



Epoxy Asphalt

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Acknowledgements

- The invaluable assistance of Terry Arnold, Jenny Rosario, and Audrey Copeland is gratefully acknowledged.
- Bob Gaul provided materials and valuable assistance.

Overview

- Background
 - Who, Why, and What
- Approach
- Findings
 - General
 - Specific to adhesion and cohesion
- Conclusions and Future Direction

OECD/ECMT Transport Research Project - Economic Evaluation of Long Life Pavements:

Design and Testing of Long Life Wearing Course

OECD EA Participants

- Denmark
- France
- Germany
- New Zealand
- United Kingdom
- United States

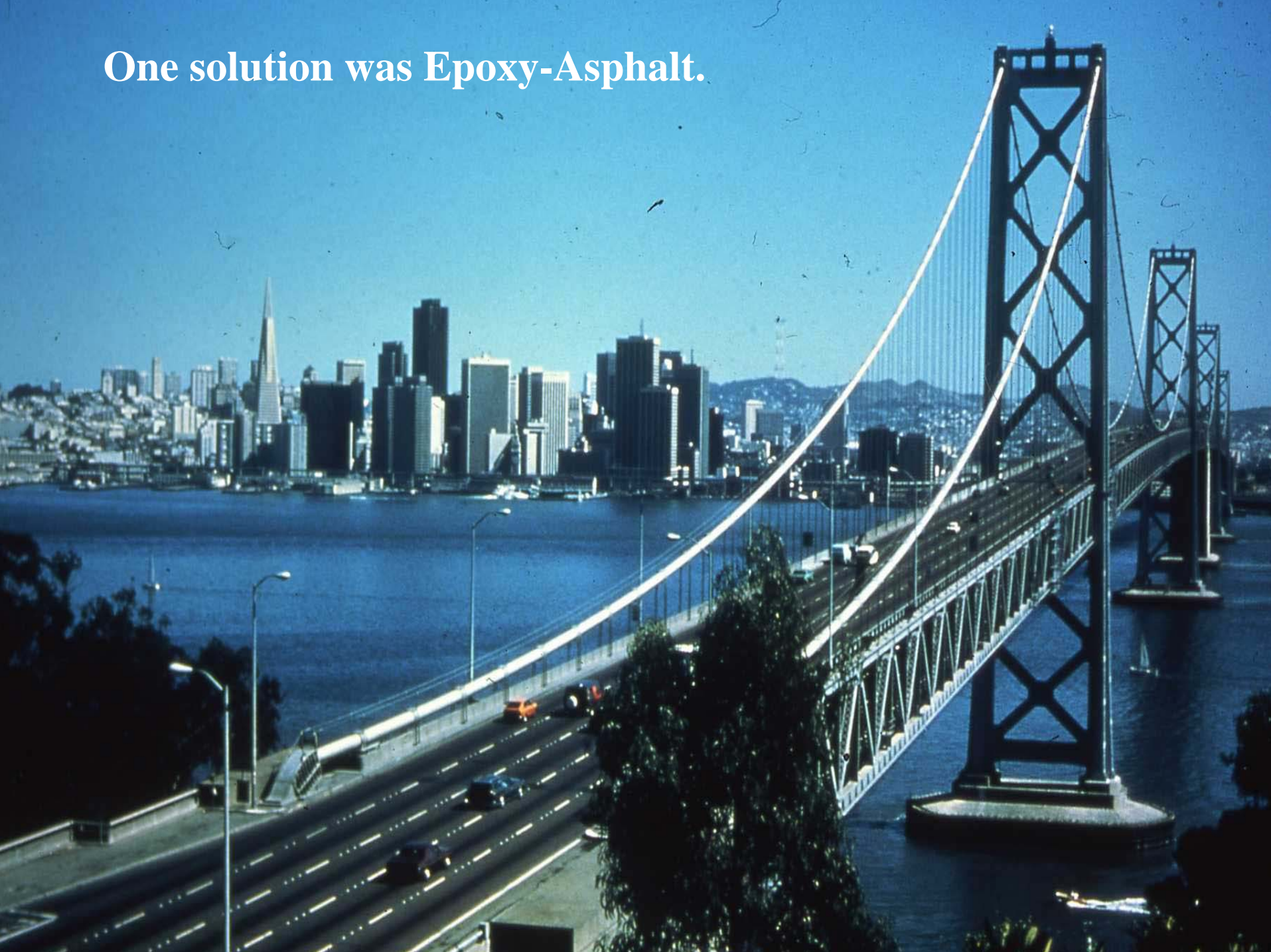
Phase I: White Paper

- Life cycle costing of wearing courses
- Improving load-carrying capacities of structures and pavements
- Investigate the use of alternative materials
- Minimize disruption to traffic due to construction
- Mitigate noise and vibration

Holy Grail

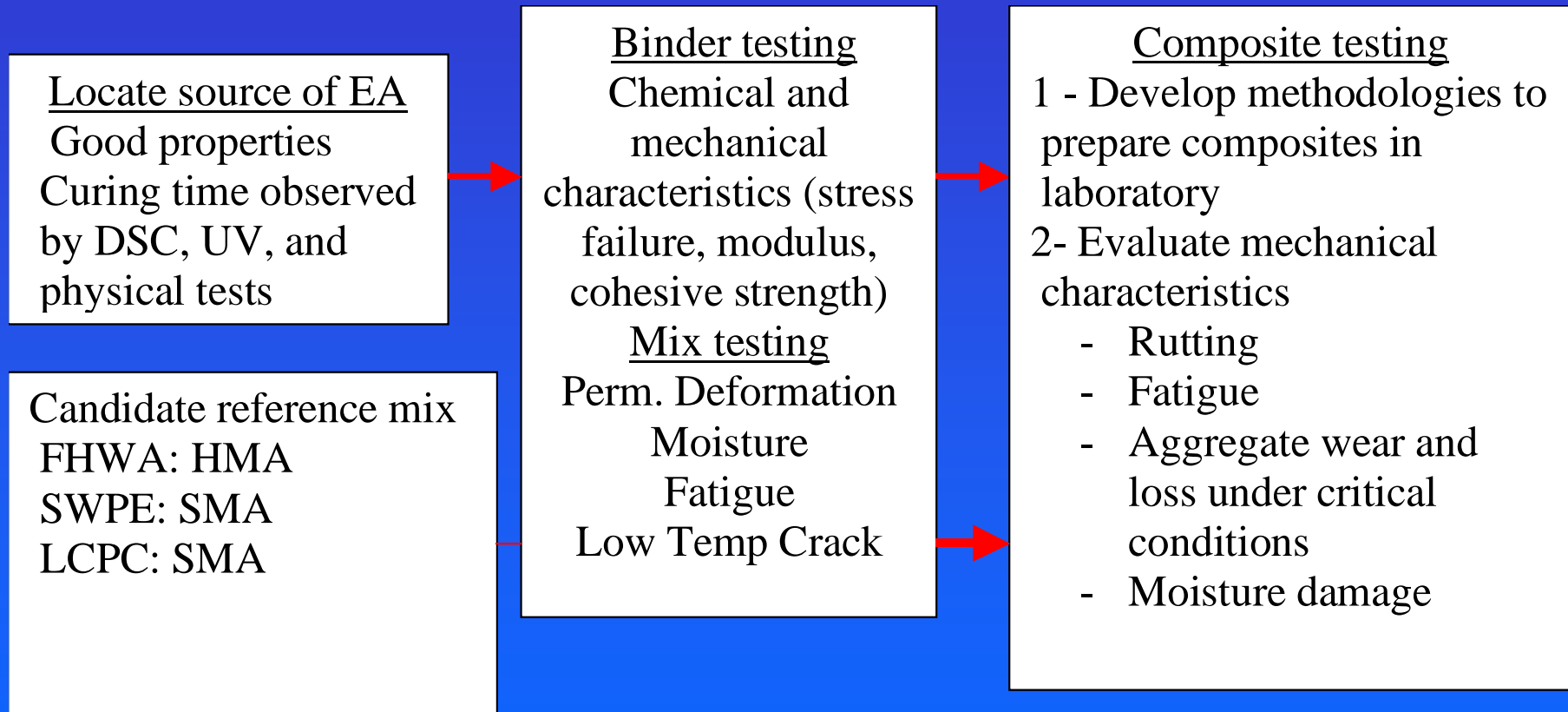
Wearing course giving 40 + years of performance on heavily trafficked roads

One solution was Epoxy-Asphalt.



APPROACH

Binder, Mix and Composite testing



Phase A

Phase B

Working with EA

Lesson #1

Cannot apply Superpave Binder Specification

Epoxy Resin Part A



Epoxy Resin Part B



Binder Test Results

Sample	Penetration (dmm)	Softening point (°C)
40/60 pen	49	50.8
Epoxy Binder Part B (binder/curing agents)	259	35.8
Epoxy Binder Part A&B	236	38.6
(A+B) + Filler	86	
40/60 + Filler	23	

Pouring Epoxy Test Specimen



Epoxy Beam 10 Seconds



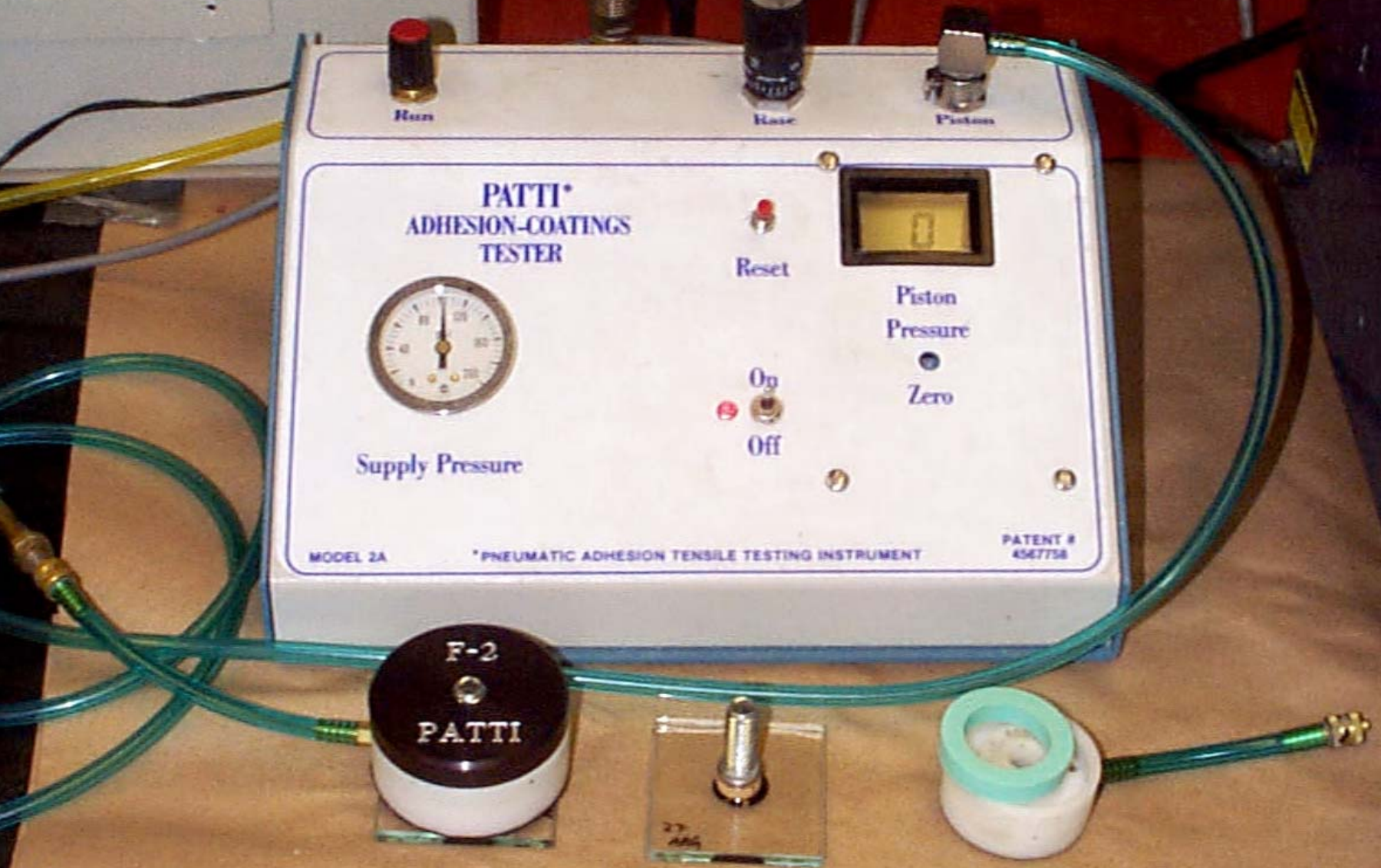
Epoxy Beam 21 Seconds



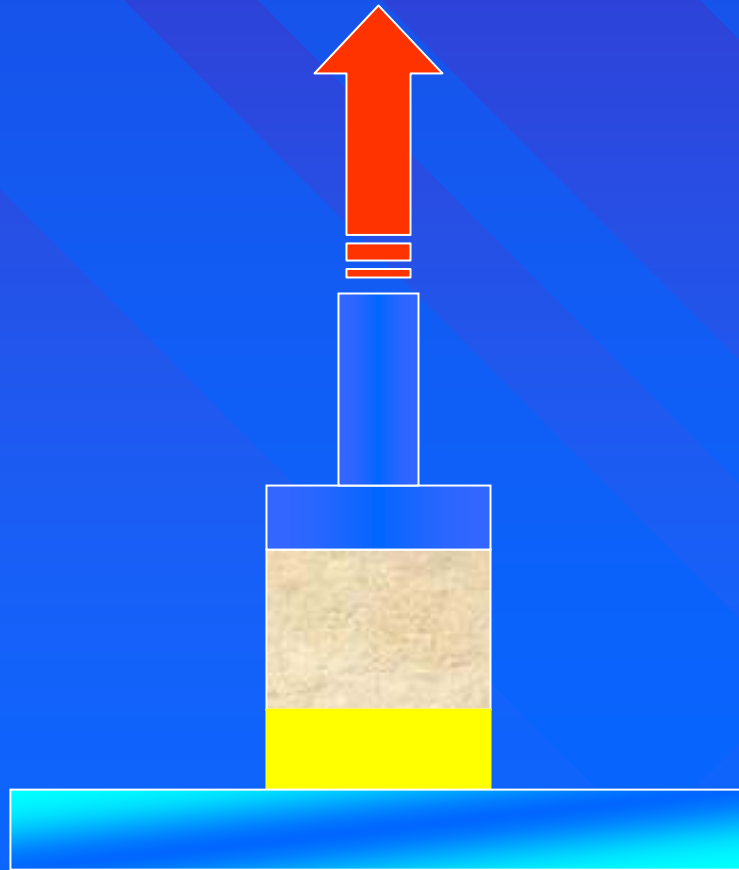
Aging Characteristics Curing and Oxidative

- Pneumatic Adhesion Test
- Weathering of beams
 - Heat + UV + moisture (cold)
- Rheology
- FTIR
- Penetration
- Microscopy

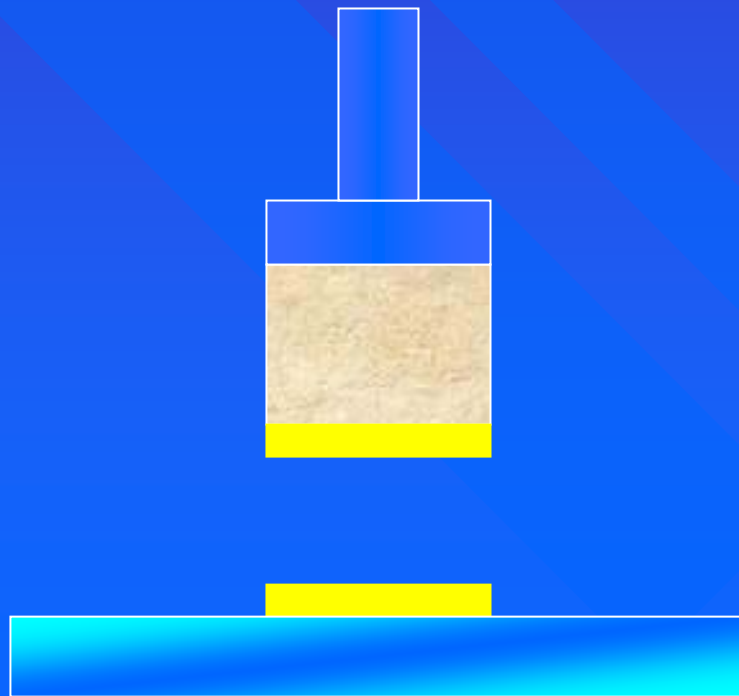
Pneumatic Pull-Off Test



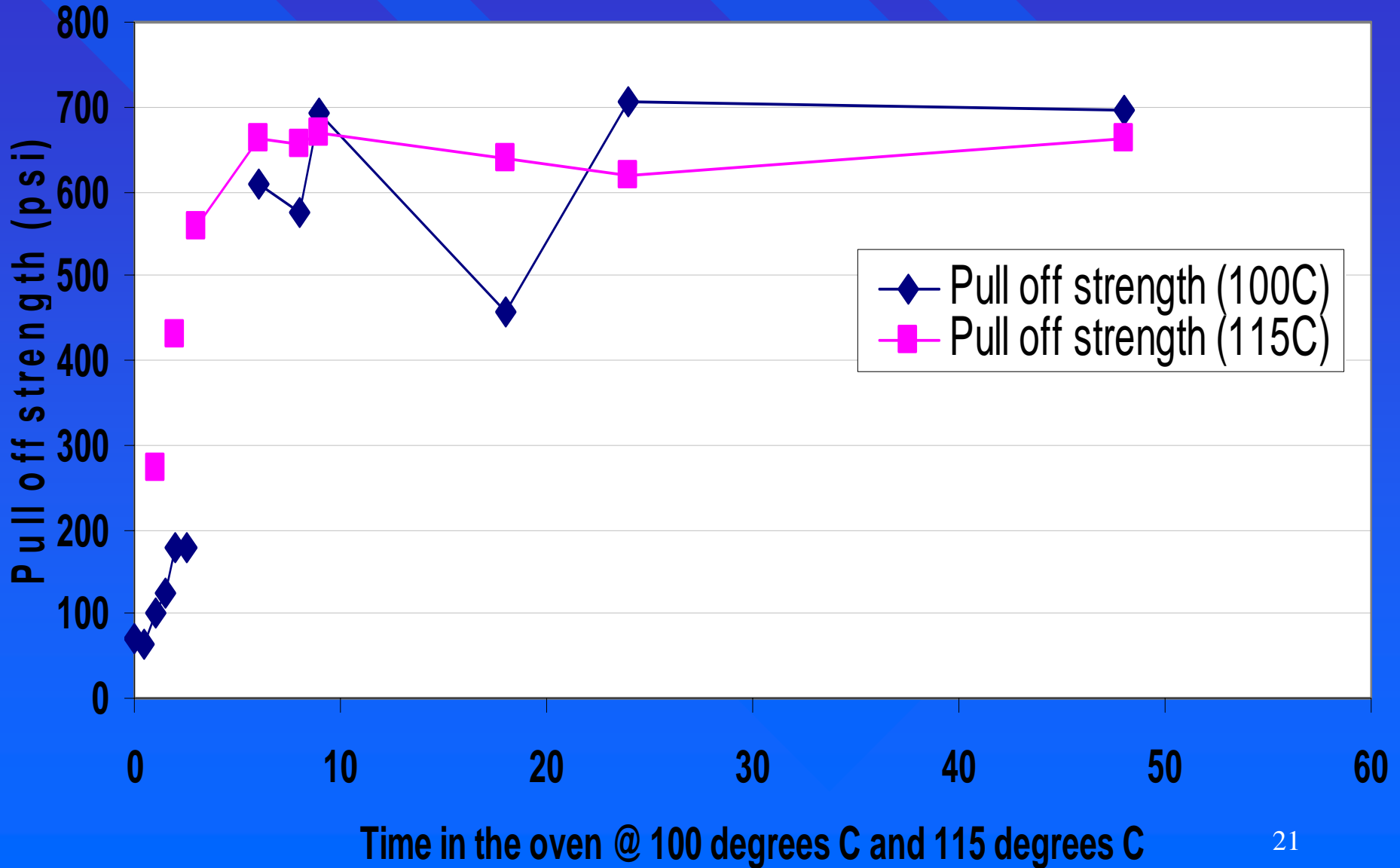
Pneumatic Pull-Off Test

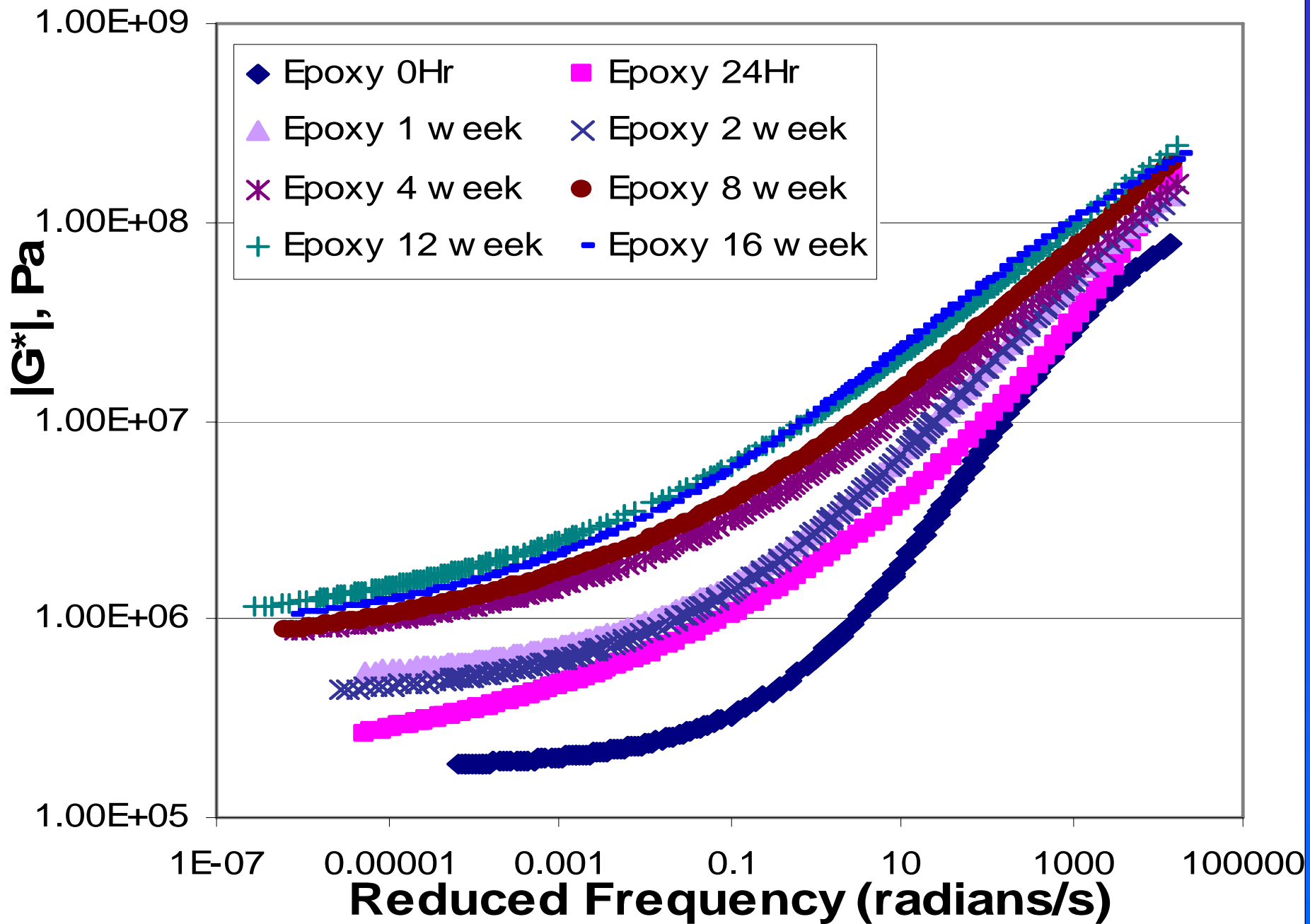


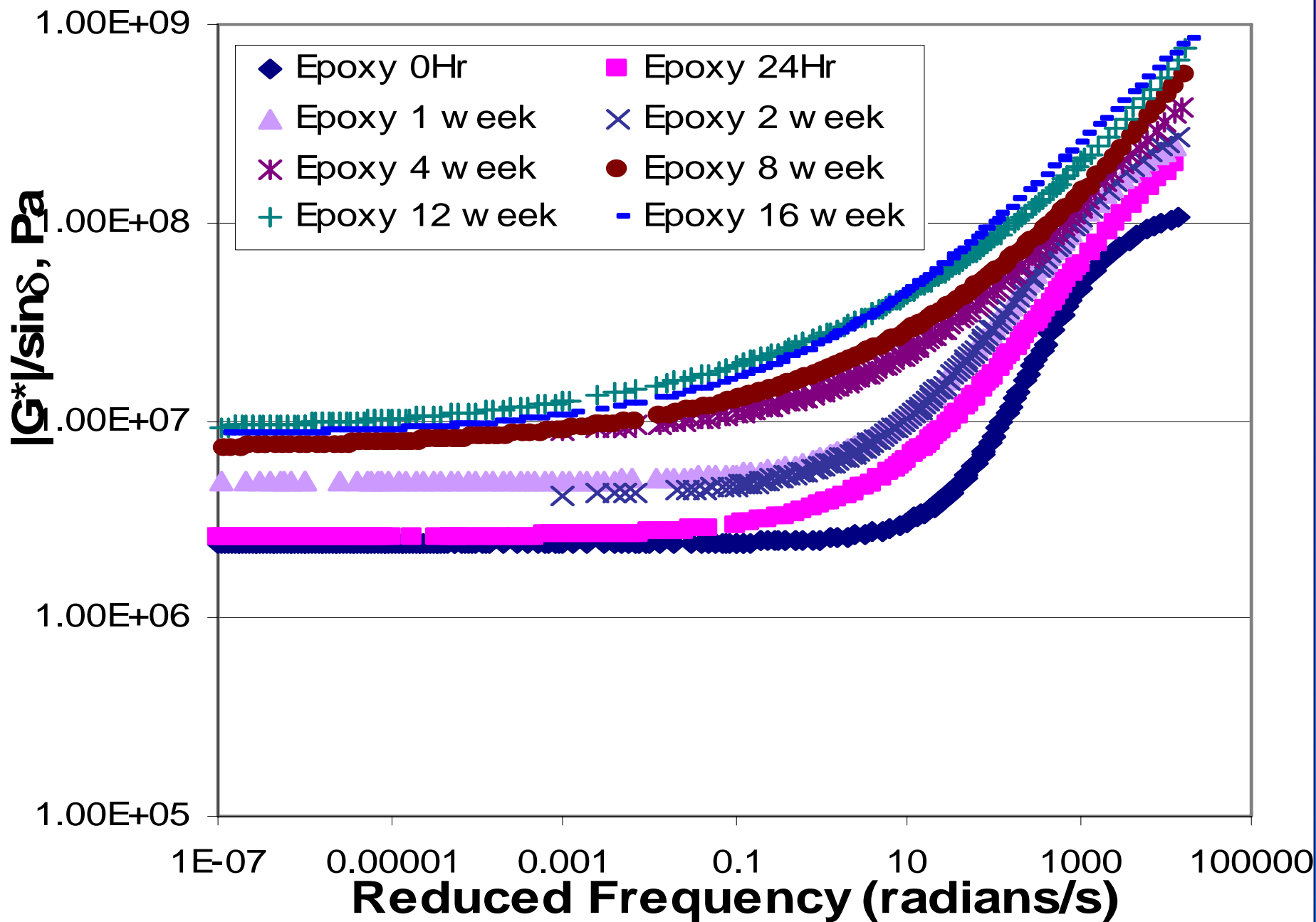
Pneumatic Pull-Off Test Cohesive Failure

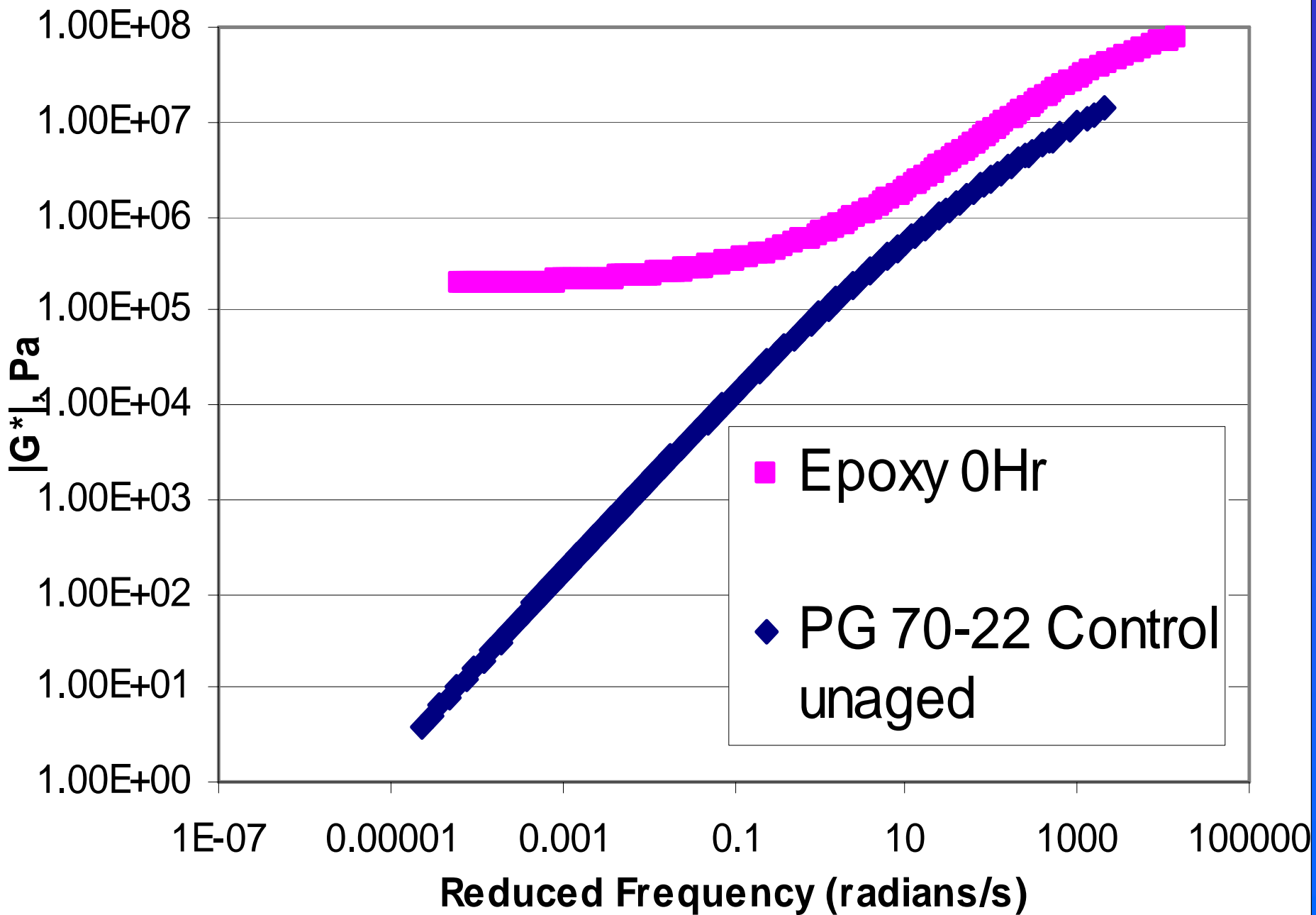


Epoxy Asphalt Curing time









Working with EA

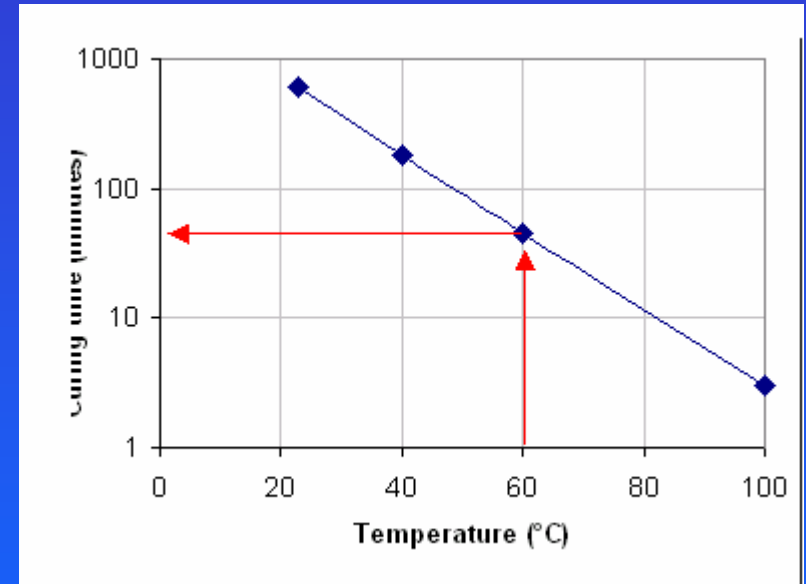
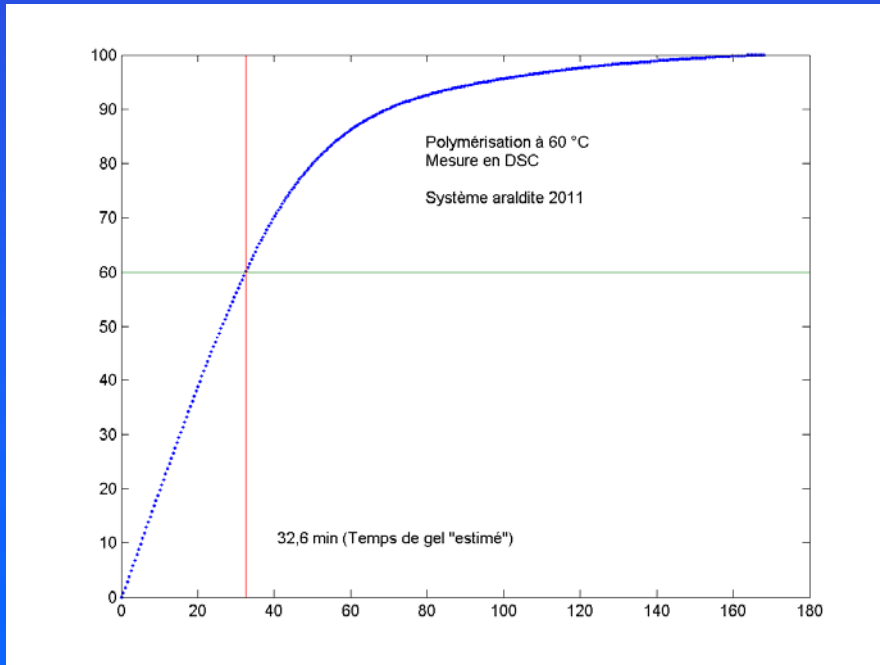
Lesson #2

Need to understand curing
characteristics of EA

Phase A

Identification and Procurement of Epoxy Asphalt ARALDITE 2011 A/B

Evaluate curing time of epoxy
by using DSC



at 100 °C, curing time \approx 3 min.

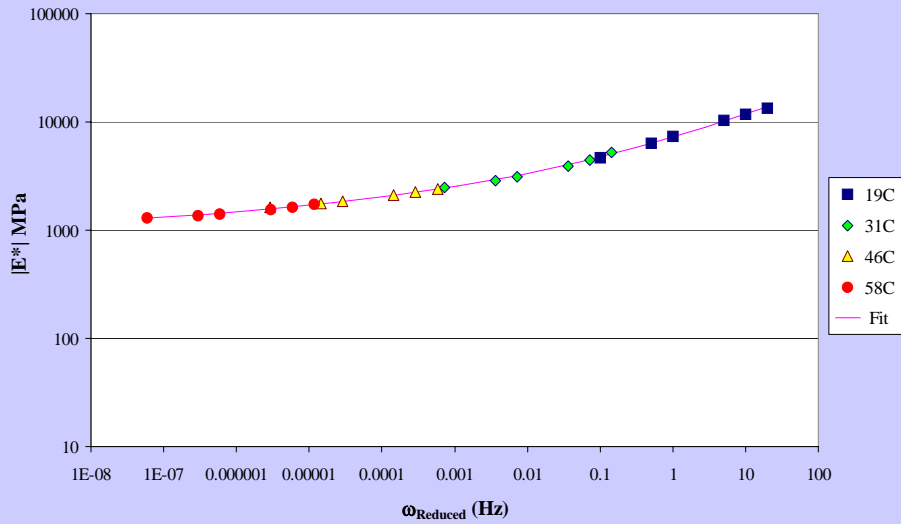
Permanent Deformation

- Binder rheology
- French Rut Tester
- SST
- Simple Performance Test

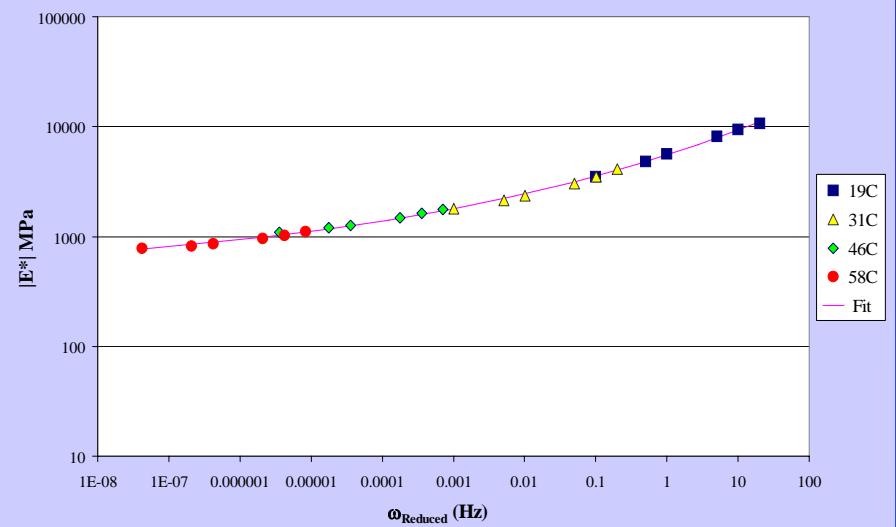
Superpave Performance Tester



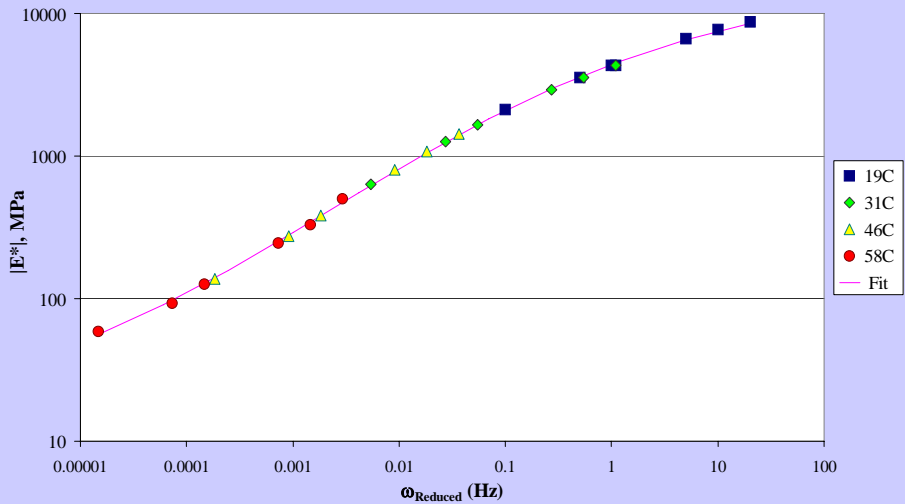
OLD ALF Epoxy



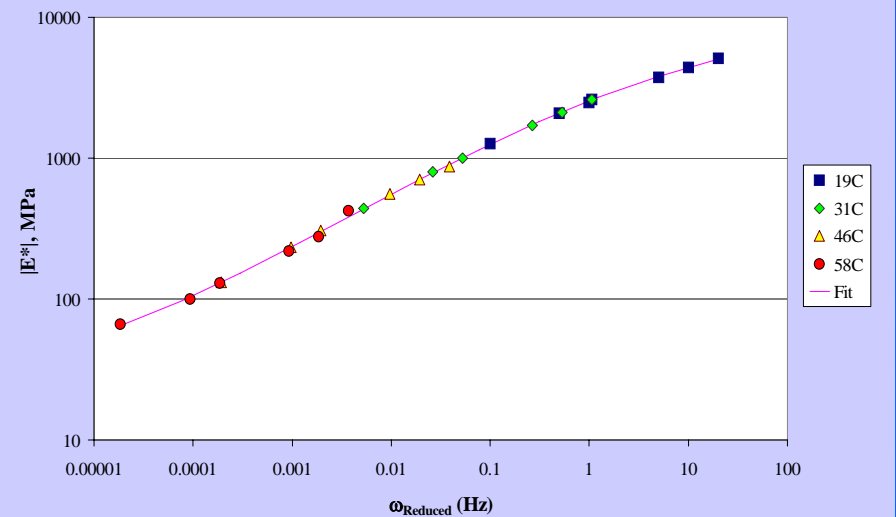
New ALF Epoxy



PG 70-22



Crumb Rubber Terminal Blend



Low Temperature Properties

- Binder

- “Superpave” grading -8

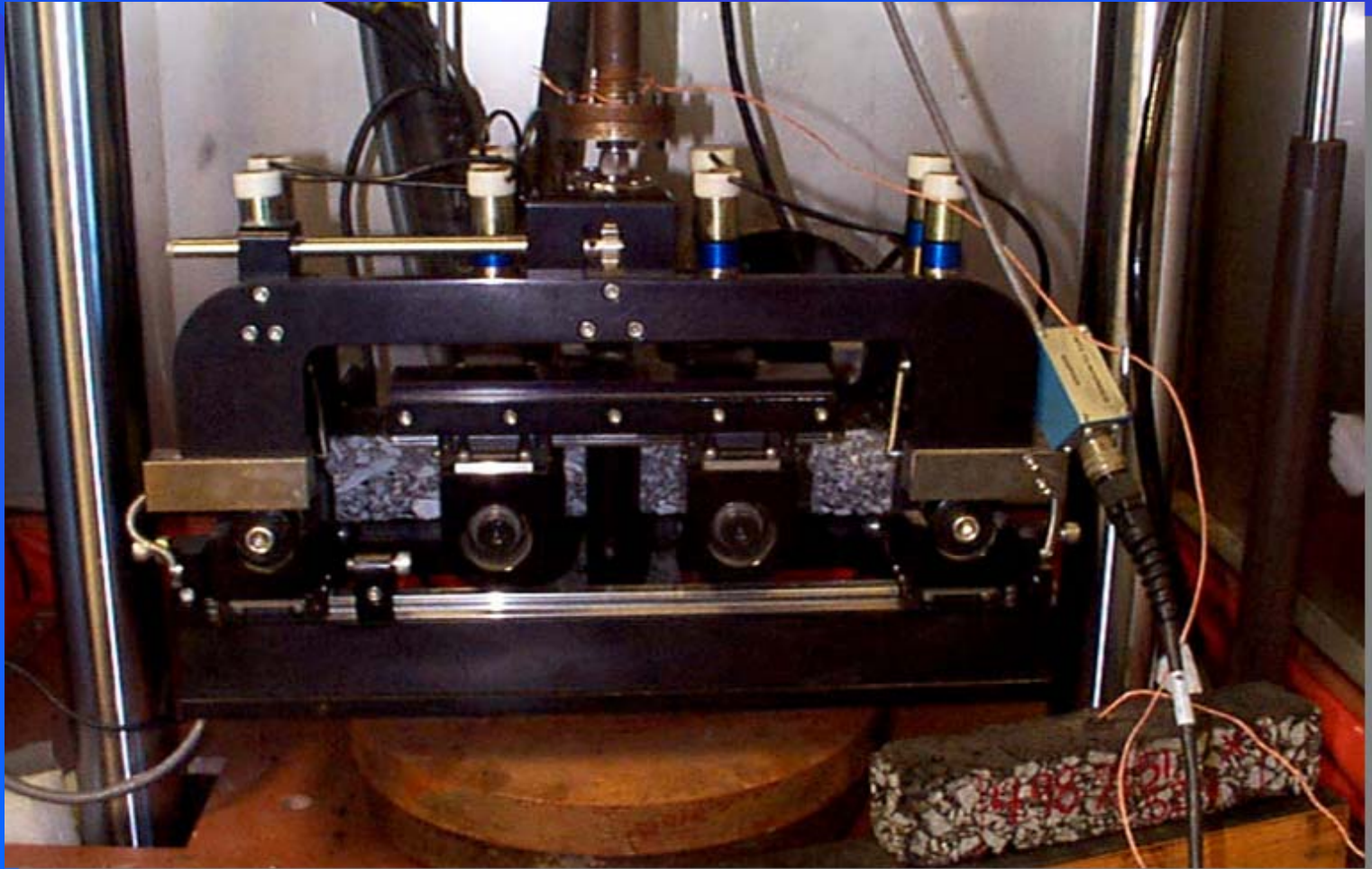
- TSRST

- Failed at -24 C

Fatigue

- Binder
 - Torsion geometry
- Mix
 - IDT
 - 4 pt bending
 - Essential work of fracture

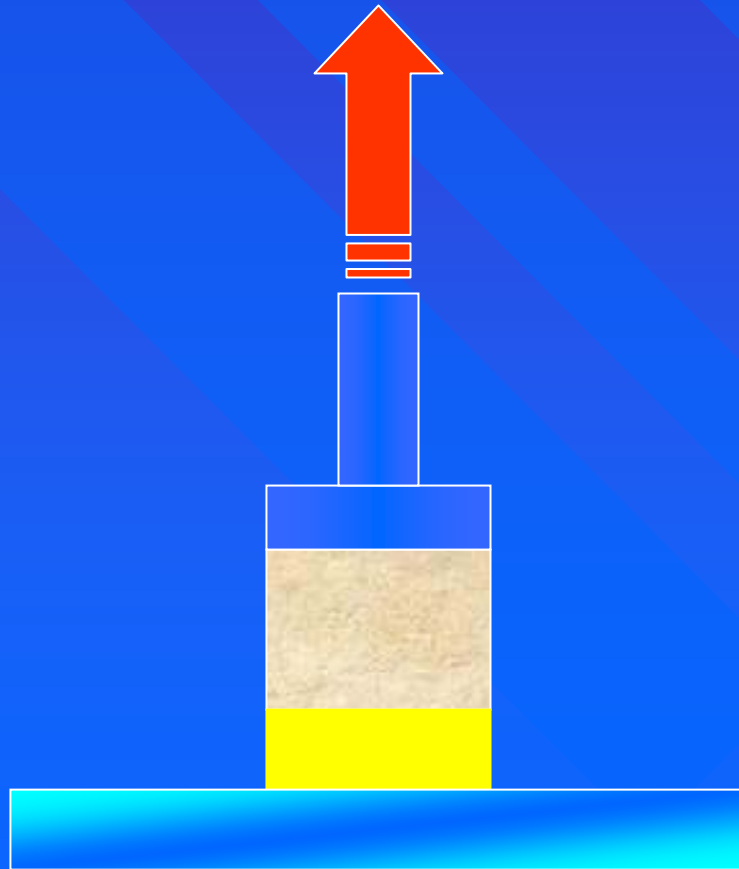
Beam Fatigue



Moisture Damage

- Pneumatic Pull-Off Testing of EA binder
- Hamburg
- Pine Rut Tester

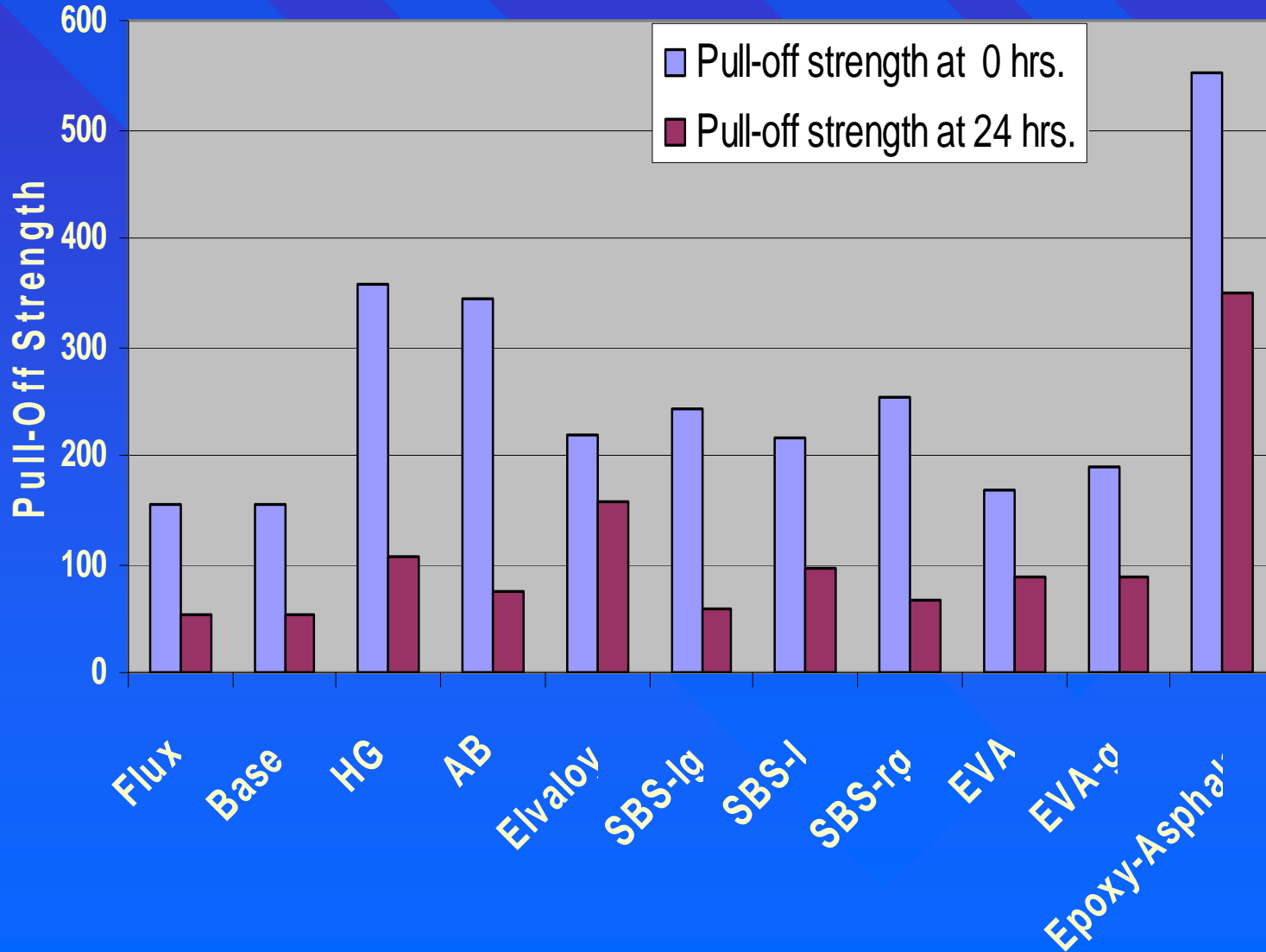
Pneumatic Pull-Off Test



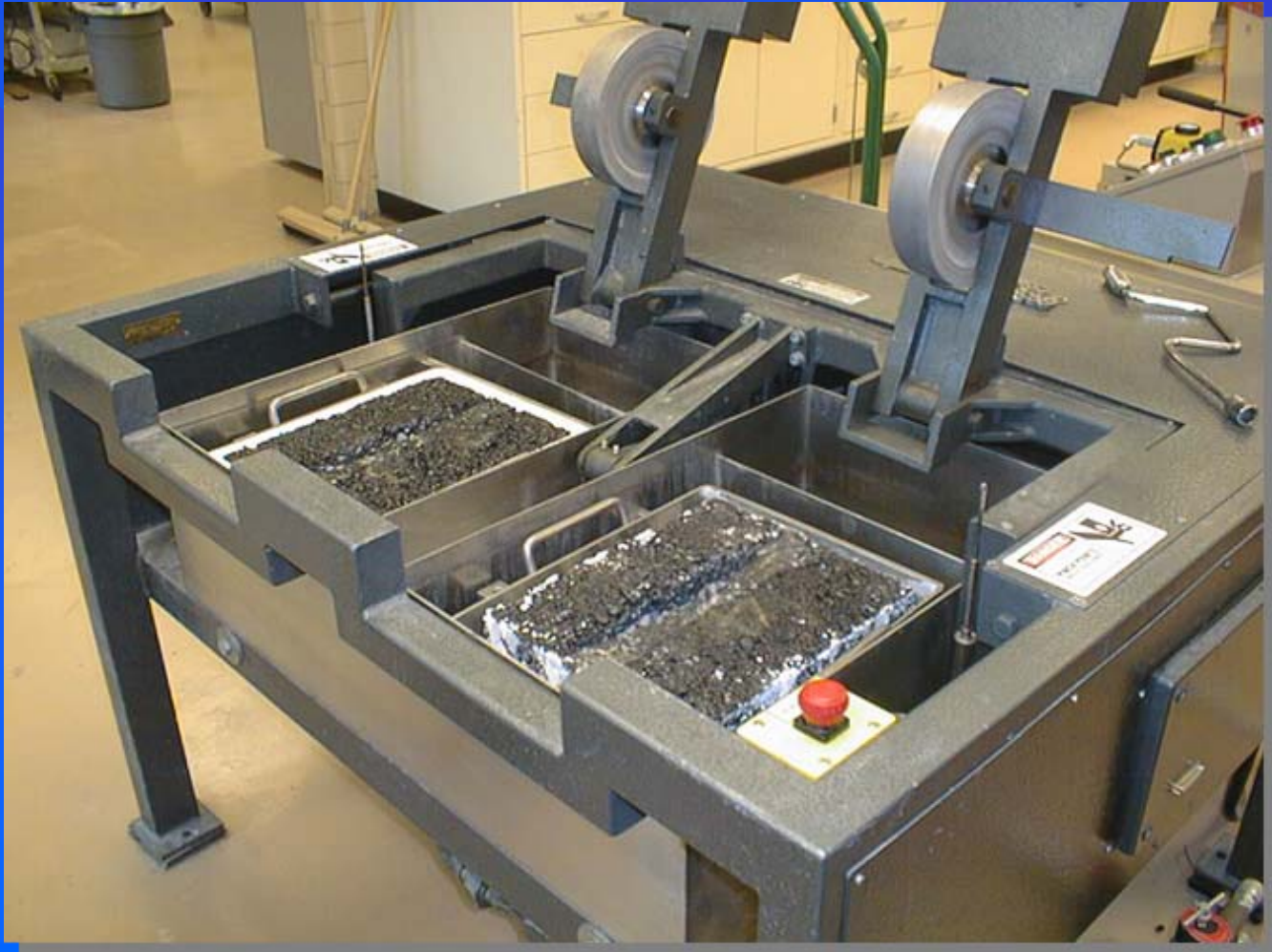
Pneumatic Pull-Off Test Adhesive Failure



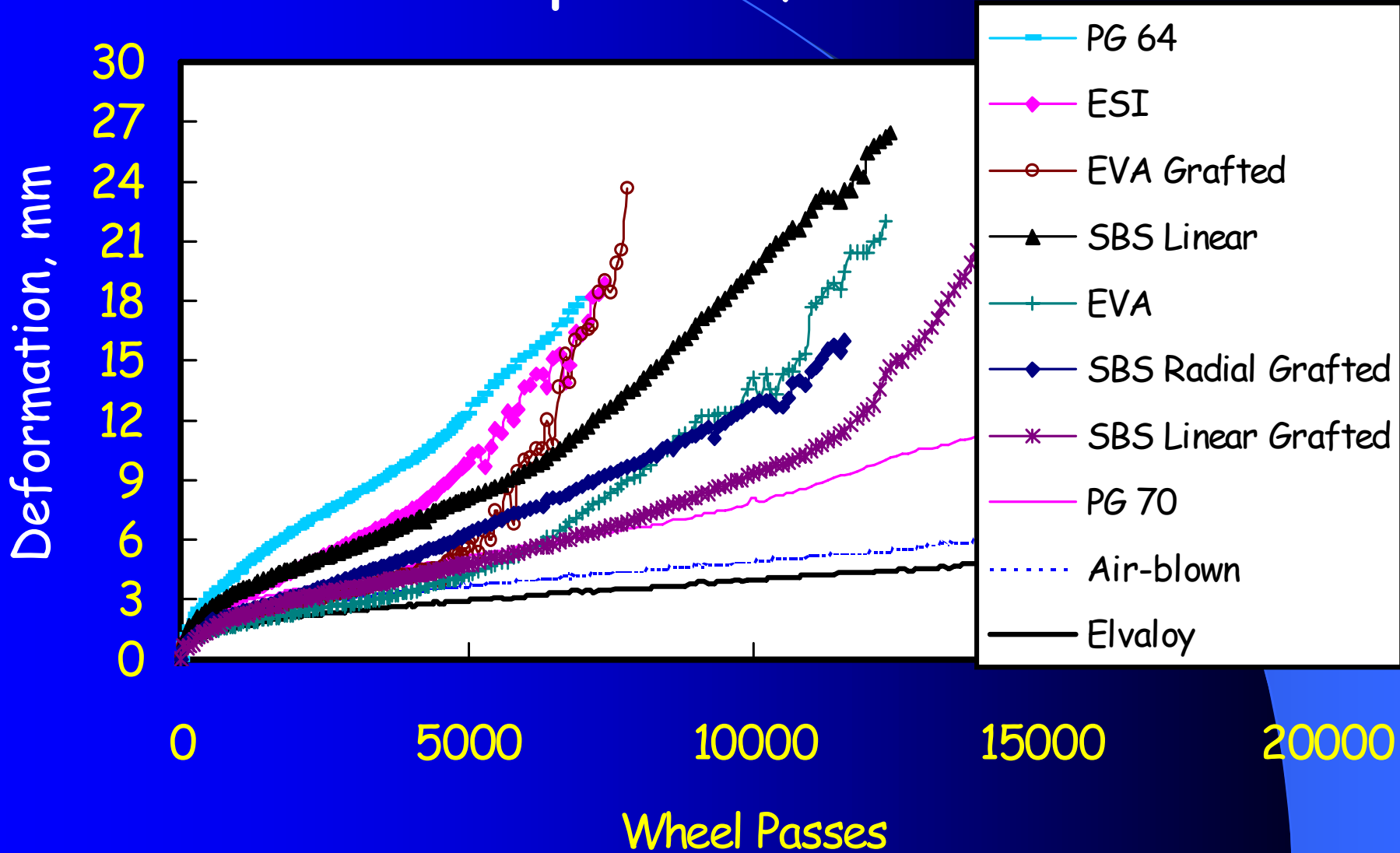
Pneumatic Adhesion Test Results



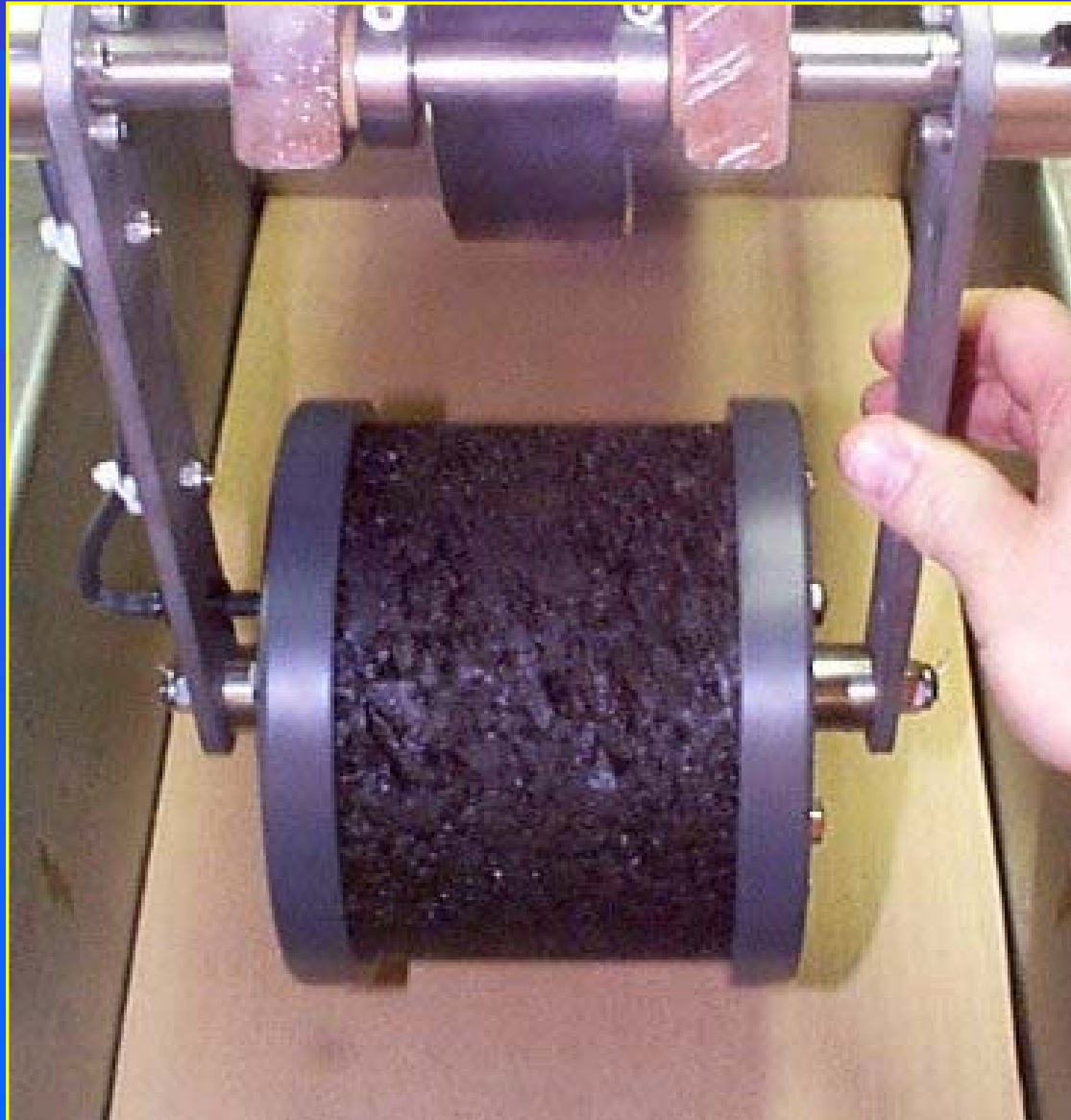
Hamburg Wheel Tracker



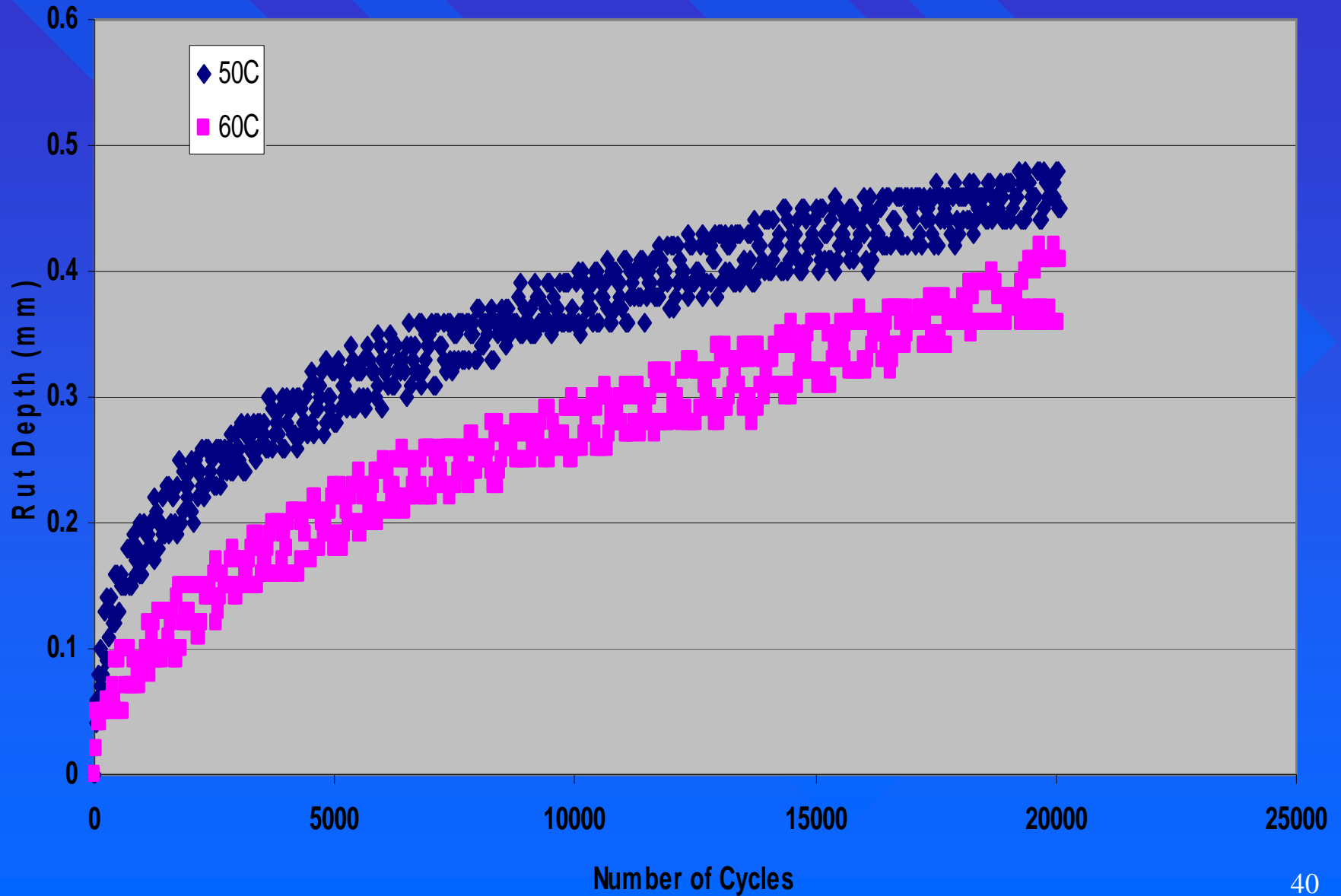
Deformation vs. Hamburg WTD wheel passes, 58 °C.

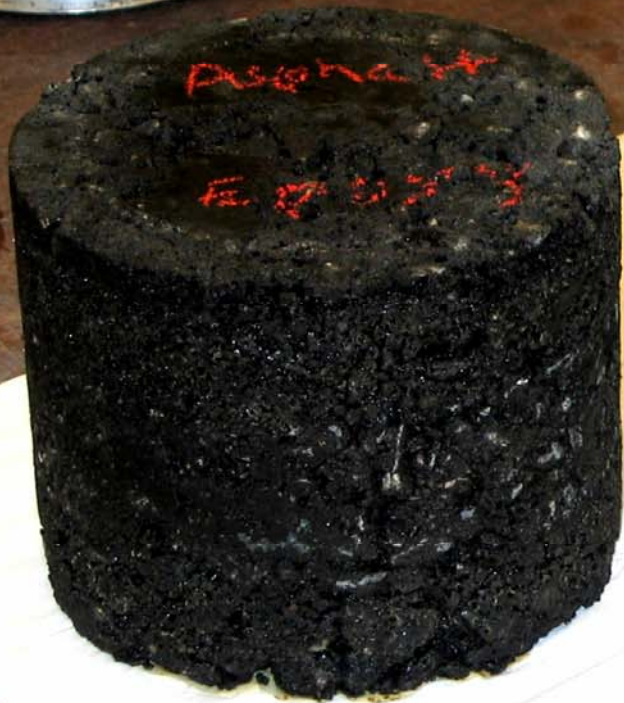


Pine Rut Tester

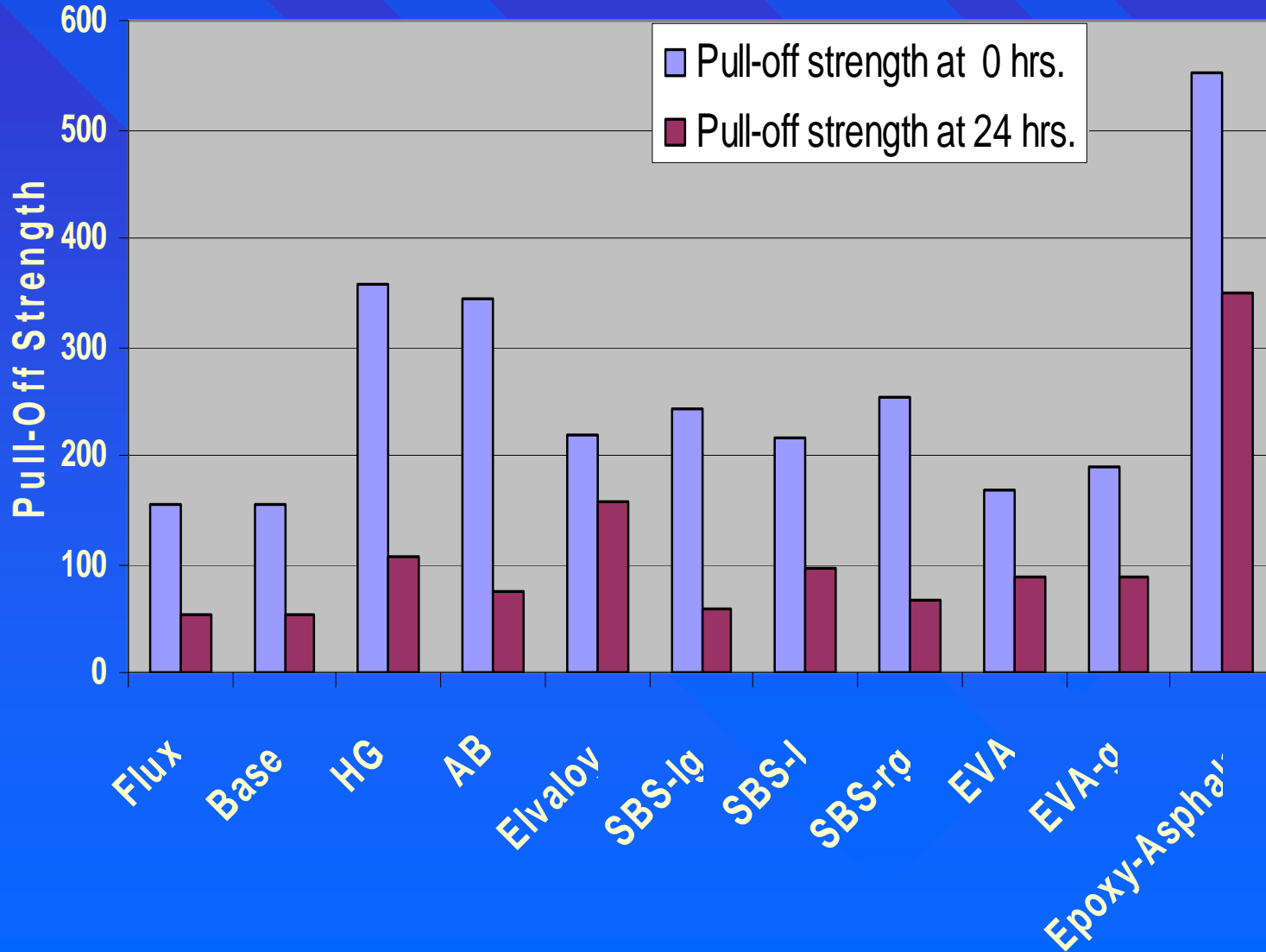


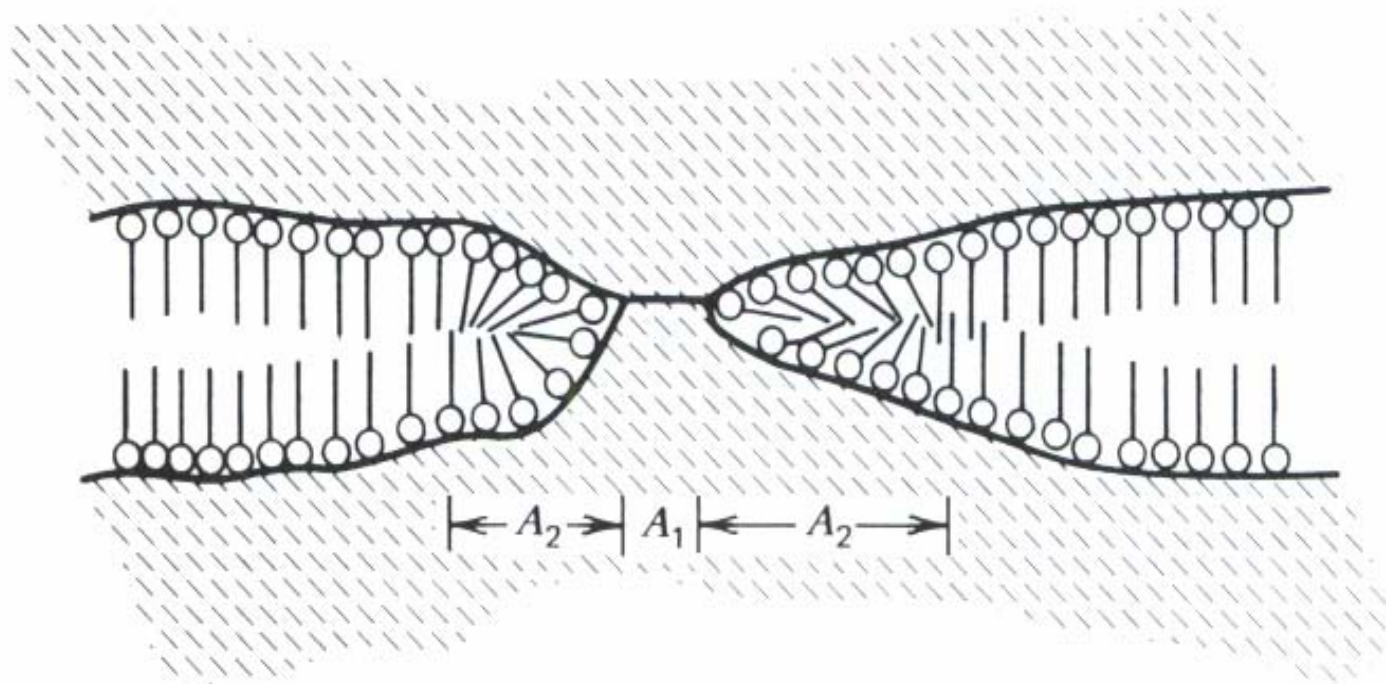
Sequential Testing of Epoxy-Asphalt on Pine RT





Pneumatic Adhesion Test Results





Nature of contact region in boundary lubrication

Bowden and Tabor, *The Friction and Lubrication of Solids*
(Oxford University Press, 1950)

Conclusions and Future Direction

- EA give rise to excellent adhesive and cohesive properties.
- Preliminary findings are quite encouraging with regard to permanent deformation, moisture damage, and aging. But models still need to be developed to predict long term environmental effects on EA.
- Low temperature and fatigue performance data are encouraging.

Future Work Continued

- Effect of aggregate type and durability on overall performance needs to be determined.
- Approaches to evaluate EA as a composite need to be developed.

Findings from other labs

Phase A

Identification and Procurement of Epoxy Asphalt

Curing agent families	Pot life	Elevated temperature	Chemical resistance	Mechanical resistance
Aliphatic amines	Fast cure at ambient or low temp.	Good	Very good	Very good
Cycloaliphatic amines	Range	Good	Very good	Very good
Aromatic amines	Range	Good	Good	Good
Amidoamines	Faster cure speed	Good	-	-
Latent Amines	Few hours to six months	-	-	-

Identification and Procurement of Epoxy Asphalt

Test 1 : ARALDITE 2011 A/B

Resin : bisphenol A-(Epichlorhydrin)

Curing agent : N(3-Dimethylaminopropyl)-1,3-Propylenediamine

Uses :

The bonding of metals, ceramics, glass, rubbers, rigid plastics and most other materials in common use

Mixing prior to use (parts by weight) :

Component A = 100

Component B = 80

Pot life :

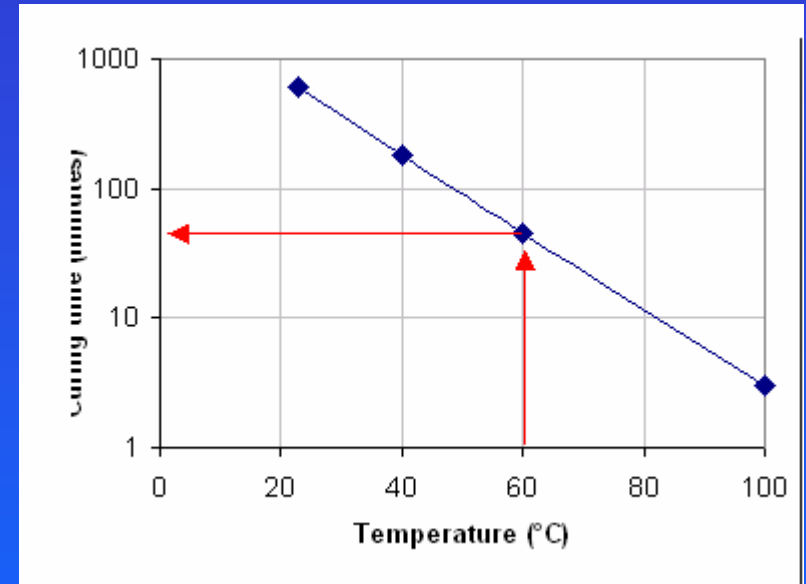
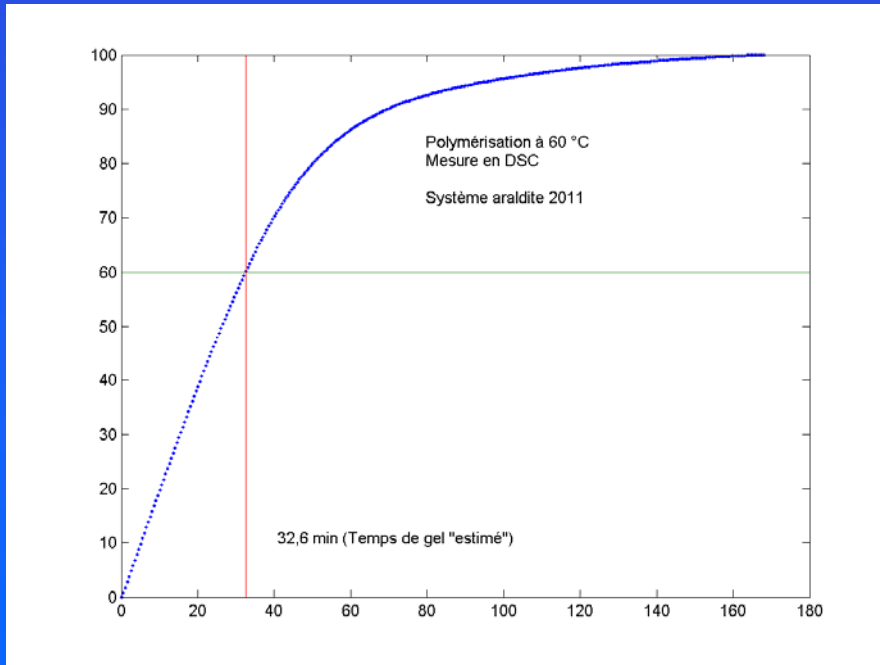
2 hours at 25°C

Increase in temperature → decrease in curing time

Phase A

Identification and Procurement of Epoxy Asphalt ARALDITE 2011 A/B

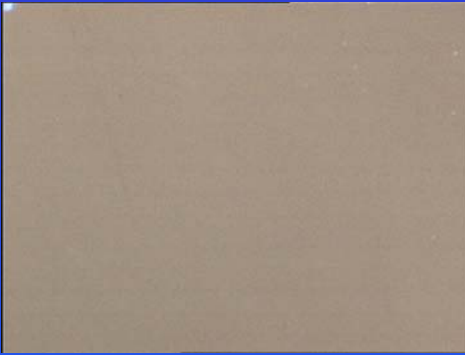
Evaluate curing time of epoxy
by using DSC



at 100 °C, curing time \approx 3 min.

Binder testing

UV Microscopic observations



Pure bitumen



Bitumen
with
25 % Epoxy



Bitumen
with
35 % Epoxy

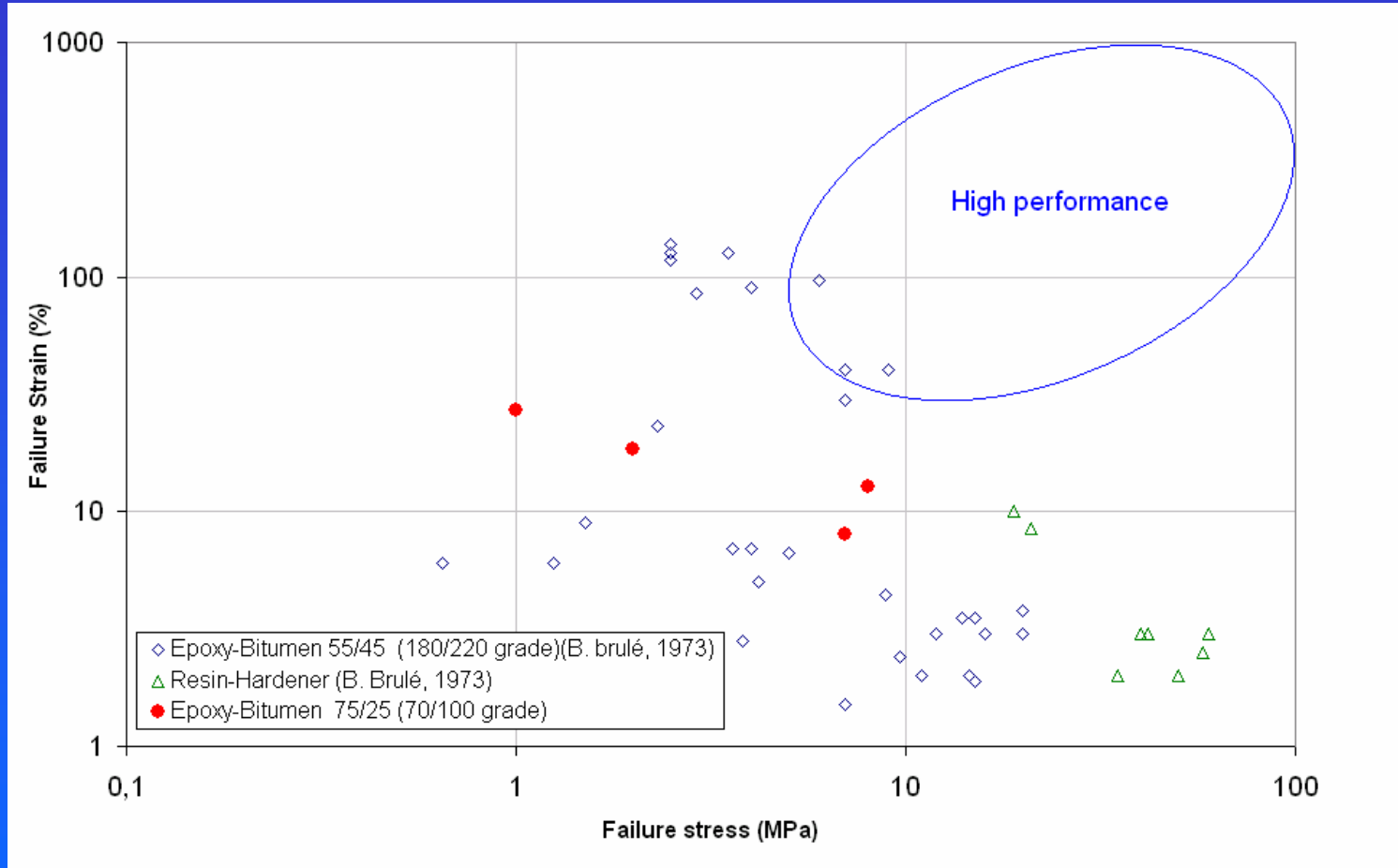
Binder testing – Direct Tension

Bitumen	Proportion Bitumen (%)	Hardener	Proportion Resin/Hardener (%)	Quantity A/B (%)	Temperature (°C)	Speed (mm/min)	Failure Strain (%)	Failure Stress (Mpa)
Bitume 70/100	100	*	*	*	0	10	20	0,83
Bitume 70/100	75	Arladite 2011 B	25	50	0	10	26,9	0,63
Bitume 70/100	65	Arladite 2011 B	35	50	0	10	18,4	0,62

Bitumen	Proportion Bitumen (%)	Hardener	Proportion Resin/Hardener (%)	Quantity A/B (%)	Temperature (°C)	Speed (mm/min)	Failure Strain (%)	Failure Stress (Mpa)
Bitume 70/100	100	*	*	*	-10	10	8,0	3,5
Bitume 70/100	75	Arladite 2011 B	25	50	-10	10	12,7	3,48

Comparison between Epoxy-bitumen and pure bitumen

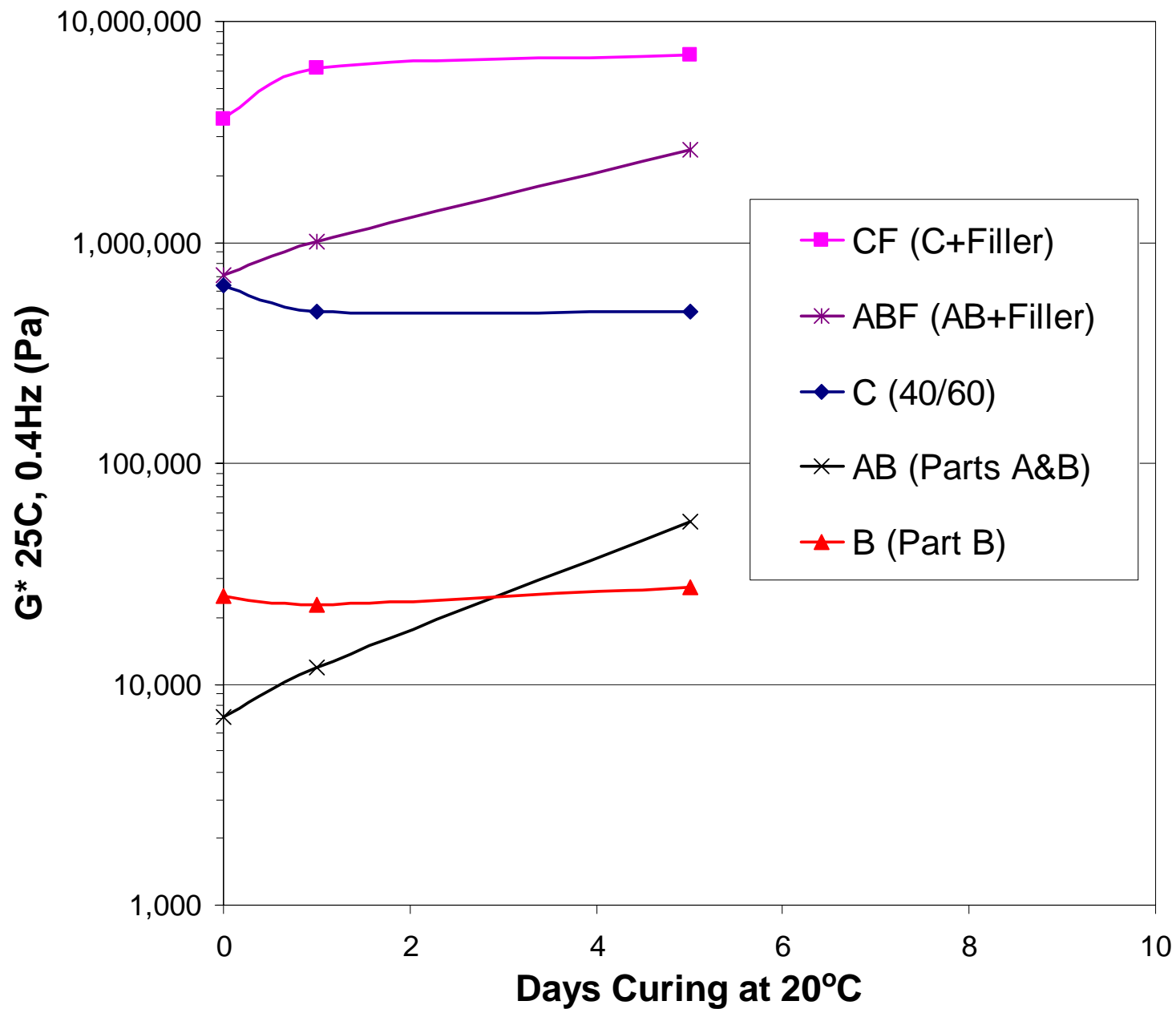
Binder testing – Direct Tension



Typical relation between stress and strain at failure conditions
Comparison with B. Brulé Work, 1973)

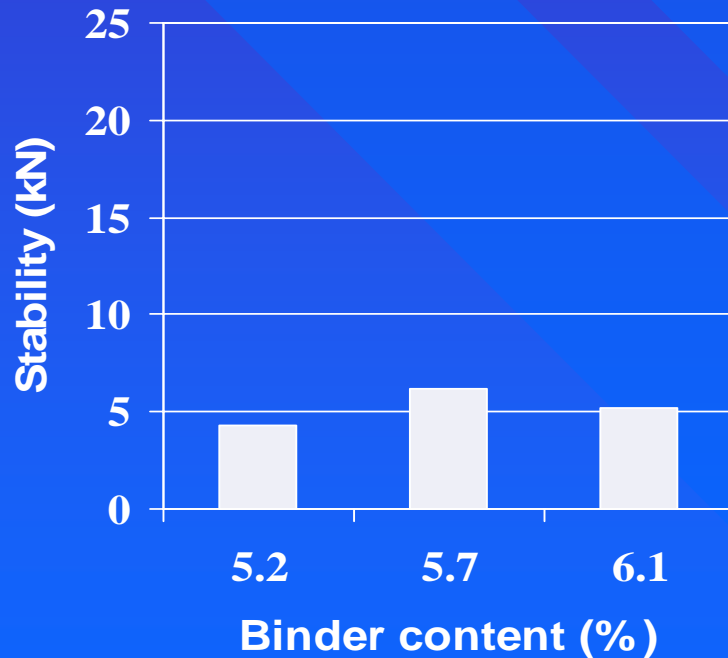
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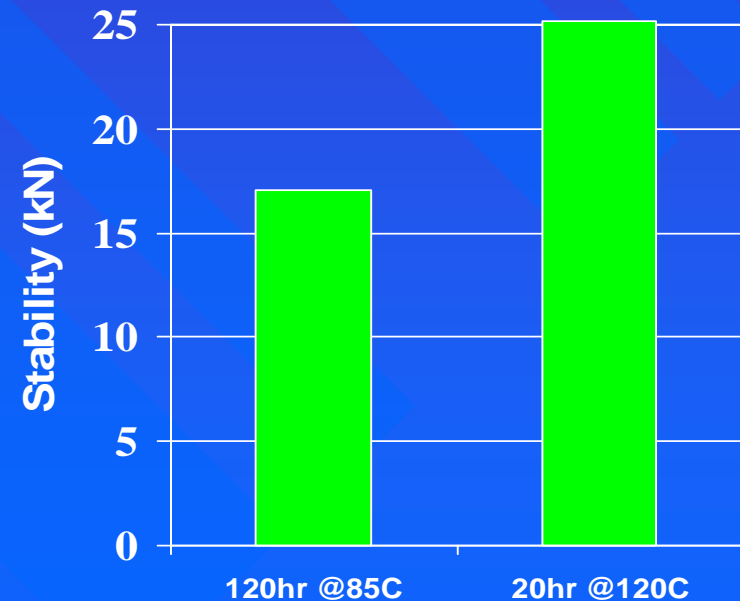


Mixture Design for SMA

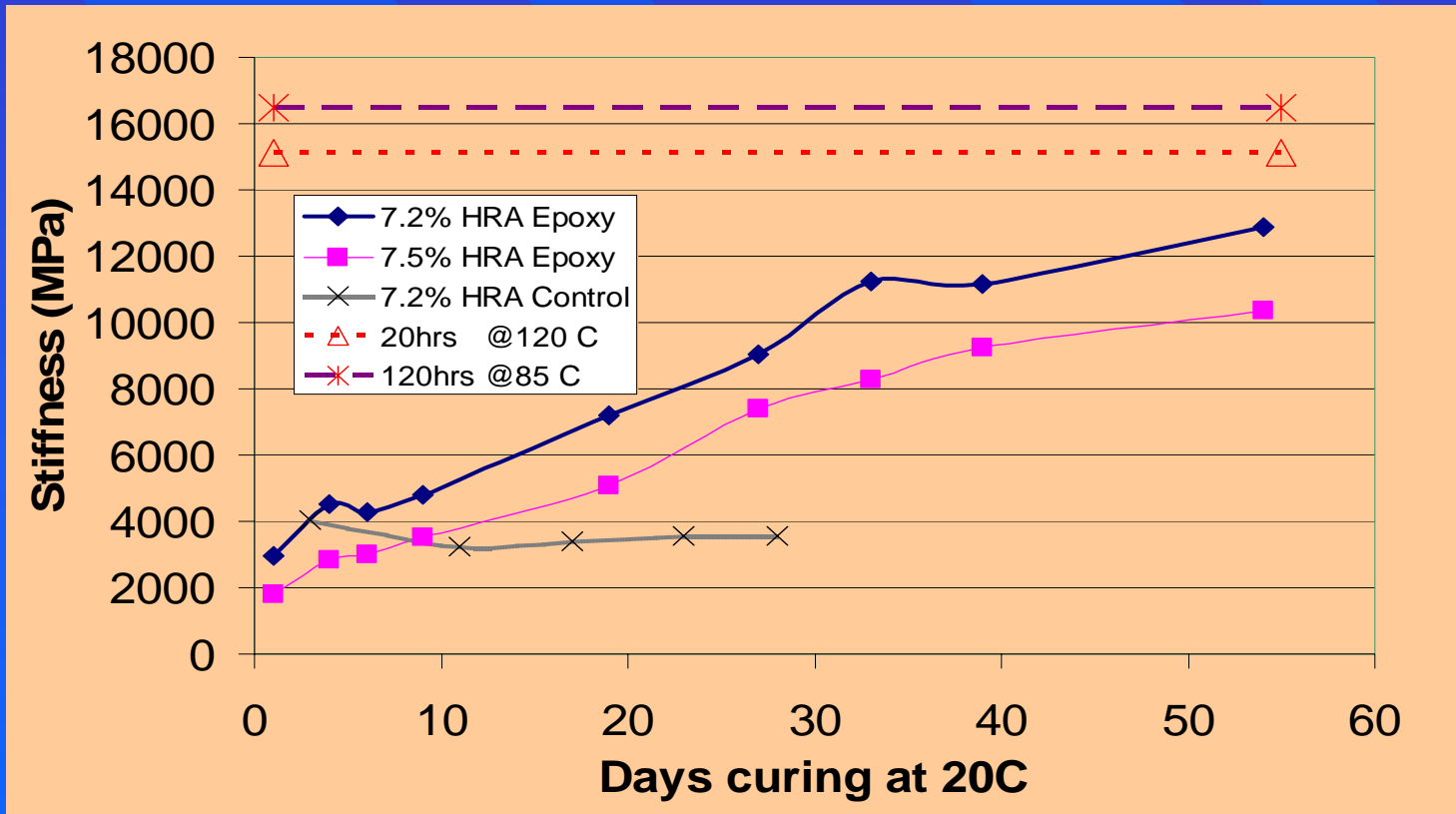
SMA Control - Unaged



SMA Epoxy @ 6.3% Binder Content

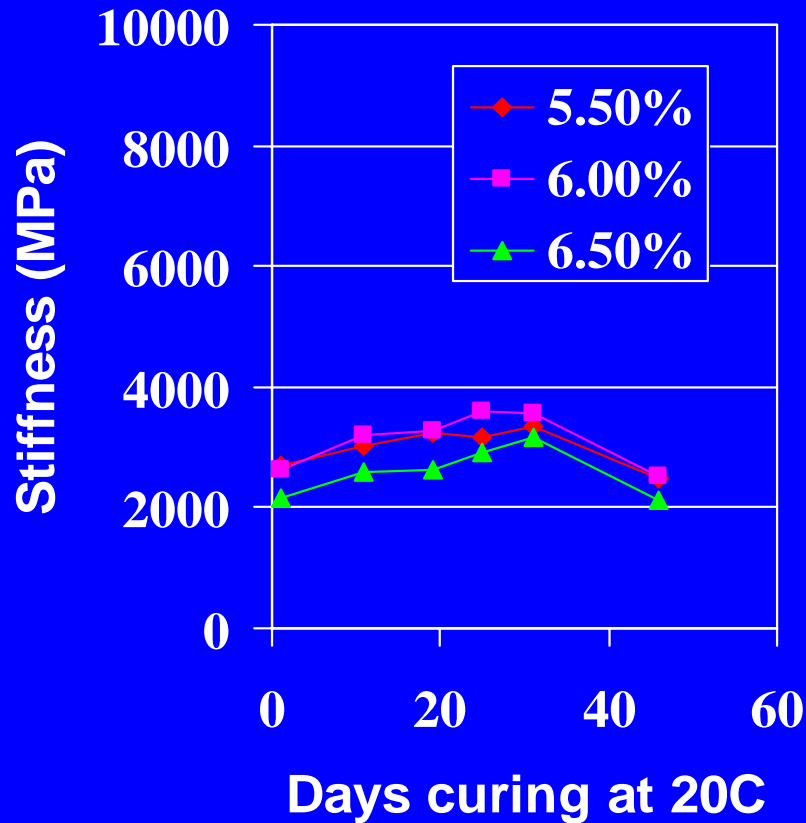


Stiffness transition - HRA

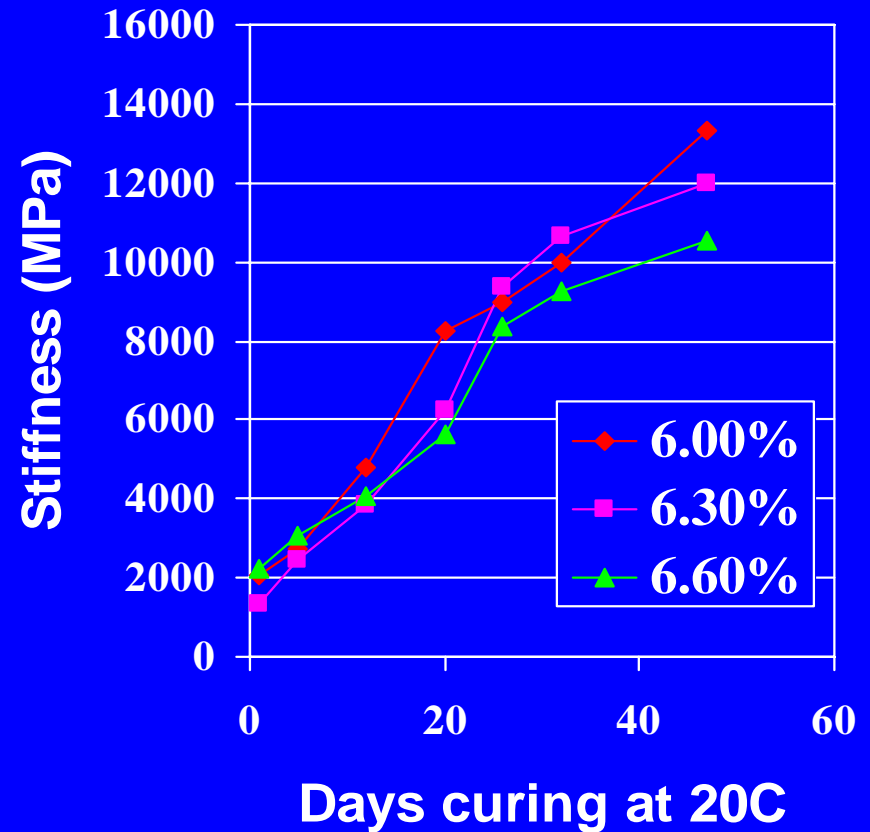


Stiffness transition - SMA

SMA with 40/60 Pen



SMA with Epoxy



Thank you.