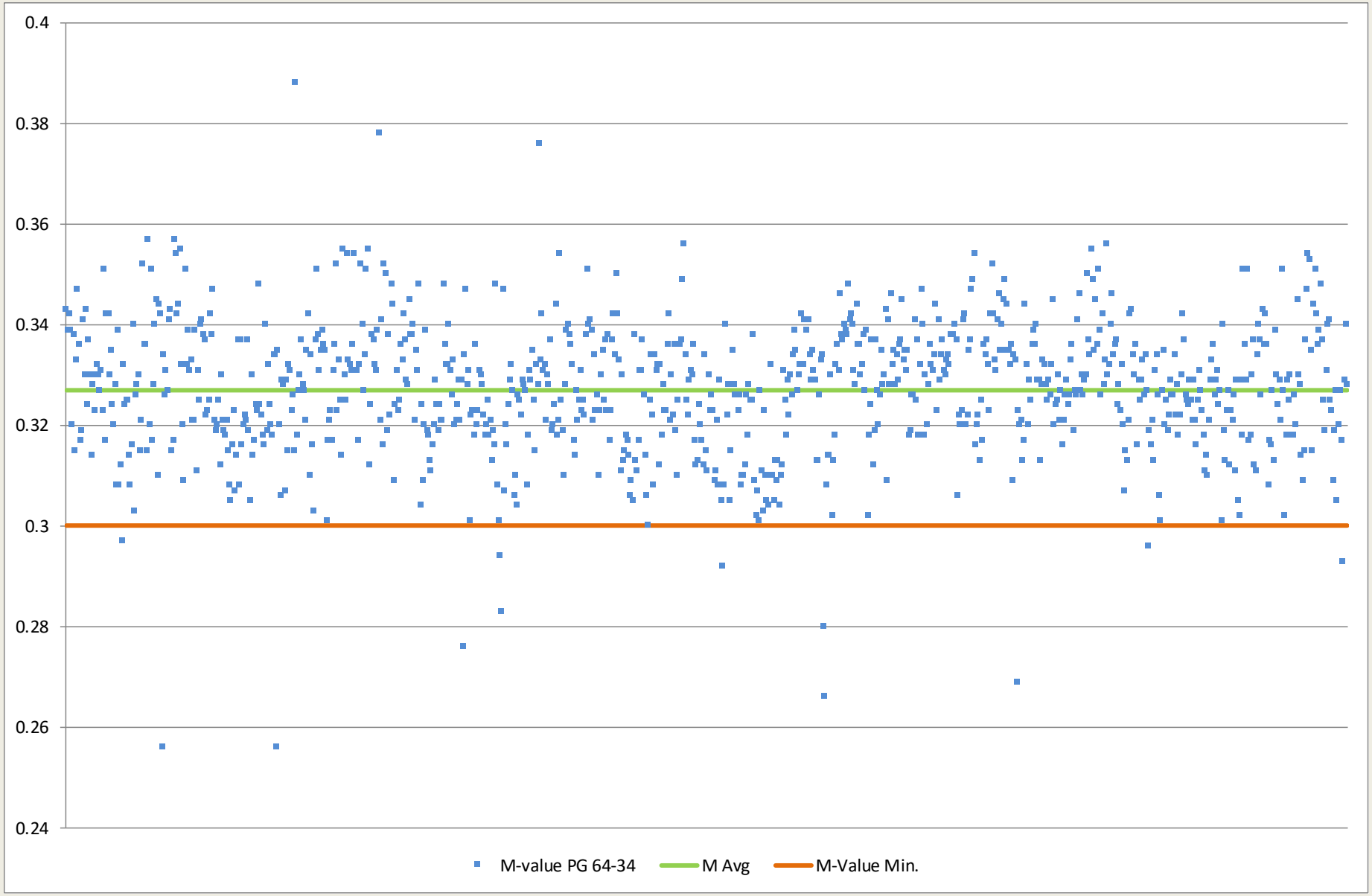

500
450
400
350
300
250
200
150
100
50
0
Stiffness PG 58-34
S AVG
Low
Asking

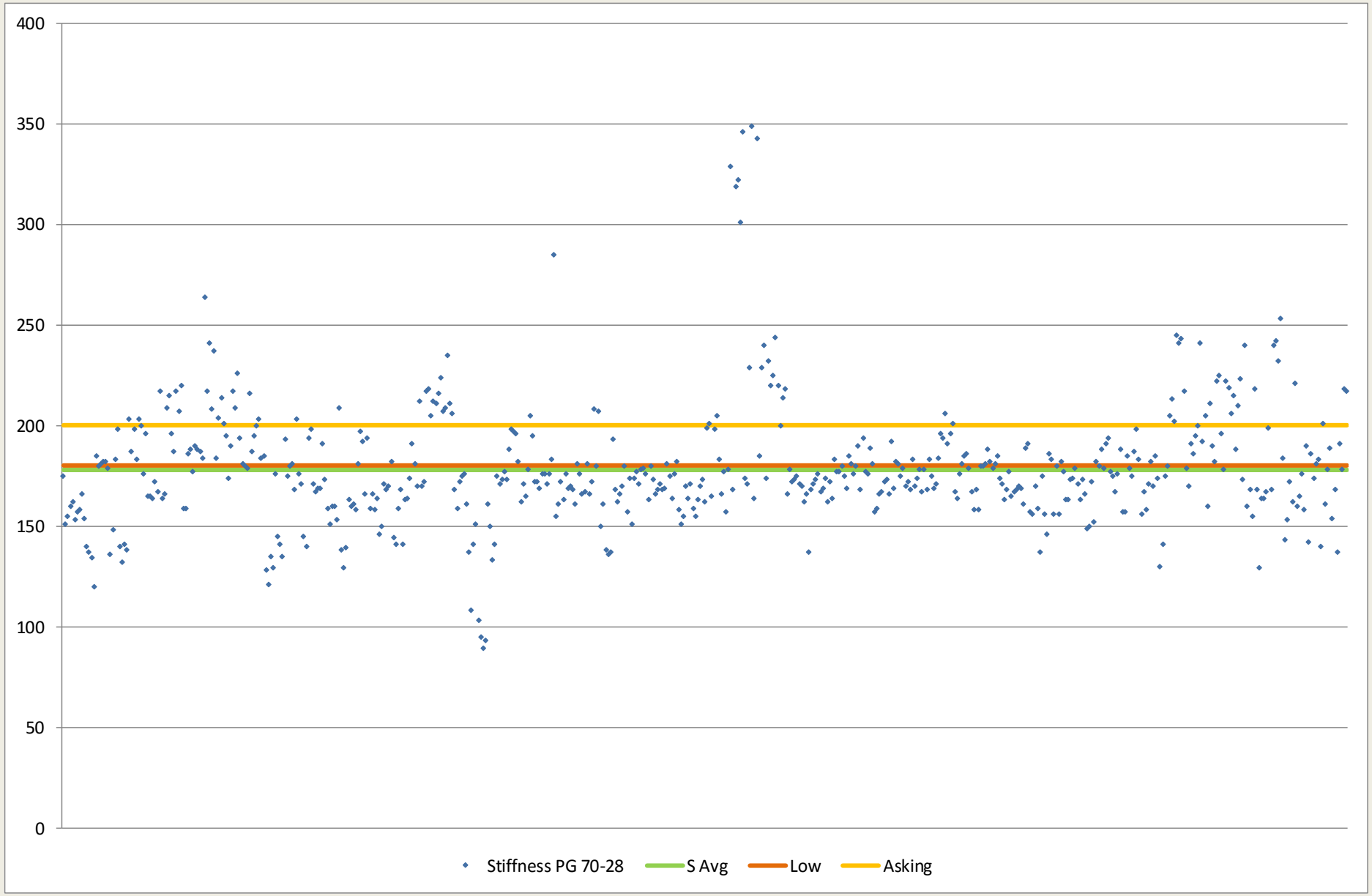

0.38
0.36
0.34
0.32
0.3
0.28
0.26
0.24
M-Value PG 58-34
M AVG
M-Value Min.

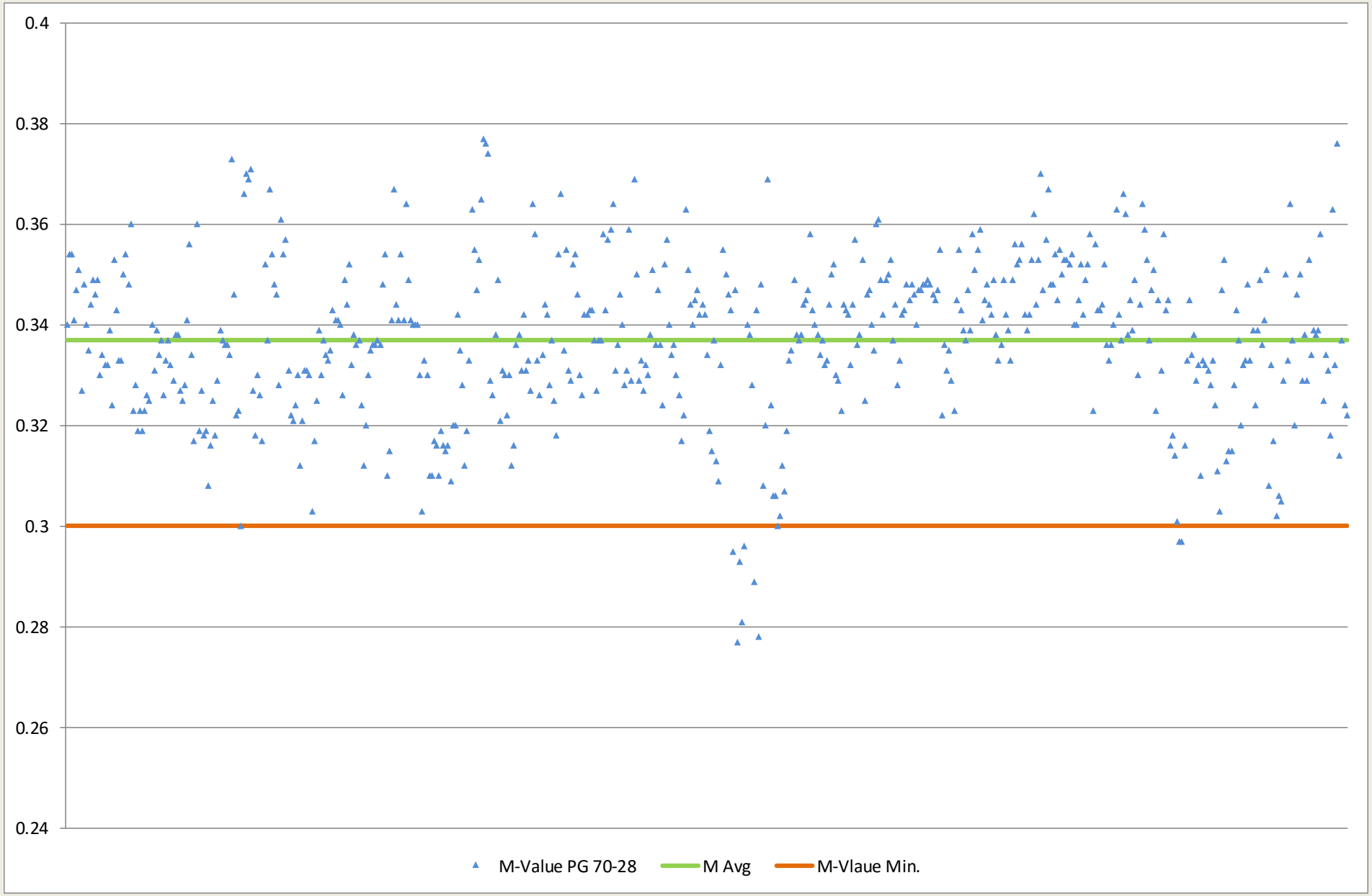

400
350
300
250
200
150
100
50
0
Stiffness PG 64-28
S Avg
Low
Asking


0.42
0.4
0.38
0.36
0.34
0.32
0.3
0.28
0.26
0.24
M-Value PG 64-28
M Avg
M-Value Min.


500
450
400
350
300
250
200
150
100
50
0
Stiffness PG 64-34
S Avg
Low
Asking


0.4
0.38
0.36
0.34
0.32
0.3
0.28
0.26
0.24
M-value PG 64-34
M Avg
M-Value Min.

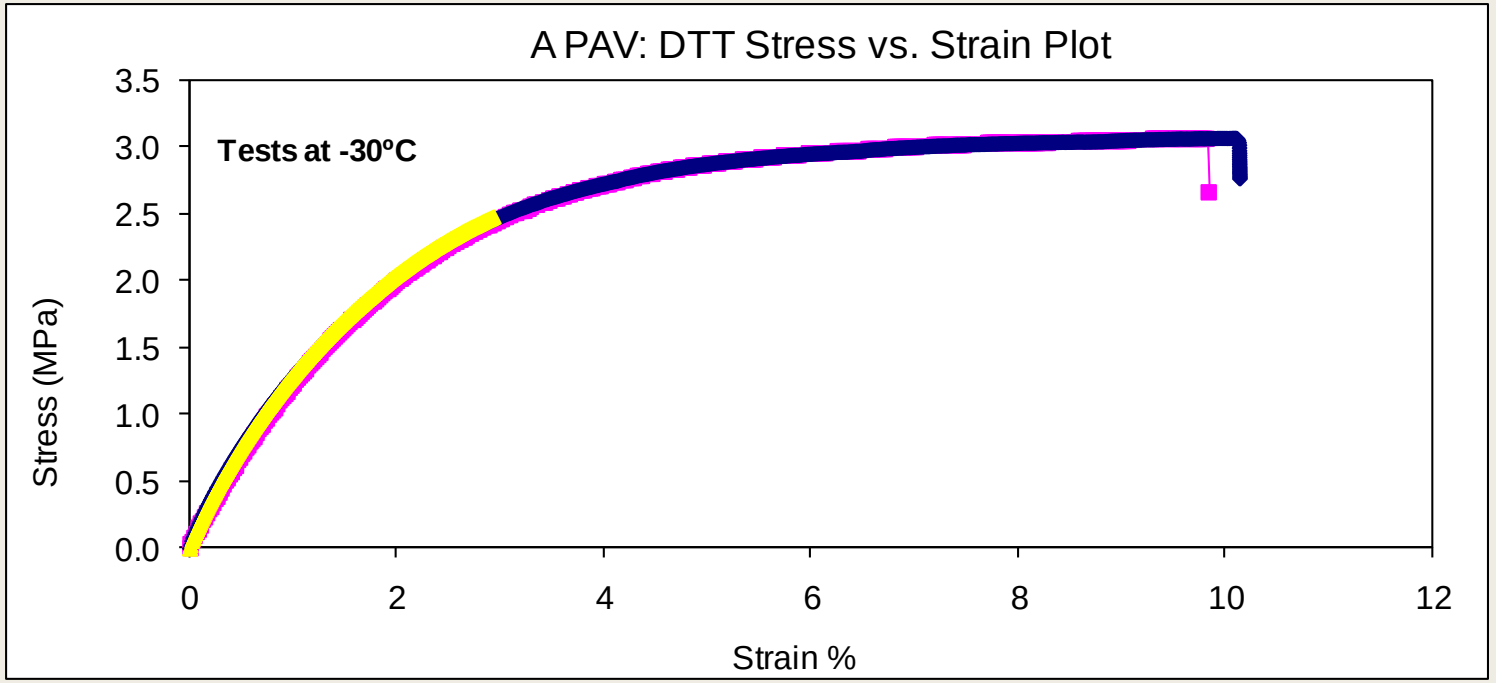

400
350
300
250
200
150
100
50
0
Stiffness PG 70-28
S Avg
Low
Asking

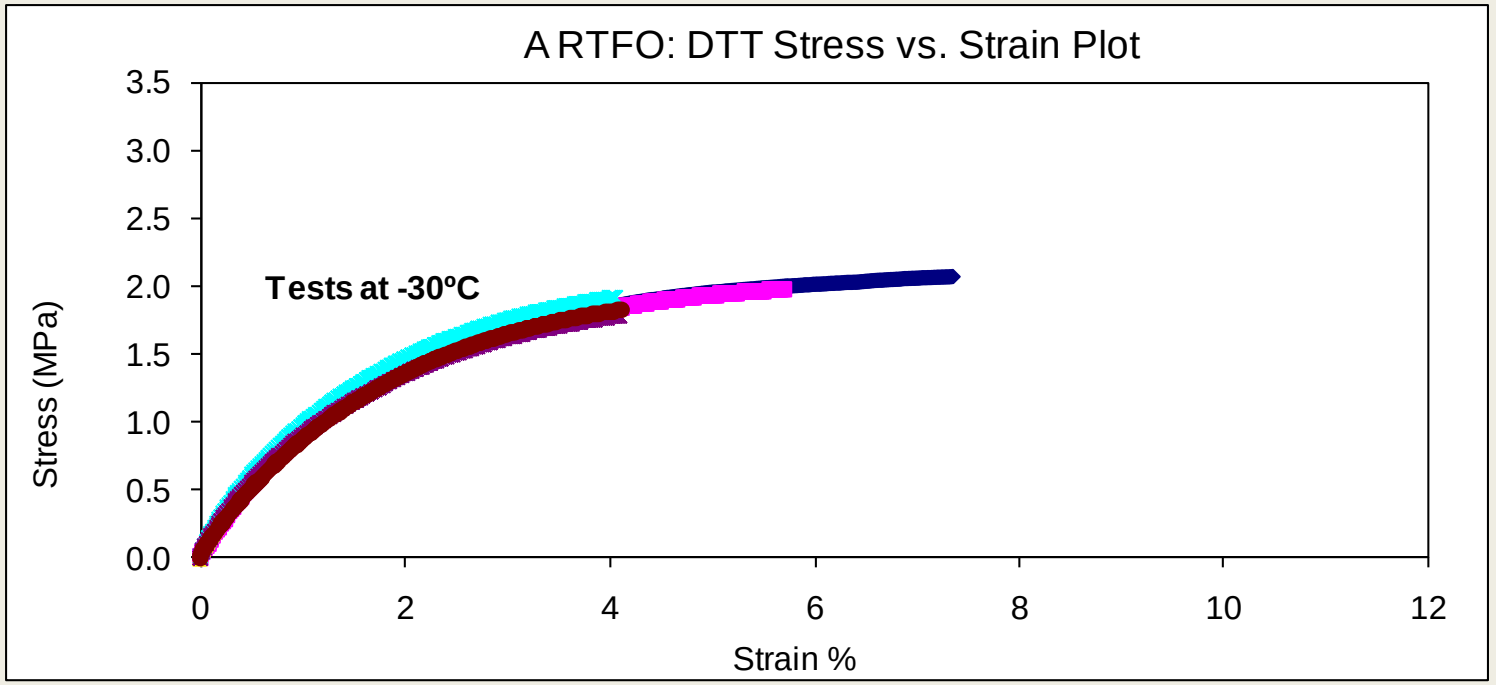

0.4
0.38
0.36
0.34
0.32
0.3
0.28
0.26
0.24
M-Value PG 70-28
M Avg
M-Vlaue Min.

Binder Aging

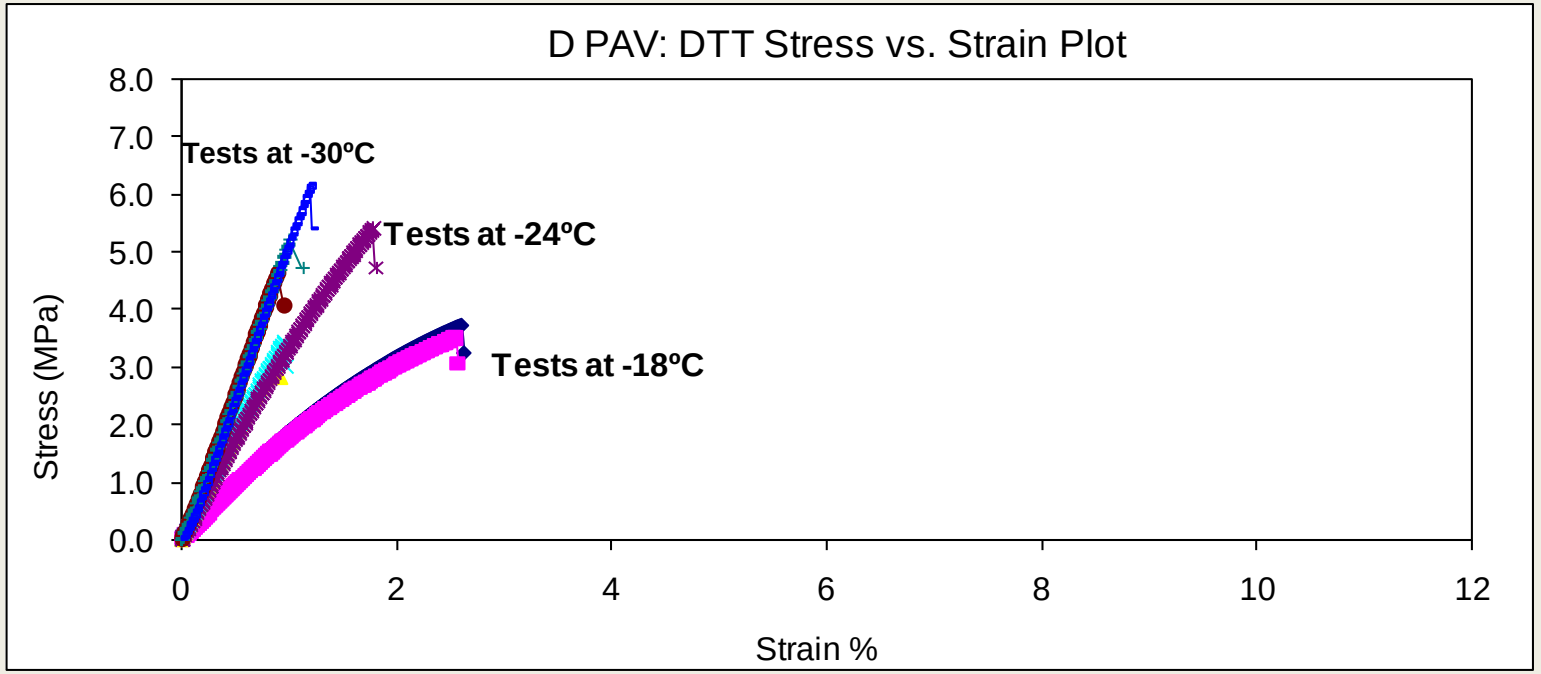
- RTFOT Issues
  - *Binder spillout*
  - *NCHRP project to suggest alternatives*
    - SAFT, German Rolling Flask
- PAV Aging Issue -- Not enough aging!
  - *Does PAV really simulate Field Aging?*
    - DTT data says otherwise
- Double PAV
  - *REOB Issue driven*
- Bottom Line – Need to determine binder embrittlement due to aging as per field
  - *Glover Rowe Parameter*

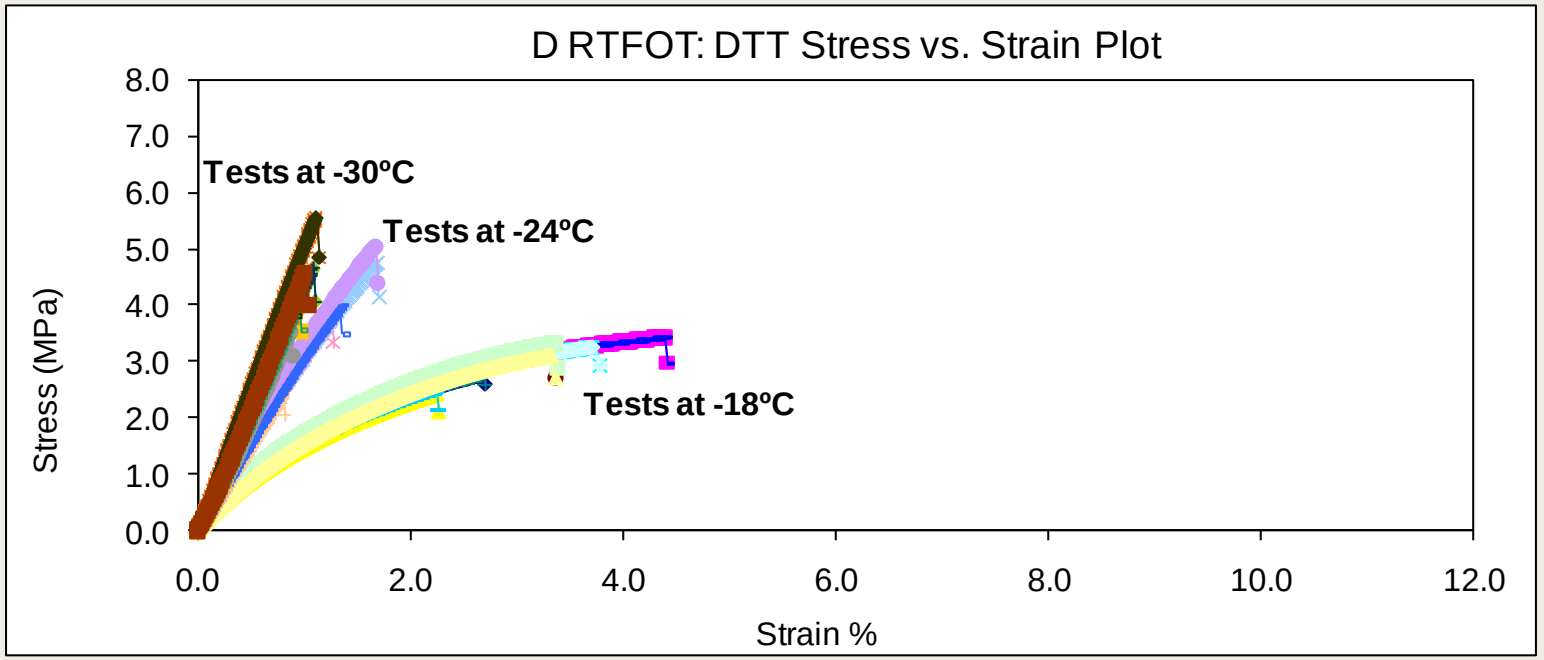
PG 58-40


A PAV: DTT Stress vs. Strain Plot
Tests at -30ºC
Stress (MPa)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
2
4
6
8
10
12
Strain %


A RTFO: DTT Stress vs. Strain Plot
Tests at -30ºC
Stress (MPa)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
2
4
6
8
10
12
Strain %

PG 58-28 plain #1





Binder Fatigue – 20 years and Counting!

- Latest NCHRP Project to study binder aging
  - *AAT and NCAT*
  - *Tasked with developing a binder fatigue specification/test*
- DENT Test
  - *Notched ductility*
  - *Shown to relate to field performance*
- LAS Test
  - *DSR based strain sweep test*
  - *Has problems with adhesion of sample to plates!*
- Bottom Line – Need to look at binder embrittlement or fracture toughness

My Take – Binder Specification Issues

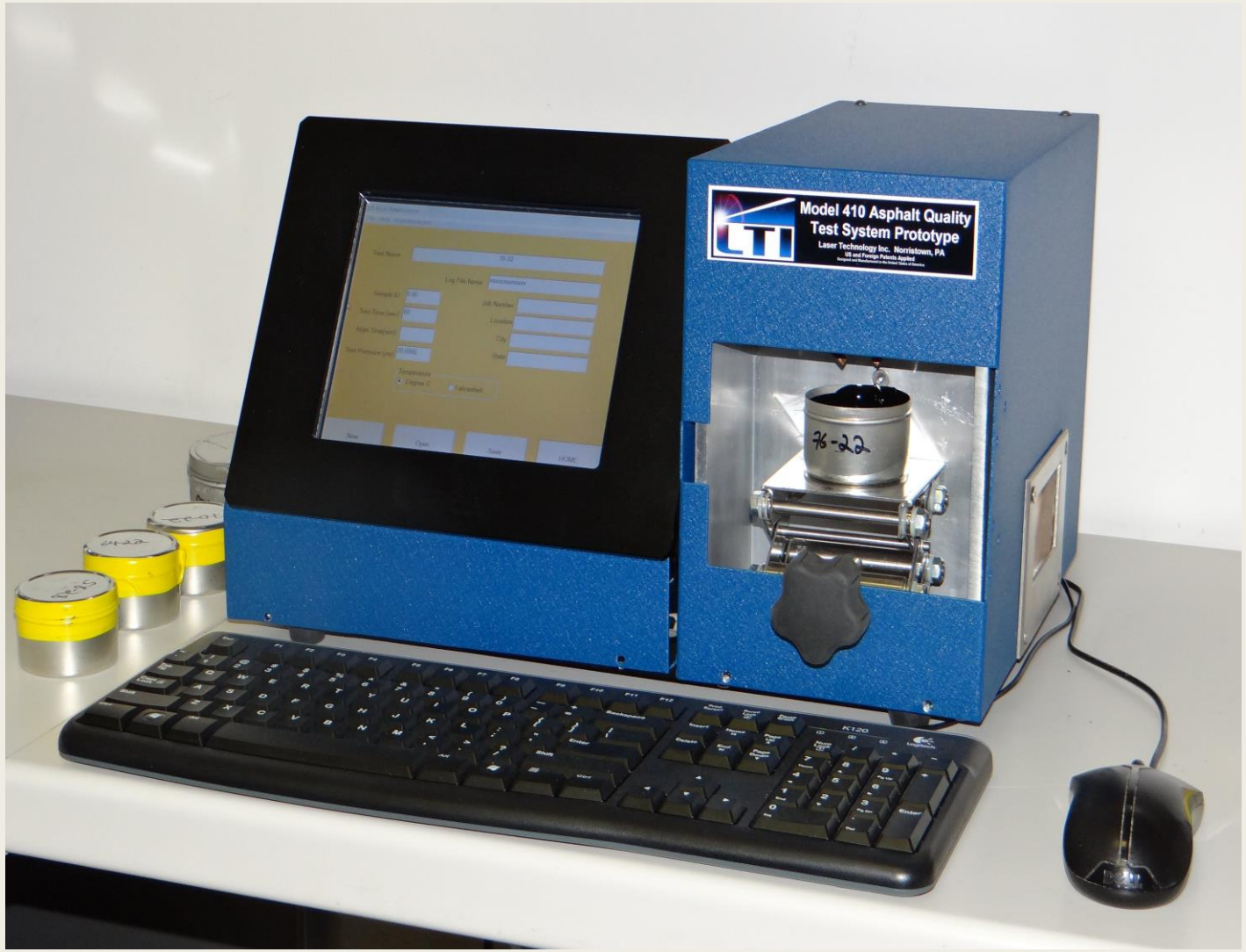
- MSCR
  - *Needs to be implemented at all agencies*
  - *Grade bumping is eliminated*
  - *Polymer use is optimized*
    - Sensitive to formulation
    - Encourages well formulated PMAs
- REOB
  - *Need to analyze existing S and m-value data from all State Agencies*
    - Jack and I are looking into this.
    - If needed we can consider putting a range on S value where m-value is 0.3

My Take – Binder Specification Issues

- Binder Aging
  - *PAV needs tweaking*
  - *Nobody knows for sure what PAV aging really represents (5 yrs, 8 yrs, etc)*
  - *A soft asphalt remains a soft asphalt after RTFO and PAV aging!!*
    - There is no criss-crossing!
- Binder Fatigue
  - *Fatigue is best handled as a mix issue*
    - AC content sensitivity
    - Air voids, VMA and other mix additives also affect fatigue!
- Bottom Line -- We need to look into QC tests for binders and mixes

New QC Tests for Binders and Mix

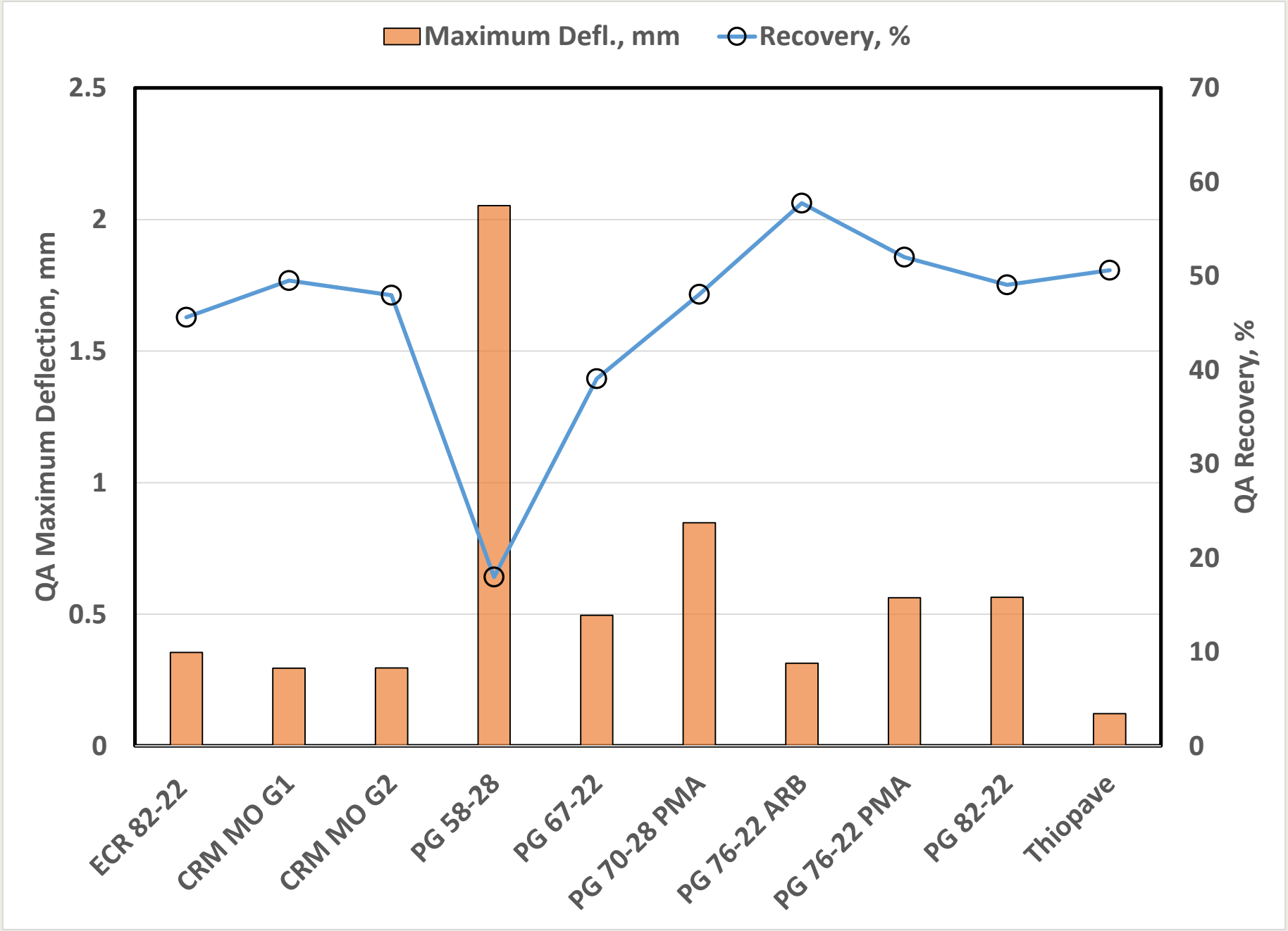
- Dongre Workability Test ‘DWT’ for mixes
  - *Based on existing Gyratory compactor*
  - *Determines Mix Workability*
  - *Also sensitive to AV, VMA, AC content, Mix Design*
- Binder and Mix QC Test
  - *Easy to use and portable*
  - *Innovative concept based on Air pressure and Laser*
  - *Produces Creep and Recovery data*

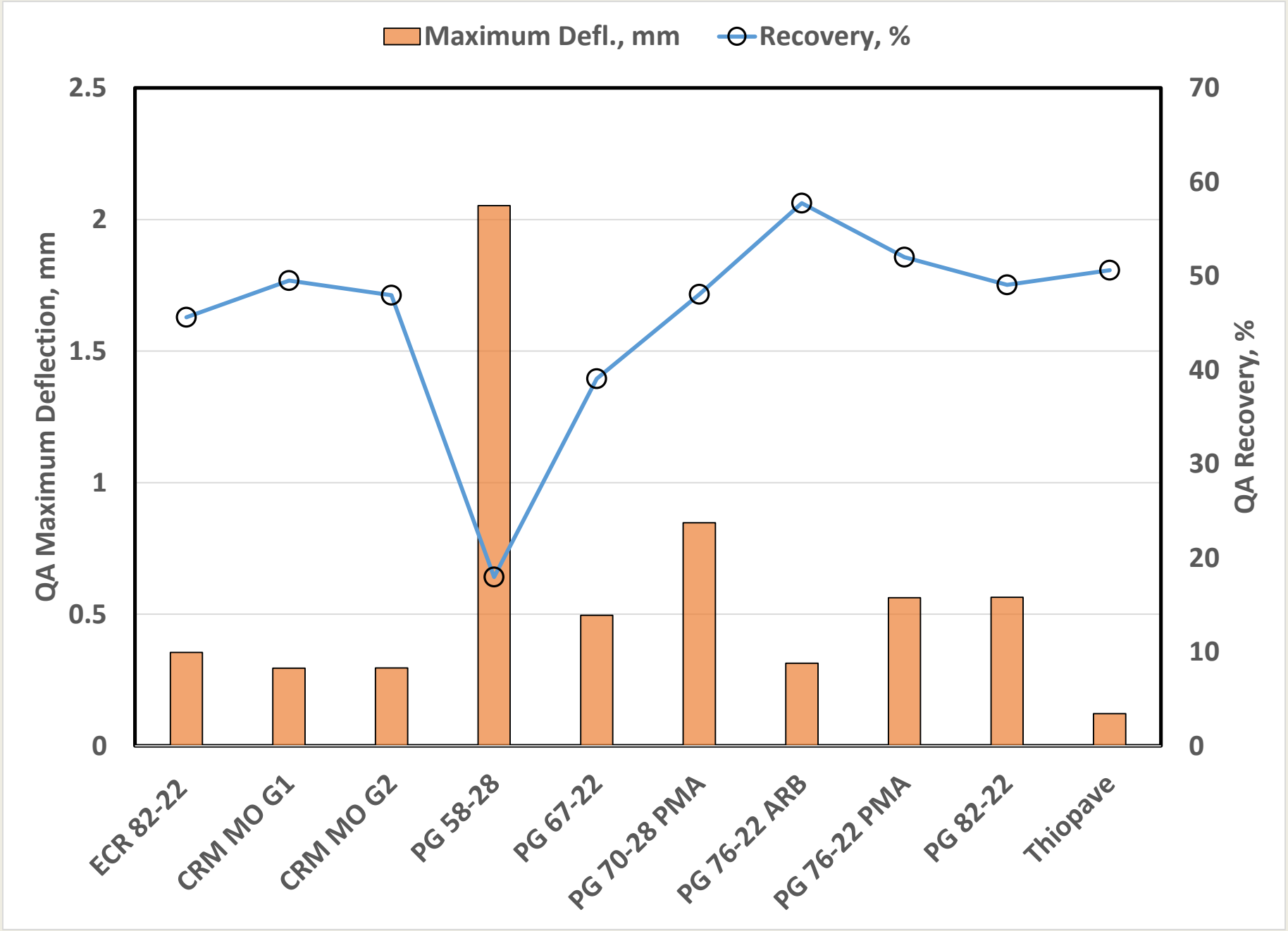


Binder Quality Control Tester

repeatability of qc data

Binder ID	Binder Type	Number of Replicates	QCT Max. Deflection, mm			QCT % Recovery		
			Average	Std. Dev	COV %	Average	Std. Dev	COV %
200/300 Pen	UnModified	5	2.8598	0.0437	2	14.4	0.4	3
#1 PG 58-28		5	0.5929	0.0370	6	20.1	1.0	5
PG 64-22		5	0.1588	0.0032	2	41.5	0.9	2
PG 76-10		5	0.0092	0.0006	6	82.0	7.8	10
#2 PG 58-28		5	0.7638	0.0192	3	15.5	0.1	1
PG 64-34	PMA	4	0.3383	0.0058	2	77.4	0.7	1
PG 76-22		5	0.0689	0.0023	3	58.0	1.1	2
PG 82-22	Crumb Rubber Modified	5	0.0533	0.0030	6	57.3	2.5	4
#1 PG 76-22		2	0.1377	0.0049	4	54.7	1.2	2
#2 PG 76-22		2	0.1055	0.0028	3	57.3	1.1	2
#3 PG 76-22		2	0.0908	0.0009	1	59.9	1.8	3
Pooled Average					**3**			**3**


Maximum Defl., mm
Recovery, %
QA Maximum Deflection, mm
QA Recovery, %
2.5
2
1.5
1
0.5
0
70
60
50
40
30
20
10
0
ECR 82-22
CRM MO G1
CRM MO G2
PG 58-28
PG 67-22
PG 70-28 PMA
PG 76-22 ARB
PG 76-22 PMA
PG 82-22
Thiopave


Maximum Defl., mm
Recovery, %
QA Maximum Deflection, mm
QA Recovery, %
2.5
2
1.5
1
0.5
0
70
60
50
40
30
20
10
0
ECR 82-22
CRM MO G1
CRM MO G2
PG 58-28
PG 67-22
PG 70-28 PMA
PG 76-22 ARB
PG 76-22 PMA
PG 82-22
Thiopave

THANK YOU!

Questions?