TODAYS AGENDA

- 9:00 to 11:30 AM
  - ECR (Engineered Crumb Rubber)
  - Value Engineering Technology – Thickness Reduction
- LUNCH Break 11;30 AM
- 12:30 PM
  - Bitumen and Mix QC Test Demonstration
  - Asphalt Specification Issues
    - DSR, BBR, MSCR etc
  - Mix Workability Test
- Summary and Discussion
- Dinner?

RAJ DONGRE, PH.D

- E-mail: Rajdongre@dongrelabs.com
- Phone: +1 (703) 395-8854
- Address: 2821Q Dorr Avenue, Fairfax, VA - 22031

ENGINEERED CRUMB RUBBER (ECR)

(INTERNATIONAL PATENT PENDING)

RAJ DONGRE

DONGRE LABORATORY SERVICES INC.,

USA

ROAD CONSTRUCTION/MAINTENANCE INDUSTRY MESSAGES

- US State DOTs:
  - Do more with less money,
  - Make roads last longer/reduce life cycle cost of roads
    - Phase angle, m-value and MSCR specifications
- Asphalt Producer Industry:
  - Improve product performance
  - Cut costs
- How can we do that? - *Engineered Crumb Rubber (ECR) Modified Asphalt*

CRUMB RUBBER MODIFIED BINDERS CHALLENGES

- Meeting performance standards
  - Binder (World) - Penetration, Soft. Point, ER
  - Binder (USA) - MSCR, Low Temperature BBR m – Value, PG Grade
  - Mixture – Rutting, Fatigue Cracking, Moisture Damage
- For Example – some State DOT CRMB Specifications
  - FL DOT – Jnr(3.2), %Recov(3.2) – Polymer Curve, Separation, phase angle, m-value
  - NY DOT – Jnr(3.2), %Recov(3.2) – Polymer Curve, Solubility, m-value
  - LA DOT – Jnr(3.2), %Recov(3.2) – Polymer Curve, phase angle, m-value

CRUMB RUBBER MODIFIED BINDERS: CHALLENGES

- Production Issues
  - Need CRM-Polymer hybrid formulation
  - Requires blending PMA (1.2 to 1.5% elastomer) and CRM
  - CRM consistency and functional polymer content
    - Truck tire CRM is required - -30 or -40 mesh
    - CRM contains dust which must be contained
- Economics
  - Competes with polymer only formulations (higher limit)
  - Need lower Cost than comparable polymer only processes
- A CRM product to meet above challenges:
  - **Engineered Crumb Rubber (ECR)**
    - May be used in "WET" blending or as a "DRY" mix additive

ECR – FOUR QUESTIONS

1. What is ECR?
    1. ECR Types
2. How is it used?
    1. "WET" Blending
    2. "DRY" Mix Addition
3. Does it work? Mix Performance?
4. Why bother considering ECR?

WHAT IS ENGINEERED CRUMB RUBBER (ECR)?

- ASTM minus #30 crumb rubber
- 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 10% or less
- ECR-WMA
  - Standard ECR with WMA additive coating
- ECR-MD (moisture damage)
  - Standard ECR with Anti-strip coating

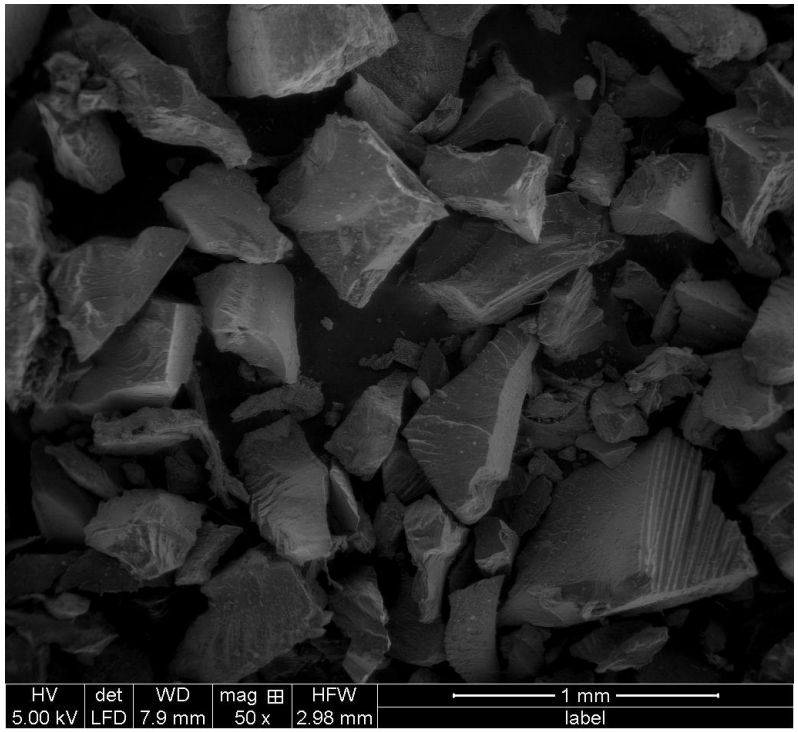
ECR TYPES……

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

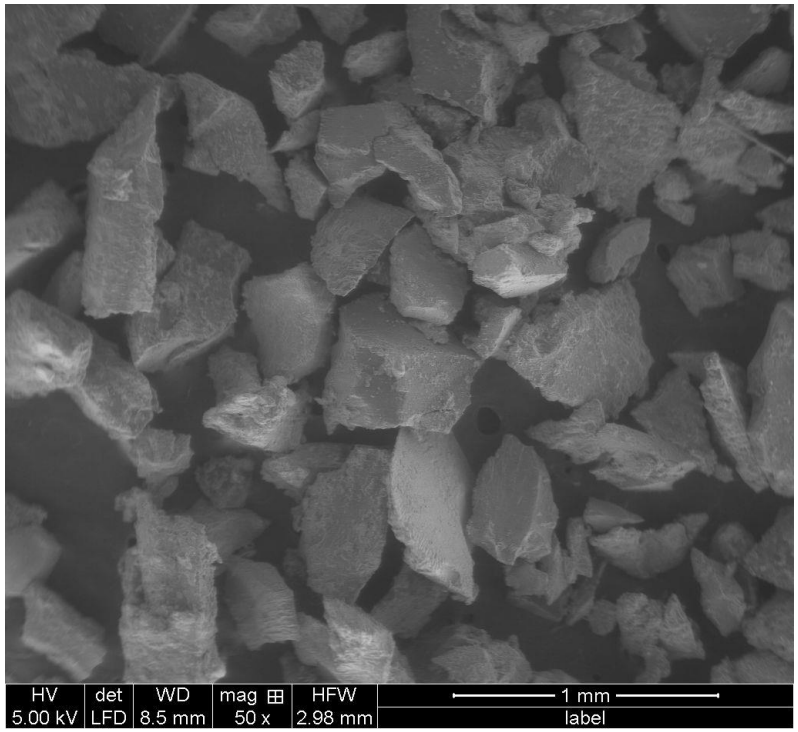
WHAT IS ENGINEERED CRUMB RUBBER (ECR)?

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

Normal Crumb Rubber



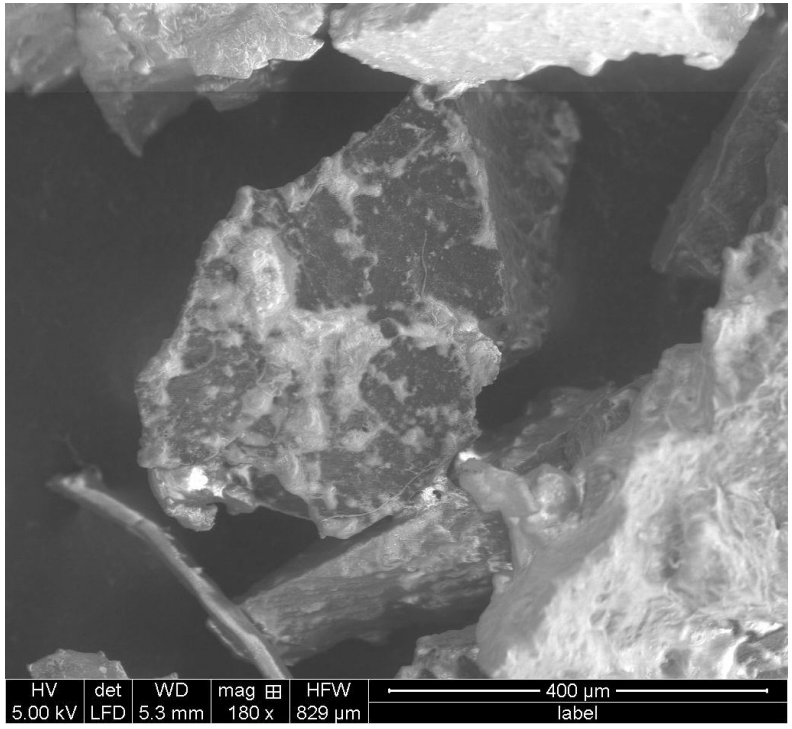
Engineered Crumb Rubber



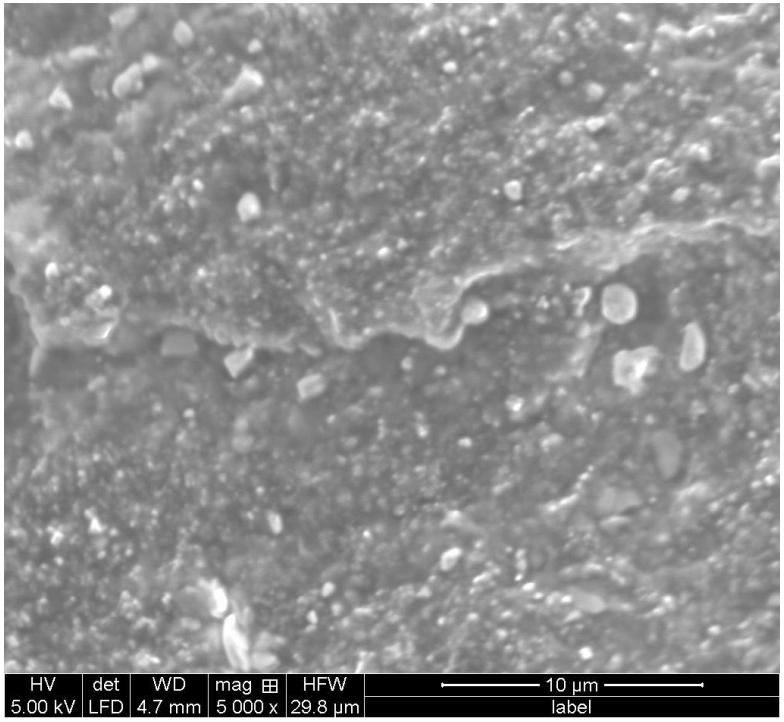
WHAT IS ENGINEERED CRUMB RUBBER (ECR)?

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

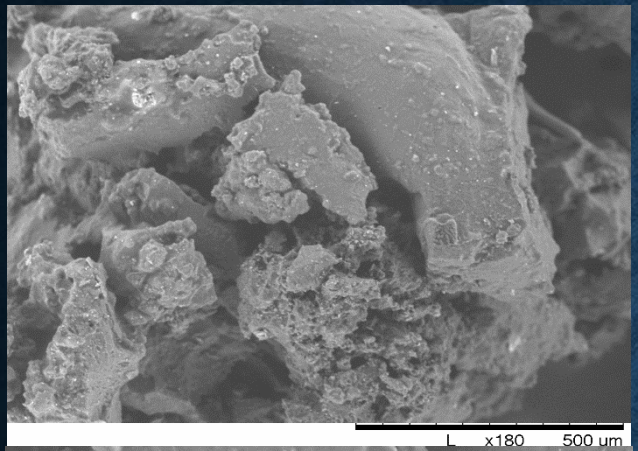
ECR at 180x mag.

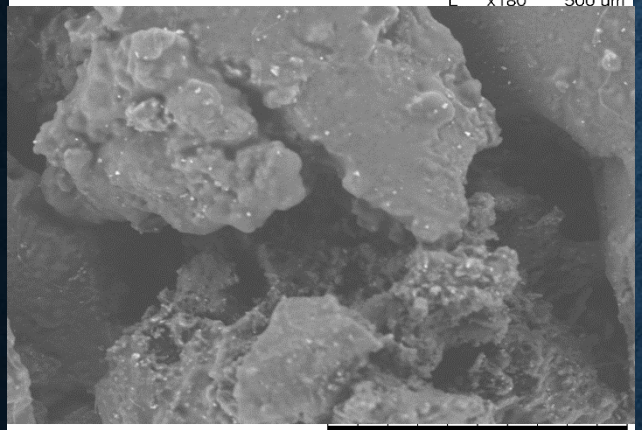


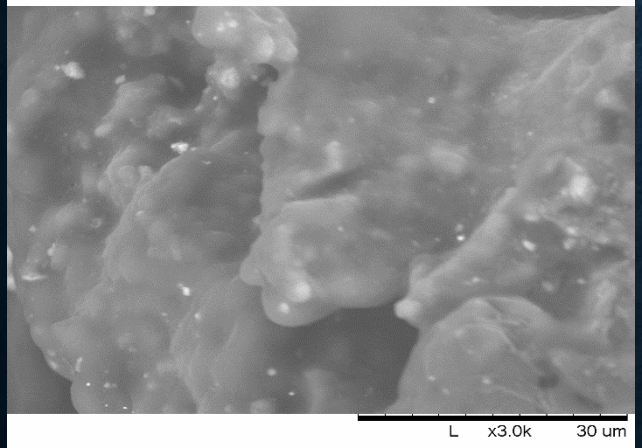
ECR at 5000x mag.



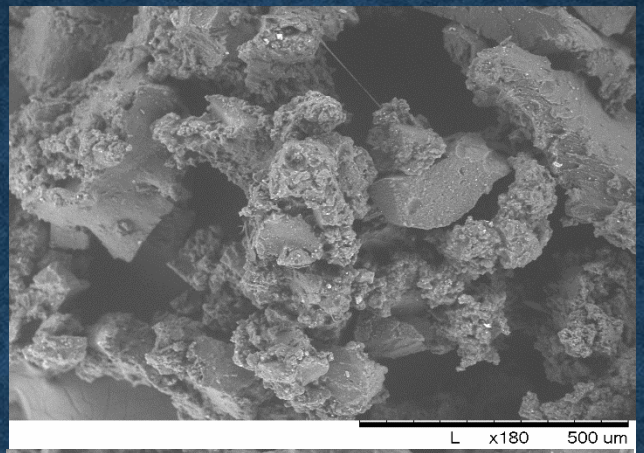
-30 mesh

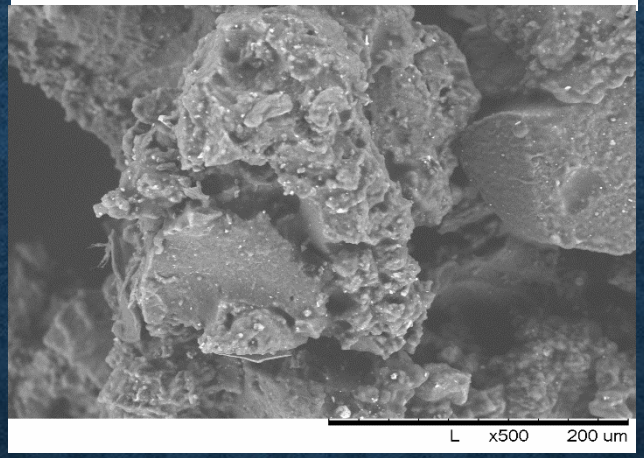


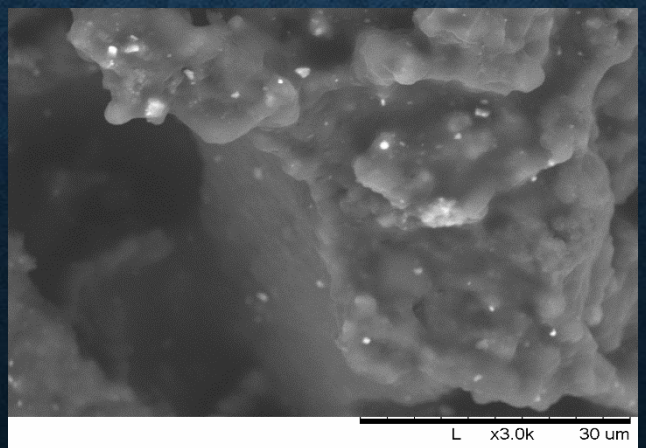




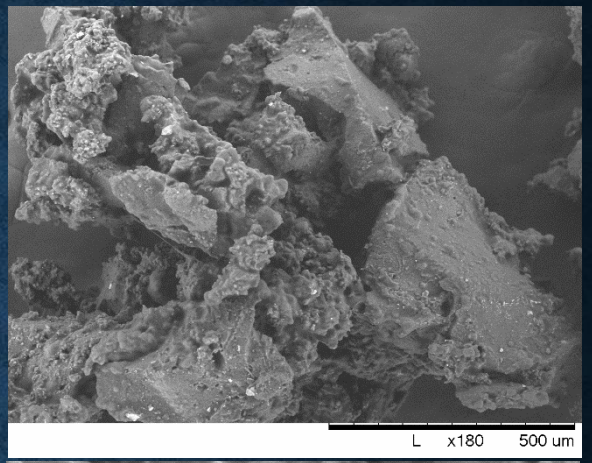
-40 mesh

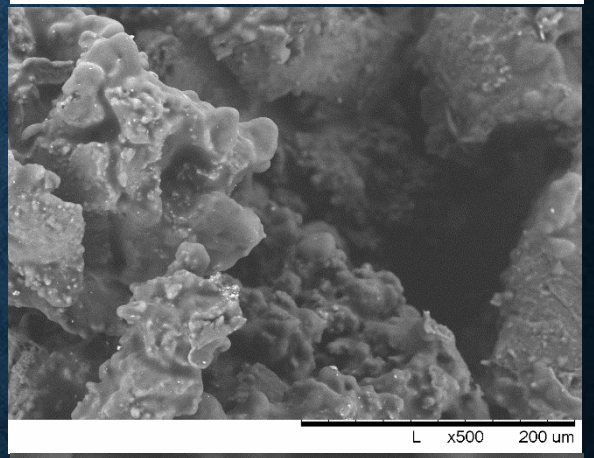


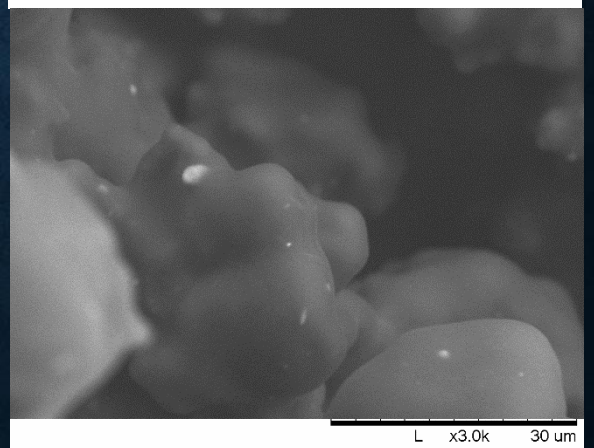




-30 mesh – Dual Polymer







HOW IS ECR USED (WET BLENDING)

- ECR Blended with binder – Hybrid binder
- “Digested” 2.5 hr. at 325F (163C) or higher
- Separation risks are minimized
- Pumping challenges minimized (<= 10% ECR)
- No special blending equipment reqd.

ECR IMPACTS ON BINDER PG & MIX PERFORMANCE

GA-DOT PG RESULTS

PG 67-22R Base Binder				
	Base	**ECR_#1**	**ECR_#2**	**SBS D1101**
Blend ID	B20	B_31	B_32	A63
% Additive	0	7	5	3
Additive Type	0	ECR	ECR	SBS D1101
PG Grade	PG 67-22	PG 88-22	PG 82-22	PG 76-22
True Grade	69.39-25.82	PG 89.65-24.91	PG 85.39-25.32	PG 77.9-23.2
Phase Angle @ 76°C	86.2	74.6	78	77.1
m-value (-12°C)	**0.338**	**0.317**	**0.321**	**0.307**
MSCR % Recov at 3.2 kPa (64°C	**10.9**	**51.3**	**37.1**	**41.1**
MSCR Jnr at 3.2 kPa (64°C)	0.7	0.1	0.2	0.5

GA-DOT PG RESULTS

PG 67-22 Base Binder				
	Base 1	**Control**	**ECR**	**SBS D1101**
Blend ID	B10	B_11	B_1E	A63
% Rubber	0	10	10.0	3
Rubber Type	0	CRM	ECR	SBS D1101
PG Grade	PG 67-22	PG 76-22	PG 82-22	PG 76-22
True Grade	68.69-25.41	79.99-22.12	PG 87.05-23.86	PG 77.9-23.2
Phase Angle @ 76°C	88.1	84.7	75.4	77.1
m-value (-12°C)	**0.336**	**0.301**	**0.313**	**0.307**
MSCR % Recov at 3.2 kPa (64°C)	**1.5**	**27.3**	**41.5**	**41.1**
MSCR Jnr at 3.2 kPa (64°C)	2.1	0.3	0.3	0.5

GA-DOT PG RESULTS

PG 64-22 Base Binder				
	Base 2	**Control**	**ECR**	**SBS D1101**
Blend ID	B20	B_11	B_2D	A63
% Additive	None	10	10	3
Additive Type	None	#30 CRM	ECR	SBS D1101
PG Grade	PG 64-22	PG 76-22	PG 76-22	PG 76-22
True Grade	66.77-26.86	79.99-22.12	PG 81.71-25.63	PG 77.9-23.2
Phase Angle @ 76°C	89.1	84.7	80.3	77.1
m-value (-12°C)	0.347	**0.301**	**0.323**	**0.307**
MSCR % Recov at 3.2 kPa (64°C)	0.8	**27.3**	**36.3**	**41.1**
MSCR Jnr at 3.2 kPa (64°C)	2.8	0.3	0.4	0.5

LA-DOT PG RESULTS

	LADOT Spec.	LA PG 64-22 Base Binder ECR		SBS D1101
Blend ID	-	**BV_10ECR**	**BM_10ECR**	A63
% Rubber	**10% max.**	9.0	10.5	3
Rubber Type	-	ECR93 - 30	ECR93-30	SBS D1101
PG Grade	**PG 76-22 E**	PG 82-22	PG 82-22	PG 76-22
True Grade	**NA**	PG 83.28-24.93	PG 82.42-26.41	PG 77.9-23.2
Phase Angle @ 76°C	**min. 75**	71	69.4	77.1
m-value (-12°C)	**0.3**	**0.313**	**0.336**	**0.307**
%R@3.2 > (29.37(Jnr,3.2)^-0.2632)	**Poly. Curv**	**42.3**	**37.4**	**36.0**
% R@3.2 kPa (67°C)	**meas. >= Poly. Curv**	**43.9**	**38.5**	**41.1**
Jnr at 3.2 kPa (67°C)	**min 0.5**	**0.3**	**0.4**	**0.5**
Jnr % Difference	**75.0**	**55**	**68**	**54**

IMPACT OF CRM TYPE FUNCTIONAL POLYMER CONTENT

	LADOT Spec.	LA PG 64-22 Base Binder		LA PG 64-22 Base Binder		LA PG 64-22 Base Binder		SBS D1101
		CRM Car Tires		CRM Truck Tires		ECR		
Blend ID	-	BV_CRM_Car	BM_CRM_car	BV_CRM_Trk	BM_CRM_Trk	BV_10ECR	BM_10ECR	A63
% Rubber	10% max.	12.0	12.0	12.0	12.0	9.0	10.5	3
Rubber Type	-	CRM Car Tires	CRM Car Tires	CRM Truck Tires	CRM Truck Tires	ECR93 - 30	ECR93-30	SBS D1101
PG Grade	PG 76-22 E	PG 76-22	PG 70-22	PG 82-22	PG 82-22	PG 82-22	PG 82-22	PG 76-22
True Grade	NA	PG 79.54-25.47	PG 75.47-25.69	PG 85.42-24.70	PG 82.60-26.75	PG 83.28-24.93	PG 82.42-26.41	PG 77.9-23.2
Phase Angle @ 76°C	min. 75	81.7	82.6	76.5	76.9	71	69.4	77.1
m-value (-12°C)	0.3	0.326	0.332	0.318	0.342	0.313	0.336	0.307
%R@3.2 > (29.37(Jnr,3.2)^-0.2632)	Poly. Curv (PC)	33.1	30.0	42.0	35.5	42.3	37.4	36.0
% R@3.2 kPa (67°C)	meas. >= PC	13.5	8.7	43.3	31.3	43.9	38.5	41.1
Jnr at 3.2 kPa (67°C)	min 0.5	0.6	0.9	0.3	0.5	0.3	0.4	0.5
Jnr % Difference	75.0	24	25	75	103	55	68	54

DONGRE LABORATORY SERVICES
Consulting and Testing Services in Asphalt Technology

Dongre Laboratory Services Inc. (DLSI)
An AASHTO Accredited Laboratory
2821 Q Dorr Avenue
(703) 395-8854, Fax: (540) 301-0839

REPORT ON SAMPLE(S) OF PERFORMANCE GRADED BINDER

New York Binder Specification Tests

Material Supplier	United Refining Company		
Supplier Sample ID			PG64-22
Supervisor	Raj Dongre		
Date Tested	5/1/2015		
New York DOT PG+ Grade			PG 64-22
DLSI Internal ID			UNTD_NY-ECR10
	AASHTO Std.	AASHTO Limits	
Un-aged Org. Binder Tests:			
Flash Point, °C	T 48	232.22 °C min.	325
Solubility, %, TCE	T44	99.0 min.	99.680
Viscosity-Rotational, Pa-s 135 C	T 316	3.0 max.	2.690
Cigar Tubes Separation at 163C 48 hours			
Softening Point, Top	T53		131.9
Softening Point, Bottom	T53		154.6
Difference Top-Bot, F		15F max dif.	22.7
Softening Point, Middle			145.4
Dynamic Shear Rheometer	T 315		
Passing Temperature, °C			64
Phase Angle, degrees			71.3
G* @10 rad/sec, kPa			6.58
G*/sin delta @10 rad/sec, kPa		1.0 min.	6.95
RTFO Residue Tests:			
Mass Loss, %	T 240	1.0 max.	-0.046
Dynamic Shear Rheometer	T 315		
Passing Temperature, °C			64
Phase Angle, degrees			58.8
G* @10 rad/sec, kPa			12.6
G*/sin delta @10 rad/sec, kPa		2.2 min.	14.8
Multiple Stress Creep Recovery AASHTO TP 70			64
Jnr, 3.2 kPa average	max	max Jnr at 3.2 kPa: E = 0.5	0.26
Jnr, diff	max	75%	43.90
% Recovery, 3.2			51.11
%R3.2 > (29.37(Jnr,3.2)^-0.2633)	min		41.87
PAV Residue Tests:			PAV 100
Dynamic Shear Rheometer	T 315		
Passing Temperature, °C			25
Phase Angle, degrees			43.9
G* @10 rad/sec, kPa			4440
G*sin delta @ 10 rad/sec, kPa		5,000.0 max.	3080
Bending Beam Rheometer	T 313		
Passing Temperature, °C			-12
s, 60s, Mpa		300.0 max.	123
m-value, 60s		0.3 min.	0.336

This sample meets or exceeds the requirements for a PG 64-22 as set forth by New York DOT.

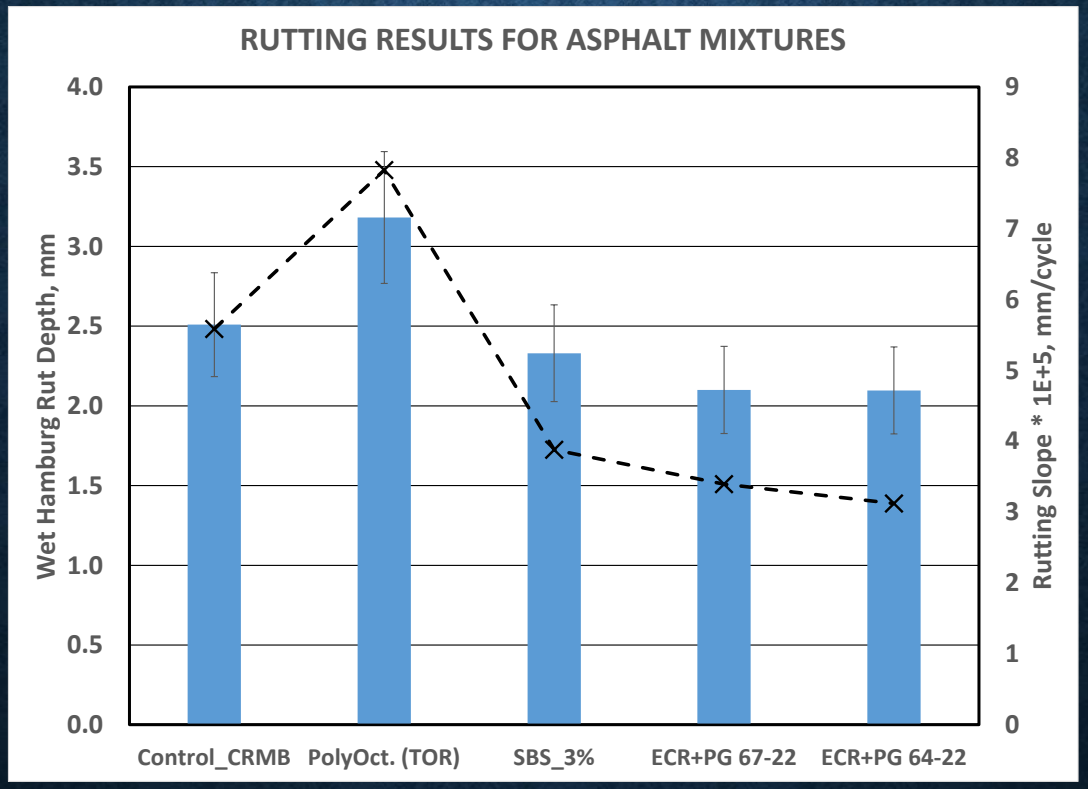
DONGRE LABORATORY SERVICES
Consulting and Testing Services in Asphalt Technology

Dongre Laboratory Services Inc. (DLSI)
An AASHTO Accredited Laboratory
2821Q Dorr Avenue
(703) 395-8854, Fax: (540) 301-0839

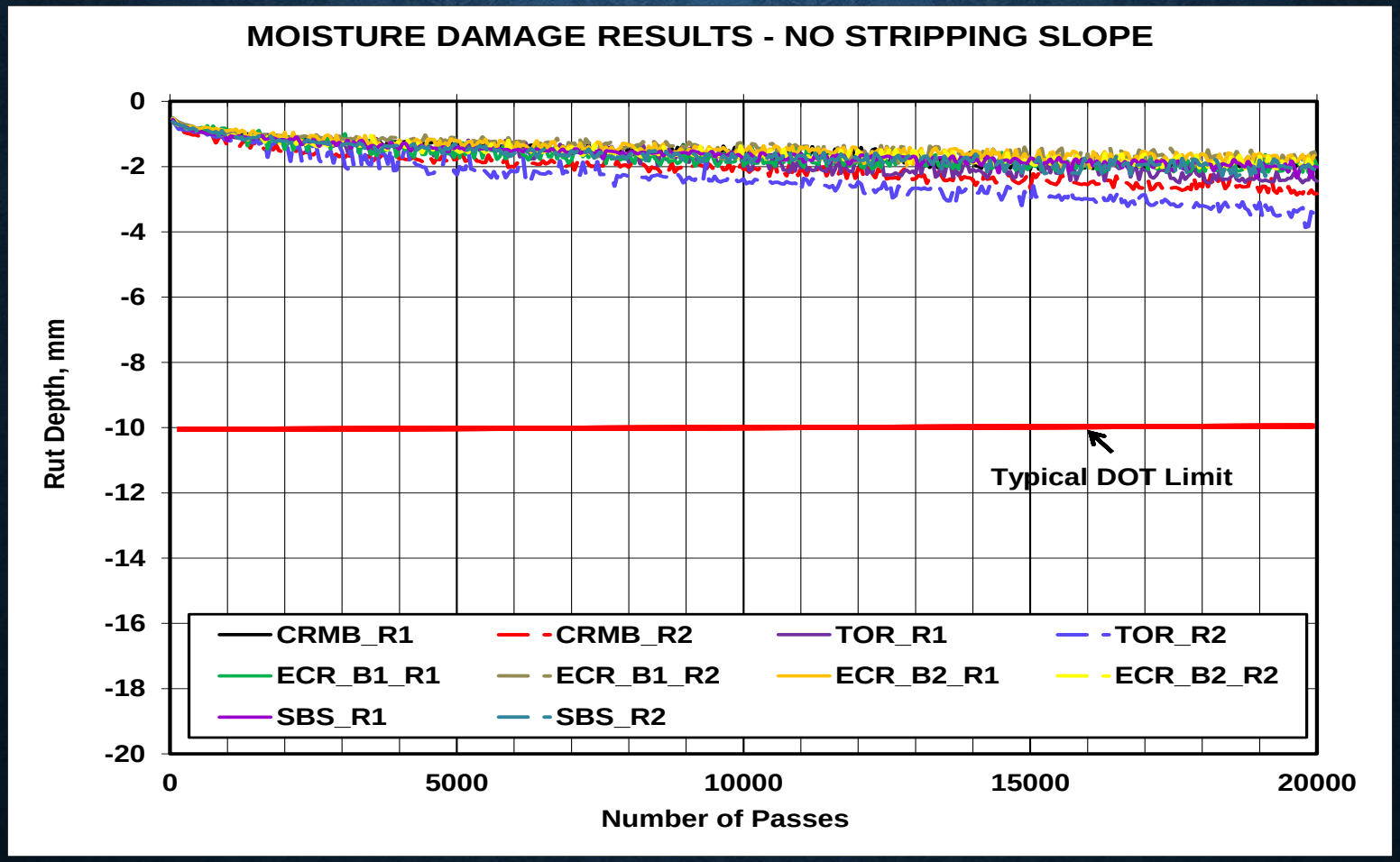
REPORT ON SAMPLE(S) OF PERFORMANCE GRADED BINDER

Florida Superpave PG+ Binder Specification Tests			
Material Supplier	SFMC		
Supplier Sample ID			SFMC 67-22
Supervisor	Raj Dongre		
Date Tested	12/15/2014		
QPL			
Florida DOT PG+ Grade			PG 76-22
AASHTO M320 Continuous PG Grade			PG 88.29-26.93
DLSI Internal ID			Q12 SECR
	AASHTO Std.	AASHTO Limits	
Un-aged Org. Binder Tests:			
Flash Point, °C	T 48	232.22 °C min.	
Viscosity-Rotational, Pa-s 135 C	T 316	report	4.400
Cigar Cubes Separation at 163C 48 hours			
Softening Point, Top	T53		161.4
Softening Point, Bottom	T53		147.7
Difference Top-Bot, F		15F max dif.	13.7
Dynamic Shear Rheometer		T 315	
Passing Temperature, °C			76
Phase Angle, degrees		75° max.	74.2
G* @10 rad/sec, kPa			3.28
G*/sin delta @10 rad/sec, kPa		1.0 min.	3.41
Second Temperature, °C			82
Phase Angle, degrees			76.2
G* @10 rad/sec, kPa			1.79
G*/sin delta @10 rad/sec, kPa		1.0 min.	1.84
AASHTO M320 ORG. Pass/Fail Temperature, °C			88.3
RTFO Residue Tests:			
Mass Loss, %	T 240	1.0 max.	-0.376
Dynamic Shear Rheometer	T 315		
Passing Temperature, °C			76
Phase Angle, degrees			66.2
G* @10 rad/sec, kPa			6.57
G*/sin delta @10 rad/sec, kPa		2.2 min.	7.91
Second Temperature, °C			82
Phase Angle, degrees			65.9
G* @10 rad/sec, kPa			4.21
G*/sin delta @10 rad/sec, kPa		2.2 min.	5.08
AASHTO M320 RTFO Pass/Fail Temperature, °C			94.7
Multiple Stress Creep Recovery AASHTO TP 70			67
Jnr, 3.2 kPa average	max	max Jnr at 3.2 kPa = 1.0	0.16
Jnr, diff	max	75%	147.39
% Recovery, 3.2			58.31
%R3.2 > (29.37(Jnr,3.2)^-0.2632)	max		47.58
Dynamic Shear Rheometer		T 315	
PAV 100C Passing Temperature, °C			26.5
Phase Angle, degrees			44.3
G* @10 rad/sec, kPa			3920
G*/sin delta @ 10 rad/sec, kPa		5,000.0 max.	2740
Bending Beam Rheometer	T 313		
Passing Temperature, °C			-12
s, 60s, Mpa		300.0 max.	119
m-value, 60s		0.3 min.	0.337
Second Temperature, °C			-18
s, 60s, Mpa		300.0 max.	262
M-value, 60s		0.3 min.	0.292
Tcr at S = 300 Mpa			-29.39
Tcr at m = 0.300			-26.93
BBR Tcr			-26.93

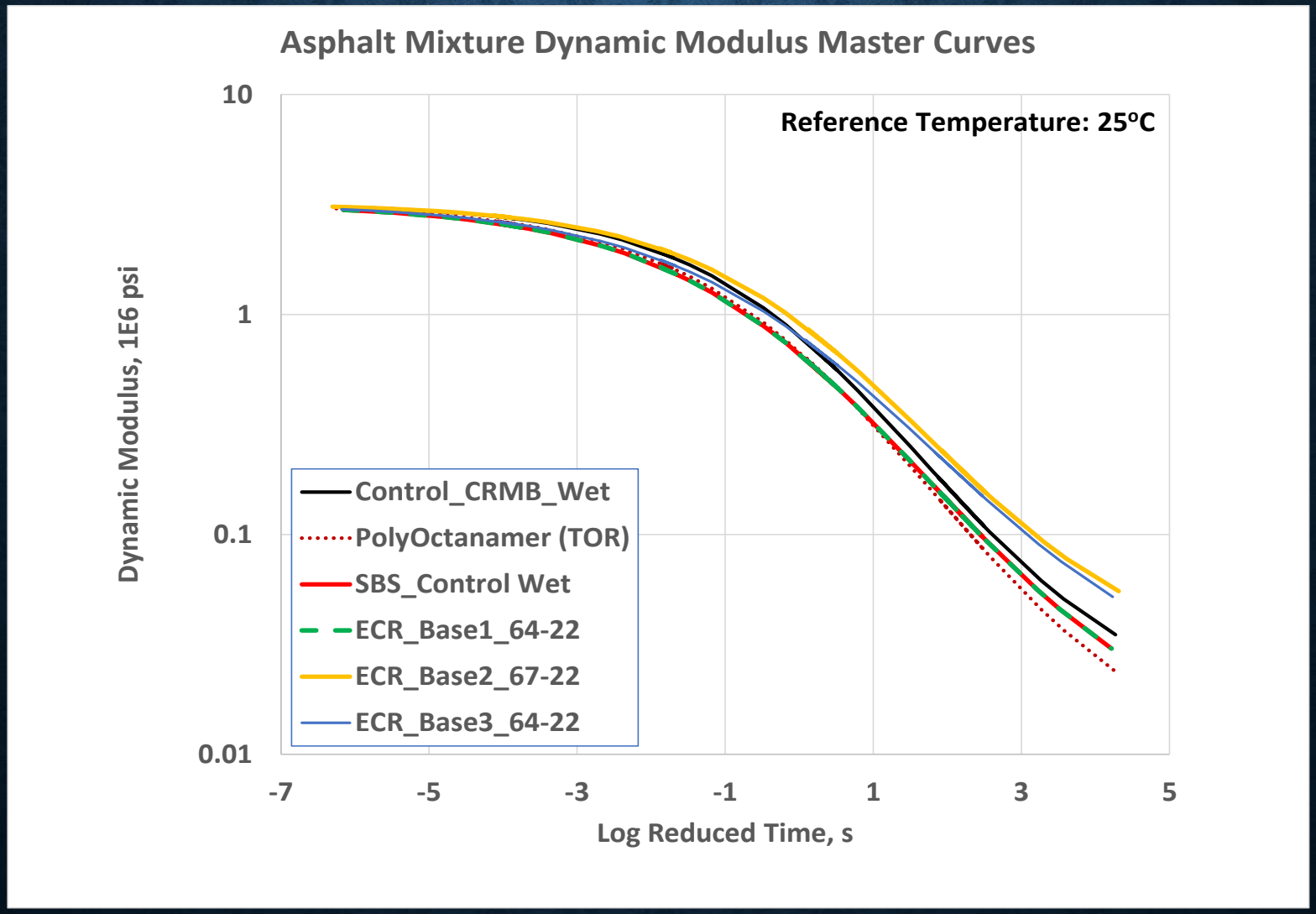
RUTTING DEPTH FOR VARIOUS ECR MODIFIED ASPHALTS



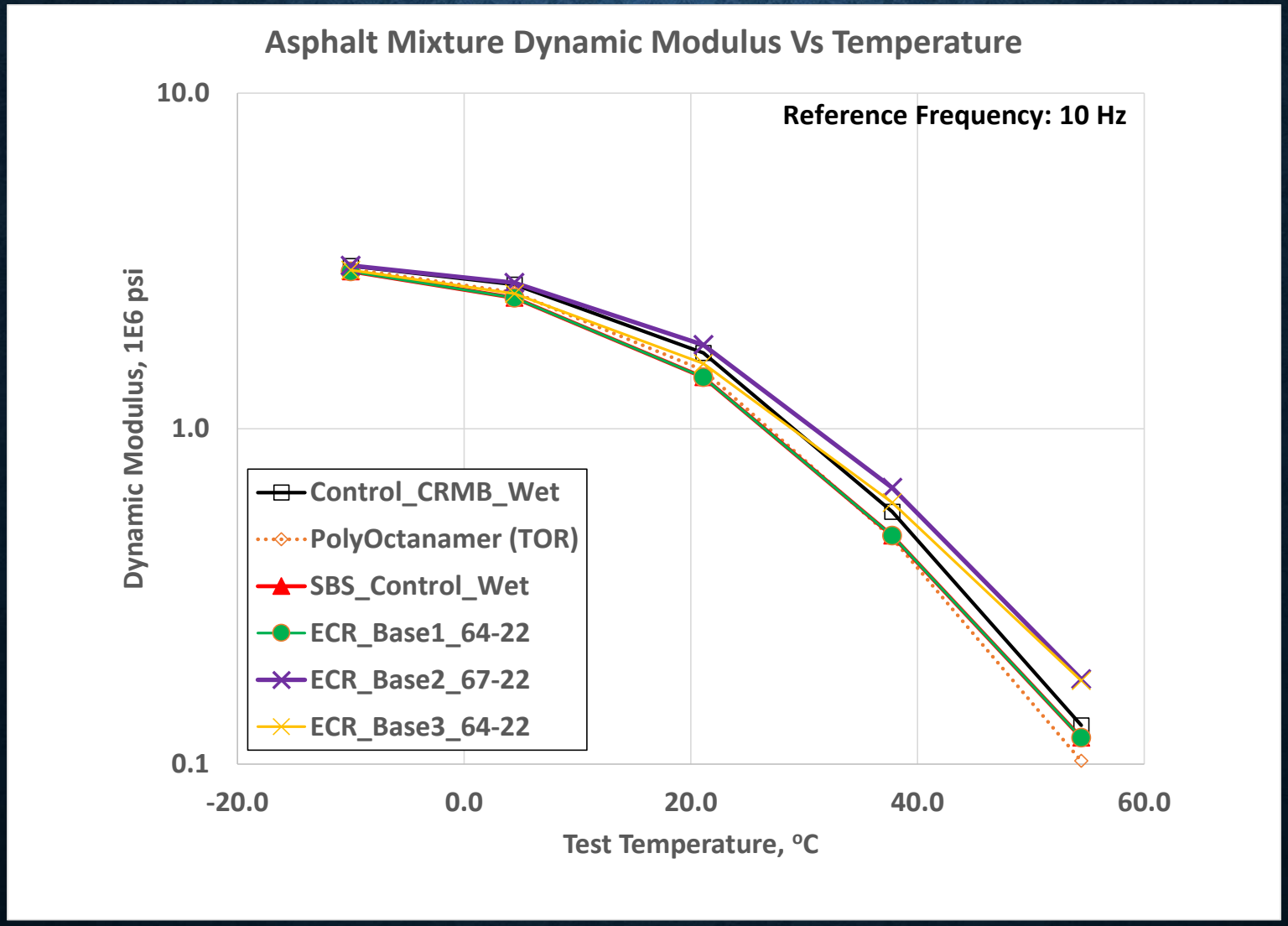
MOISTURE DAMAGE



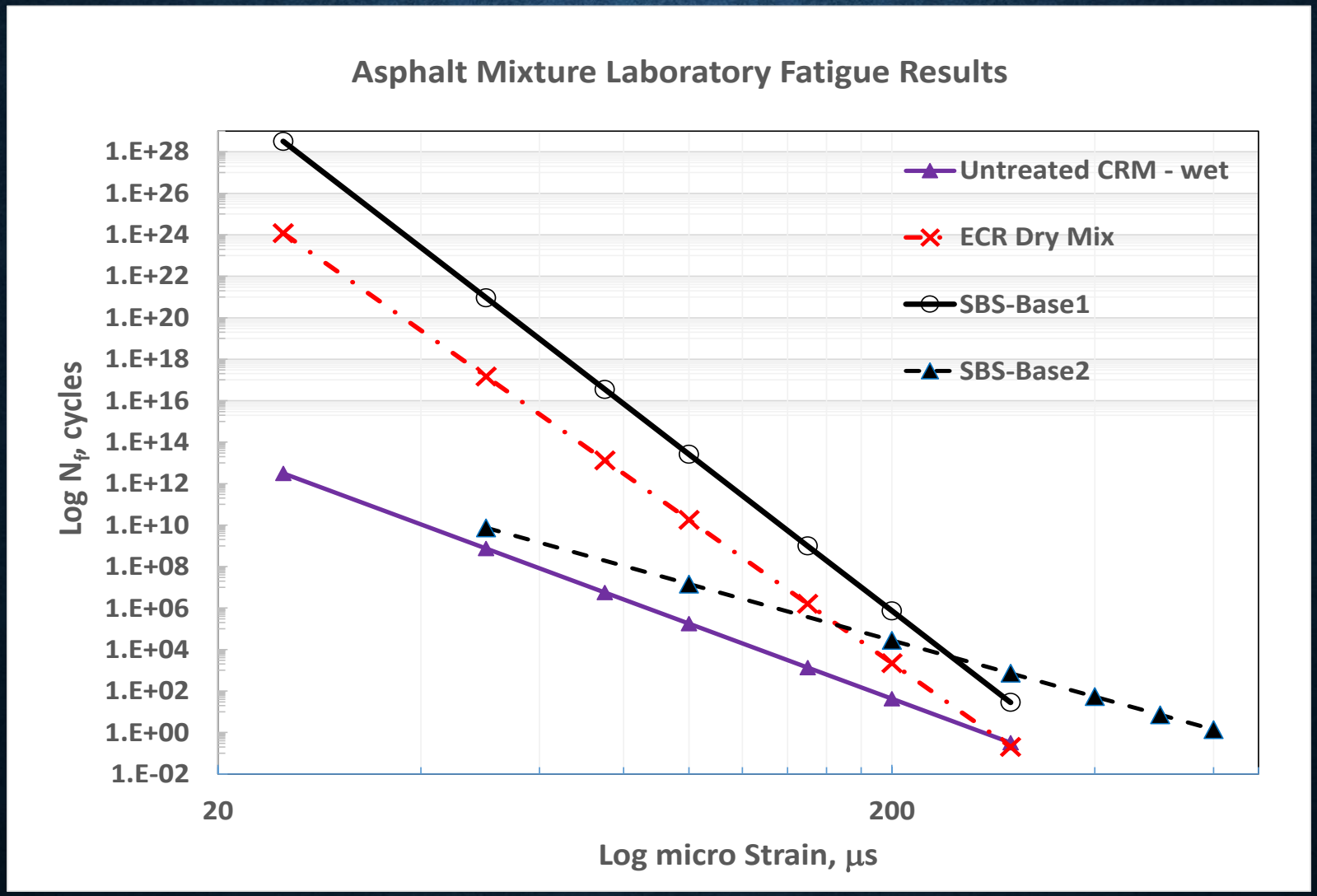
MASTER CURVE



DYNAMIC MODULUS VERSUS TEMPERATURE



MIX FATIGUE ANALYSIS



ECR DRY MIX BENEFITS

- 15 – 40% cheaper than alternatives
- No pumping issues with rubber
- Composite means no separation issues
- The process is on-off: no wasted modified binder
- No loss of product/pavement quality
- Process can carry other chemicals into production
- More economical High Modulus Mixes – ECR-HM + PMA Hybrid
- Makes sustainability affordable

FINAL THOUGHTS
WHY BOTHER WITH ECR?

- FOR US DOTs:
  - Reduces LCC of roads: Better pavements
  - Allows known performance specs – Hybrid Binders and Mixes
  - Reduces production risks – ease of use
  - Sustainable roads
- FOR CONTRACTORS
  - Drives cost down
  - Allows inexpensive, simple on-site modification
  - Allows more participation – No specialized plants reqd.

THANK YOU!