WARM MIX ASPHALT
Flexural Stiffness & Fatigue Performance

Kim Jenkins
Alex Mbaraga, Johann van den Heever, Stephan van der Walt
SANRAL CHAIR in Pavement Engineering
Stellenbosch University

5th September 2011

ACKNOWLEDGEMENT

warm mix asphalt rsa

National Asphalt

ETHEKWINI MUNICIPALITY

South African Roads Federation
SARF

WMA in KwaZulu Natal

OUTLINE

1. Introduction
2. WMA Technologies
3. Mix Compositions
4. Recycled Asphalt Content
5. Laboratory Procedure
6. Laboratory Results – Compaction
7. Laboratory Results – Flexural Stiffness
8. Laboratory Results – Fatigue
9. Laboratory Results – Visco-elastic Indication
10. Conclusions and Recommendations

Trends Europe (& South Africa?)

- Growing health, safety and environmental awareness of the general public and industry (**yes**, to lesser degree)
- Significant efforts to save non-renewable fossil fuels and aggregates, conserve energy and reduce emissions and exposures (**yes**, to much lesser degree)
- Advances in technology, coupled with growing environmental concerns, have led to research into more environmentally friendly production processes (**yes**)

Acknowledge: Martin van de Ven (TU Delft)

Europe versus SA

- European Community strategy:
  - sustainable construction techniques
  - EFCT: Environmentally Friendly Construction Technologies **(WMA Interest Group in SA)**
- But…. In realistic competition: the benefits of the lower operating temperatures resulting in asphalt mixture quality and durability on the road must compete with the properties that can be obtained with Hot mix (WMAIG is trying to answer this question)

Road Agencies (EU vs SA)

- Most agencies are withdrawing from direct technical involvement (not entirely in SA)
- New contracts are making there impact (not yet)
- Agencies are strongly influenced by politicians (safety, noise reduction, health, individual rights, etc: what scores for a government to get elected again) (not quite the same in SA)
- Financial budget is (always) under pressure (same)

Consequence of political decisions in Europe

- LCA approach: search for Environmentally friendly materials satisfying LCA requirements
- Producing asphalt mixtures at lower temperatures.
- Recycling at highest possible level: RAP can be a very important material in the decision between cold and hot/warm recycling (black gold)
- Perpetual pavements: (functional) performance forever. Durability is very important in LCA

INTRODUCTION

- Evaluate Flexural Stiffness and Fatigue Performance
- Flexural Stiffness - Mix Property
- Fatigue - Performance Criteria
- Test - Pneumatic 4-Point Beam Apparatus

INTRODUCTION Cont'd

- WMA mix recipes – plant produced **Surface** and **Base Mixes**
- **Equivalent** HMA Mix as **Control Mixes**
- 2 Main WMA Technologies - **Additive** (Chemical and Organic) and **Foaming Process Technologies**

WMA TECHNOLOGIES

- **Additive Technology -** Rediset™ WMX (Chemical Additive) and Sasobit® (Organic Additive)
- **Foaming Process** – NA Foam Tech

MIX COMPOSITIONS

Binder Grades

– 60/70 and 80/100

Modifiers

– A-P1 (EVA) and A-E2(SBS)
– Mix Type 1:- EVA + Rediset™ WMX and EVA + NA Foam Tech
– Mix Type 2:- SBS and Sasobit® -Sasoflex
– Mix Type 3:- Additive (Rediset or Sasobit) or foaming Technology but no EVA or SBS

RECYCLED ASPHALT CONTENT

Surface Mixes

– 10% RA

– 20% RA

Base Mixes

– 10% RA

– 40% RA

Table 1 Summary of Mix Types

HMA Surface Mix Control Mixes (Type D Mix)	WMA Surface Mix Plant & Field Trials (Type D Mix)	WMA Technology
10% RA 60/70 (Control 1)	10% RA 60/70 Rediset™ WMX	
20% RA 80/100 A-P1 (EVA) (Control 2)	20% RA 80/100 A-P1 (EVA and Rediset™ WMX)	Chemical Additive
10% RA 60/70 (Control 1)	10% RA 60/70 Foam Tech	Foaming Process
10% RA 60/70 (Control 1)	10% RA 60/70 Sasobit®	
20% RA 80/100 A-E2 (SBS) (Control 3)	20% RA 80/100 A-E2 (SBS and Sasobit) Sasoflex	Organic Additive
HMA Base Mix Control Mix (Type B)	**WMA Base Mix Plant and Field Trials (Type B)**	**WM Technology**
10% RA 60/70 A-P1 (EVA) (Control 4)	10% RA 60/70 A-P1 (EVA and Rediset™ WMX)	Chemical Additive
	10% RA 60/70 A-P1 (EVA and Foam Tech)	Foaming Process
40% RA 80/100 A-P1 (EVA) (Control 5)	40% RA 80/100 A-P1 (EVA and Rediset™ WMX)	Chemical Additive
10% RA 60/70 A-E2 (SBS) (Control 6)	10% RA 60/70 A-E2 (SBS and Sasobit) Sasoflex	
40% RA 80/100 A-E2 (SBS) (Control 7)	40% RA 80/100 A-E2 (SBS and Sasobit) Sasoflex	Organic Additive

LABORATORY SPECIMENS

Manufacture of Specimens

- Compaction – Modified method (KZN)
- Sawing of Slabs – Beams (SU)
- Evaluation–BRD test

LABORATORY – Compaction

Modified Compaction Method

LABORATORY – Compaction2

LABORATORY RESULTS – Compaction

Table 2 Compact-ability of Mixes vs. Field Compaction

Modified SUCM @ 35 Passes Type D: 20% RA 80/100 A-E2 (Sasobit and SBS) Sasoflex				
A-E2 Sasoflex	**Thickness (mm)**	**Rice Density(kg/m^3)**	**Core Bulk Density (kg/m^3)**	**Percentage of Rice (%)**
Slab 1	73	2464	2378	96.51
Slab 2	77	2464	2370	96.19
Slab 3	72	2464	2376	96.43
Average Compaction (%) (Void Content %)				**96.93 (3.1%)**
Field Compaction				
A-E2 Sasoflex	**Thickness (mm)**	**Rice Density(kg/m^3)**	**Core Bulk Density (kg/m^3)**	**Compaction of Rice (%)**
Core 1	54	2464	2330	94.56
Core 2	74	2464	2359	95.74
Core 3	60	2464	2351	95.41
Core 4	75	2464	2365	95.98
Core 5	70	2464	2362	95.86
Core 6	60	2464	2355	95.58
Average Compaction (%) (Void Content)				**95.52 (4.5%)**

LABORATORY RESULTS – Compaction (2)

Table 3 Compact-ability of Specimens

Beam No	Mass in Air (g)	Mass in water (g)	Rice Density (kg/m³)	BRD (kg/m³)	Void Content (%)
Type D: 10% RA 60/70 AP-1(EVA + Rediset™ WMX) (SLAB 2) at 35 Passes					
1	3012	1754	2476	2392	3.4
2	3140	1838	2476	2410	2.7
3	3004	1762	2476	2416	**2.4**
4	2990	1751	2476	2413	2.5
Type D: 10% RA 60/70 AE-2 (SBS + Sasobit®) Sasoflex (Slab 1) at 35 Passes					
1	3023	1749	2471	2371	4.0
2	3013	1751	2471	2385	3.5
3	3045	1766	2471	2378	3.8
4	3074	1779	2471	2373	4.0
Type D: 20% RA 80/100 AE-2 (SBS and Sasobit®) Sasoflex (Slab 1) at 35 Passes					
1	3063	1765	2470	2353	4.7
2	3147	1832	2470	2388	3.3
3	3057	1783	2470	2394	3.1
4	3007	1739	2470	2366	4.2
Type B: 10% RA 60/70 AE-2 (SBS and Sasobit®) Sasoflex (Slab 2) at 35 Passes					
1	3146	1827	2489	2373	4.7
2	3079	1800	2489	2405	3.4
3	3030	1767	2489	2394	3.8
4	2949	1719	2489	2393	3.9
Type B: 40% RA 80/100 AP-1 (EVA and Rediset™ WMX) (Slab 3) at 35 Passes					
1	2959	1713	2500	2355	**5.8**
2	3049	1776	2500	2378	4.9
3	3050	1770	2500	2377	4.9
4	3124	1816	2500	2378	4.9

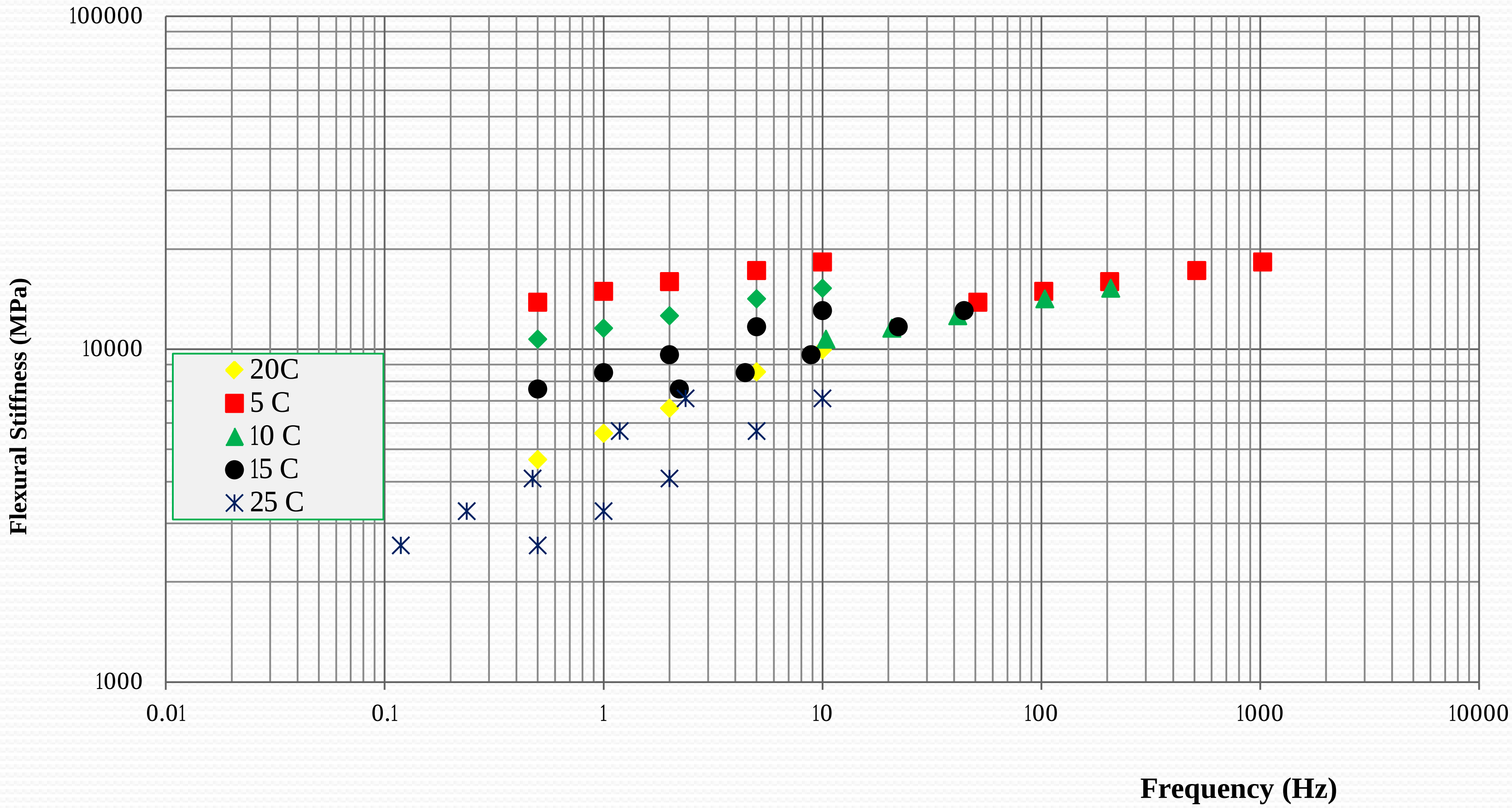
LABORATORY TESTING

1. Flexural Stiffness Test

- Sinusoidal Constant Strain for 300 cycles
- Strain regime - 300με
- Temperature Sweeps - 5 ^{0}C to 25 ^{0}C (Interval of 5 ^{0}C)
- Frequencies – 0.5Hz, 1Hz, 2Hz,5Hz & 10Hz
- Thus, Isotherms
- Development of Master Curve at Reference Temperature 20 ^{0}C

LABORATORY – Flexural Stiffness

Development of the Flexural Stiffness Master Curve

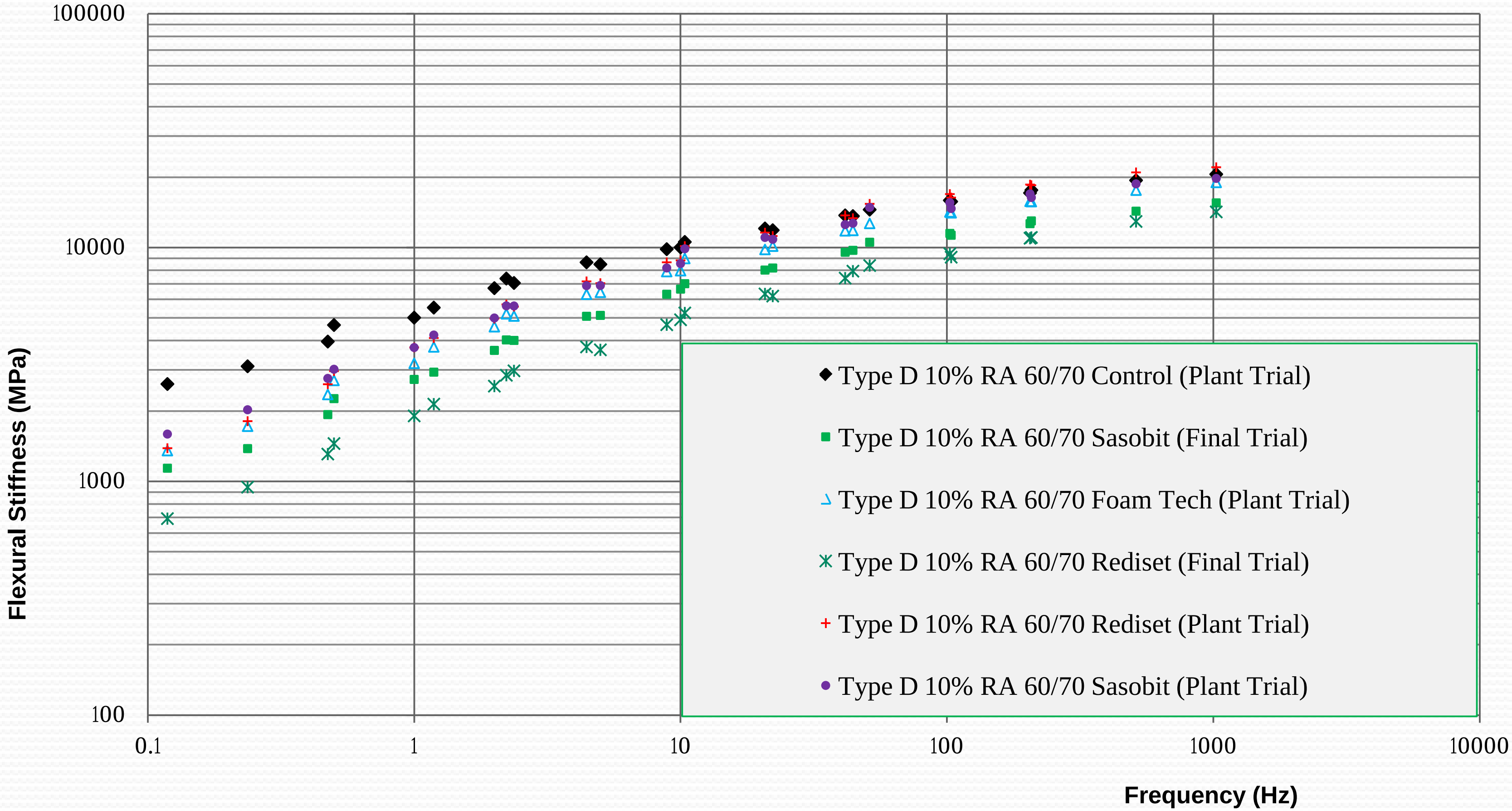


LABORATORY TESTING

2. Fatigue Test

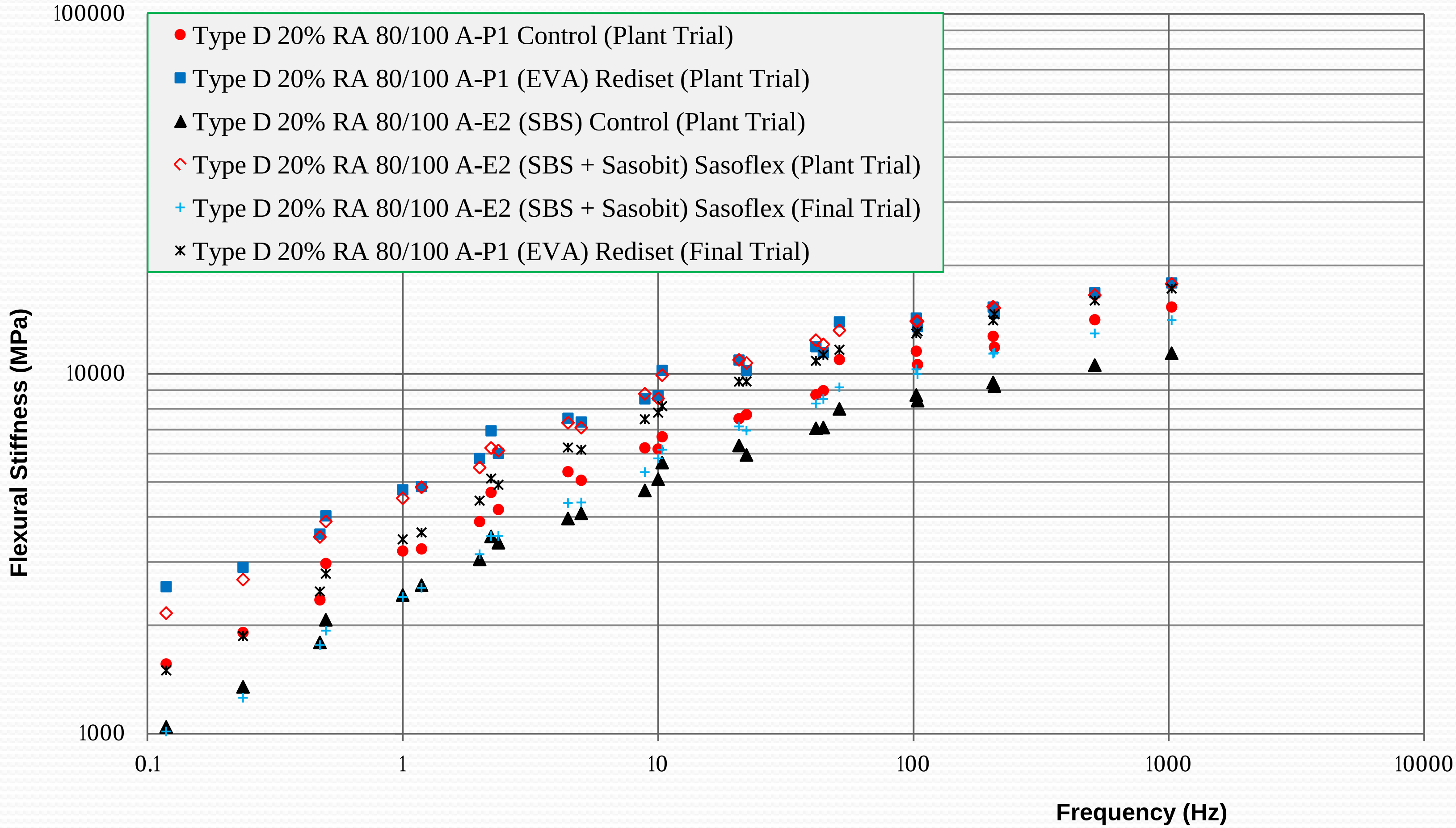
- Sinusoidal Constant Strain for a maximum of 3.5million cycles
- Frequency – 10Hz
- Test Temperature - 5^0C
- 3 Selected Strain regimes – from Low, High and 300με
- Test begun at a strain of 300με
- Development of the Log $\mathbf{N_f}$ vs. Log $\boldsymbol{\varepsilon}$

LABORATORY RESULTS – Flexural Stiffness



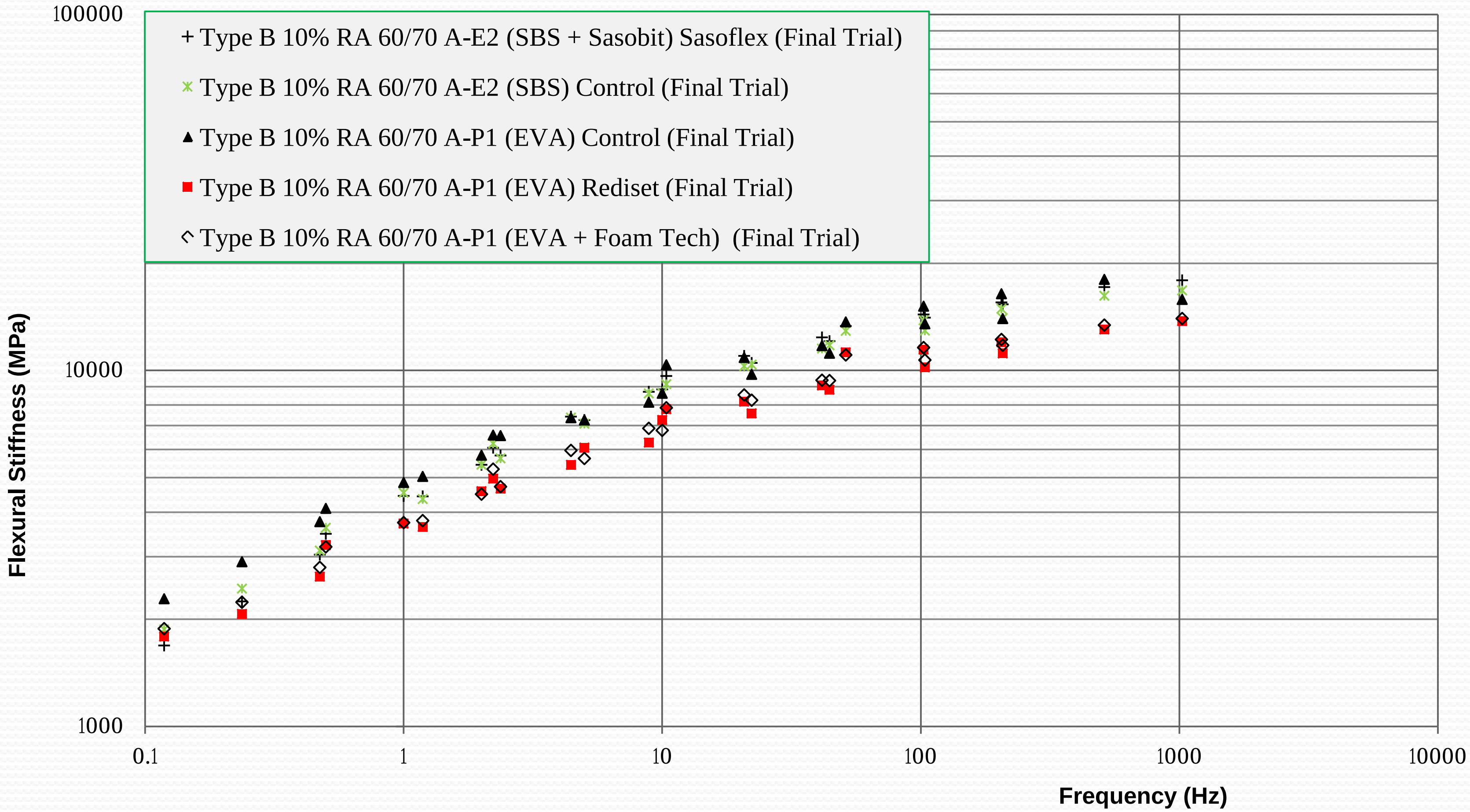
Graph 1 Type D 10% RA 60/70 Surfacing Mixes

LABORATORY RESULTS – Flexural Stiffness



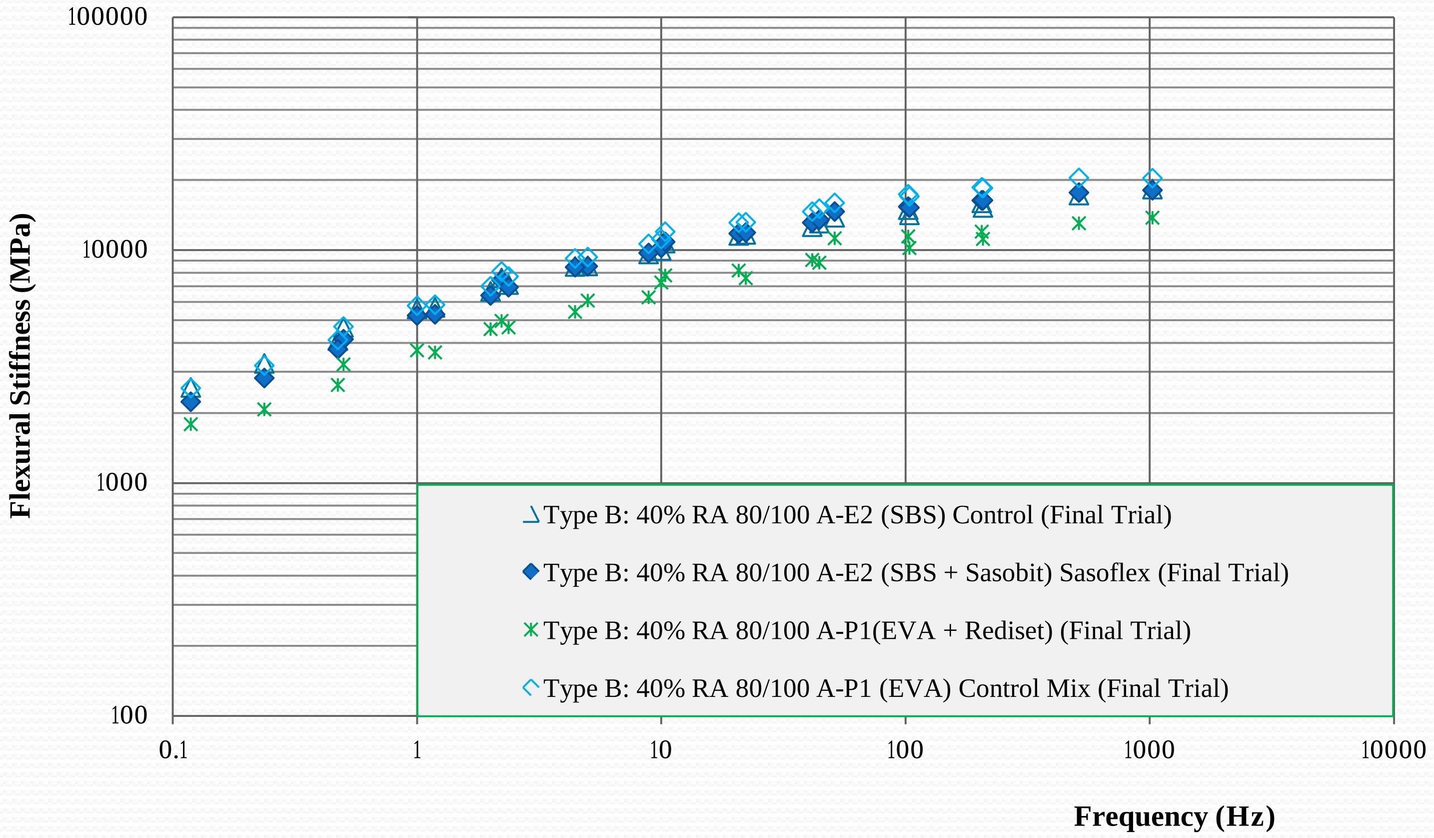
Graph 2 Type D 20% RA 80/100 Surfacing Mixes

LABORATORY RESULTS – Flexural Stiffness



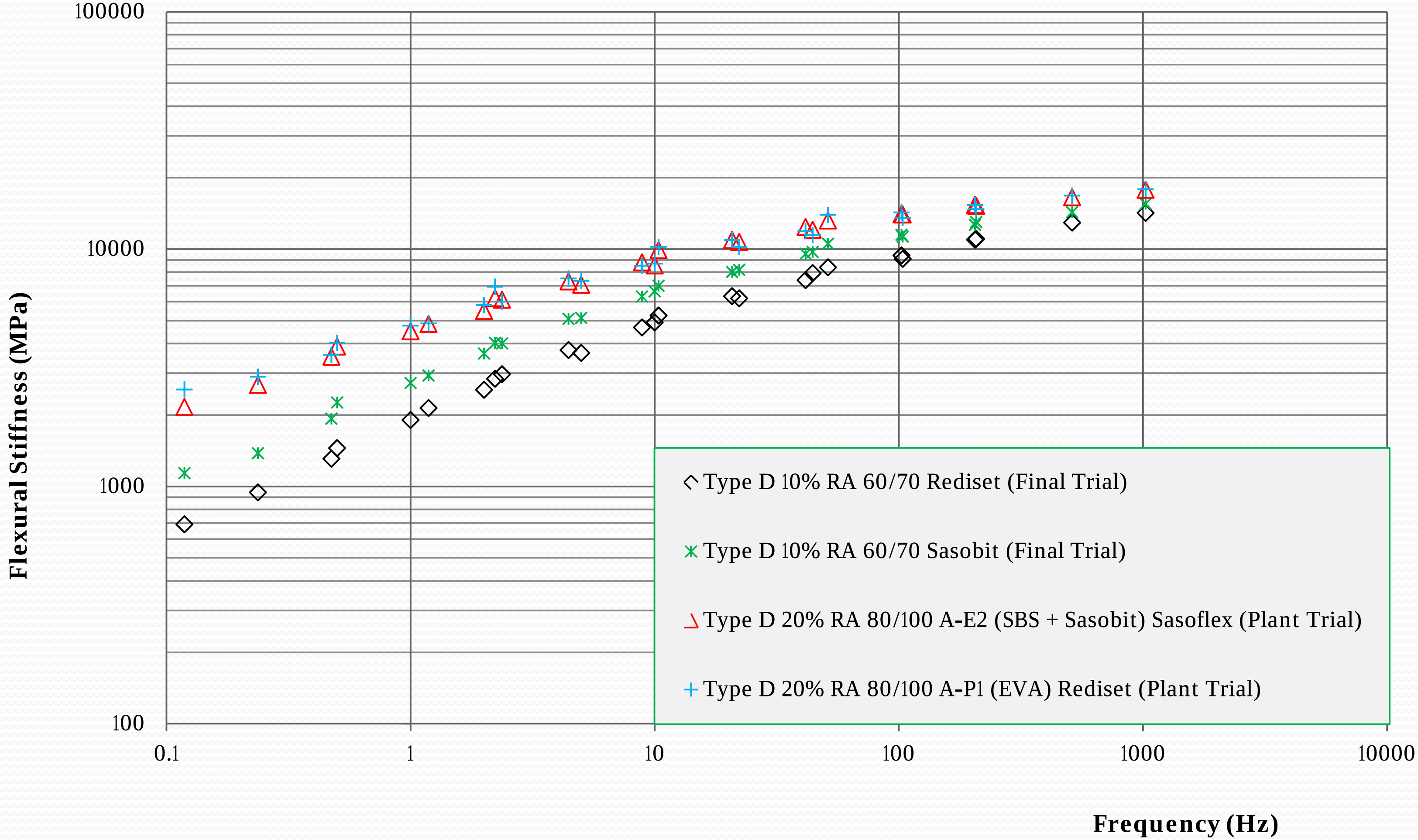
Graph 3 Type B 10% RA 60/70 Base Mixes

LABORATORY RESULTS – Flexural Stiffness



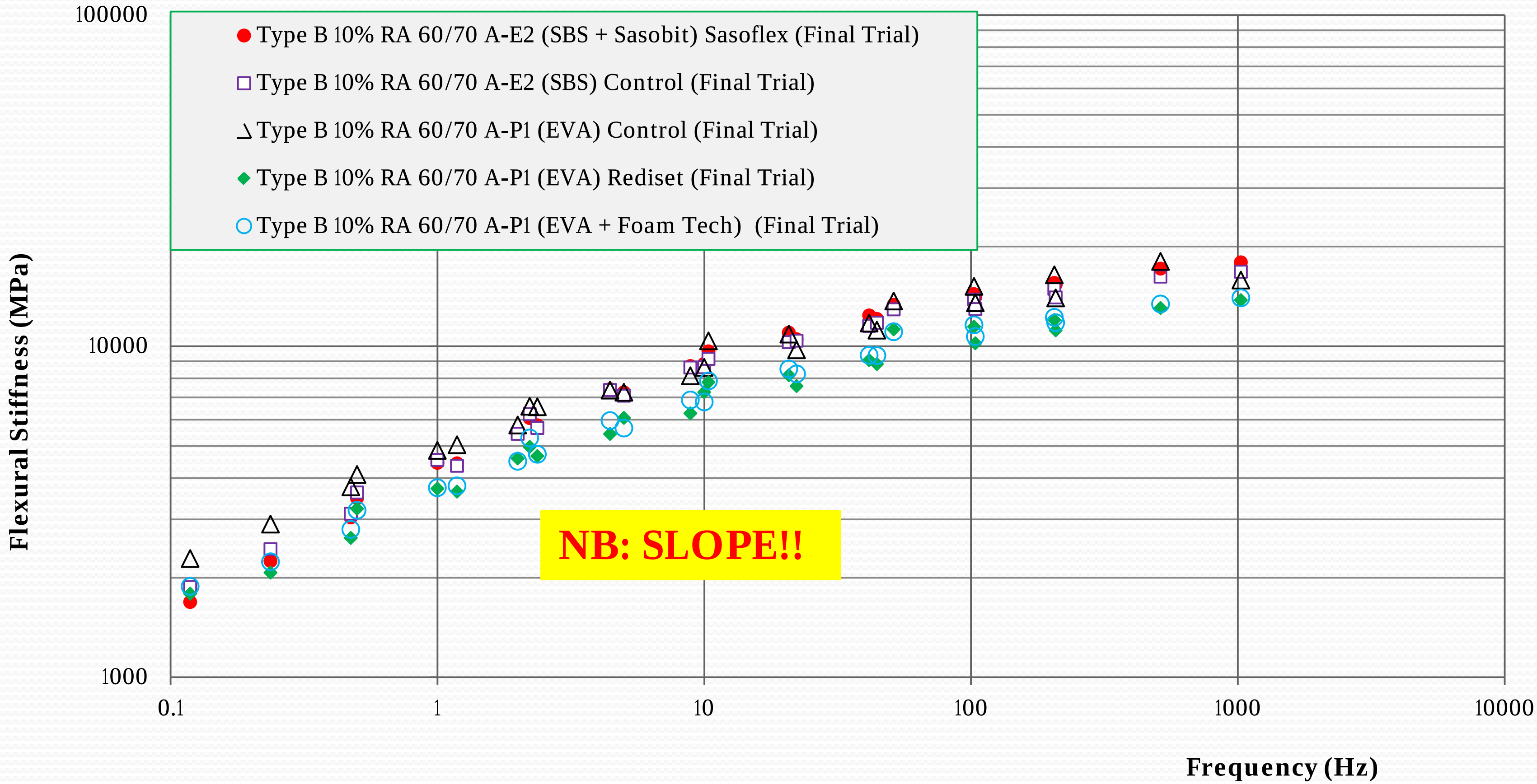
Graph 4 Type B 40% RA 80/100 Base Mixes

LABORATORY RESULTS – Flexural Stiffness



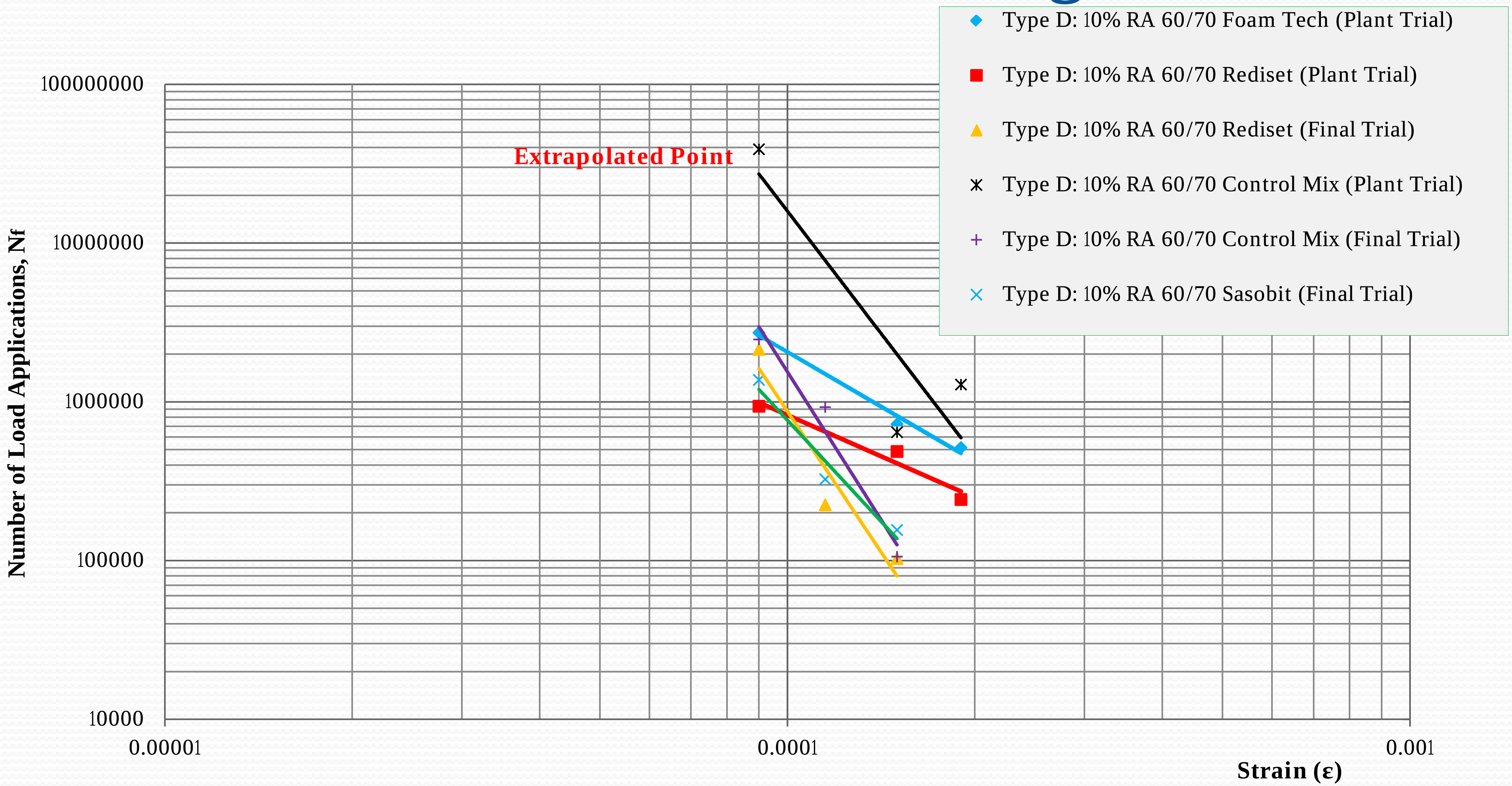
Graph 5 Type D Surfacing Mixes – Additive Technology

LABORATORY RESULTS – Flexural Stiffness



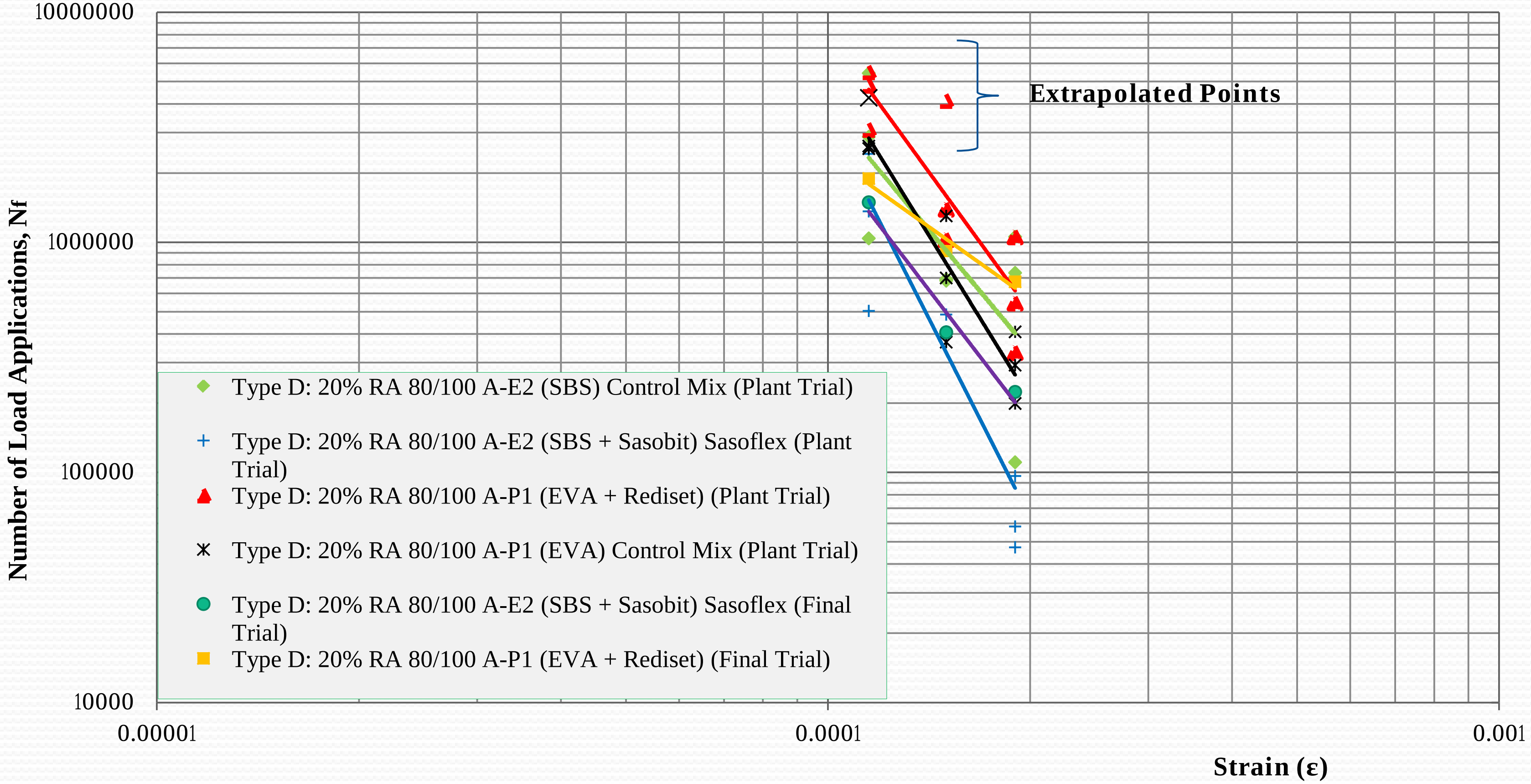
Graph 6 Type B Base Mixes –Technologies and Modifiers

LABORATORY RESULTS – Fatigue



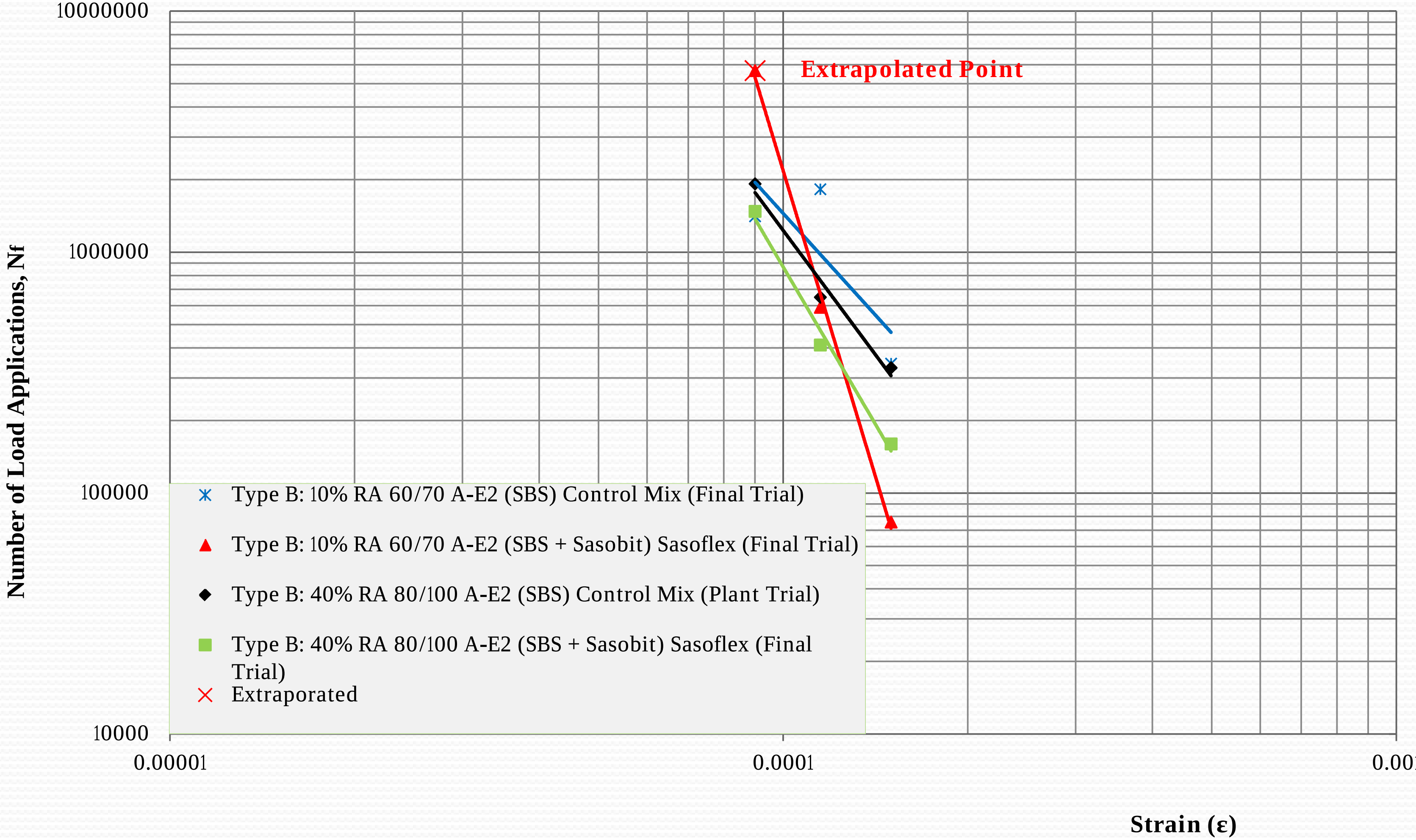
Graph 7 Type D 10% RA 60/70 Surfacing Mixes

LABORATORY RESULTS – Fatigue



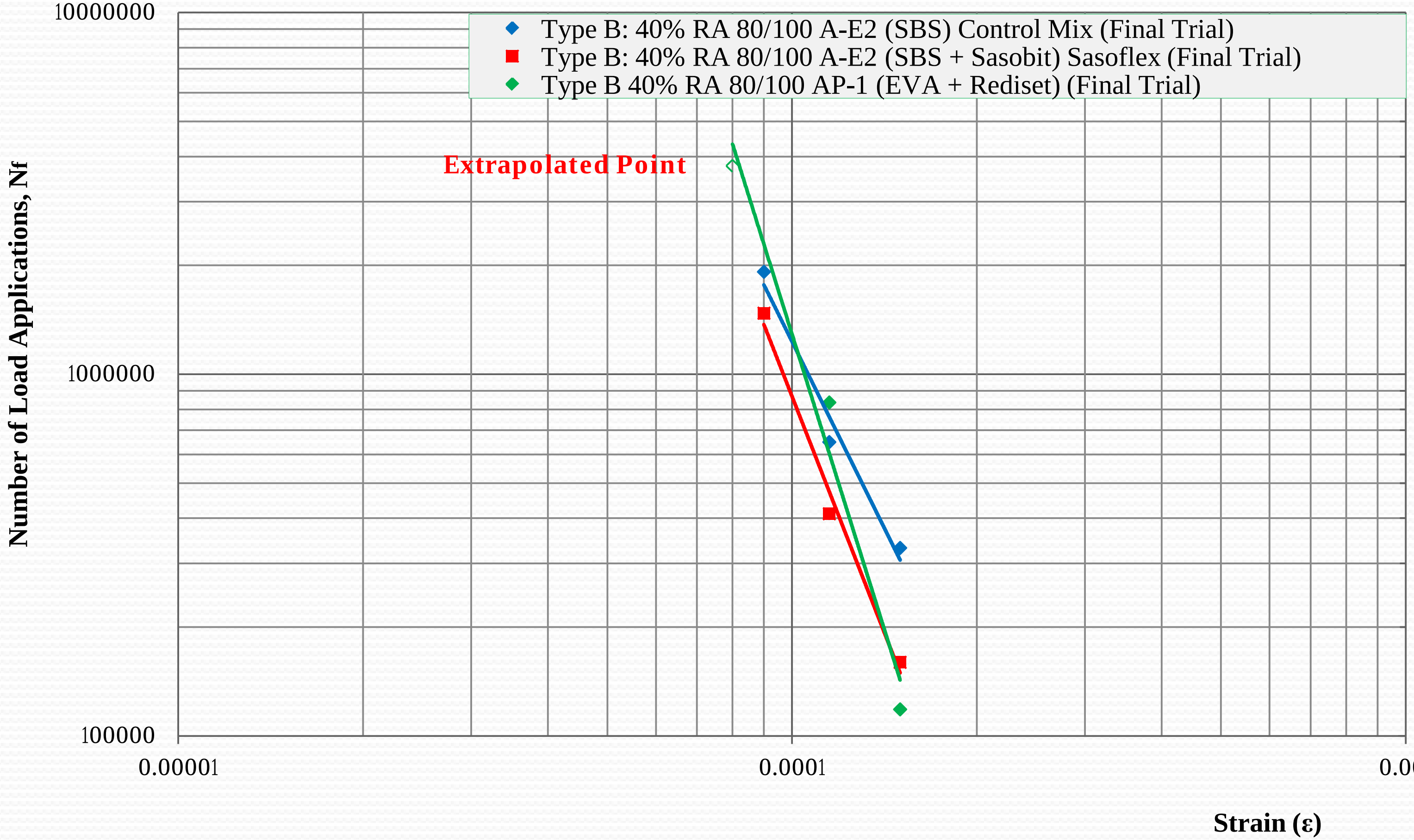
Graph 8 Type D 20% RA 80/100 Surfacing Mixes

LABORATORY RESULTS – Fatigue



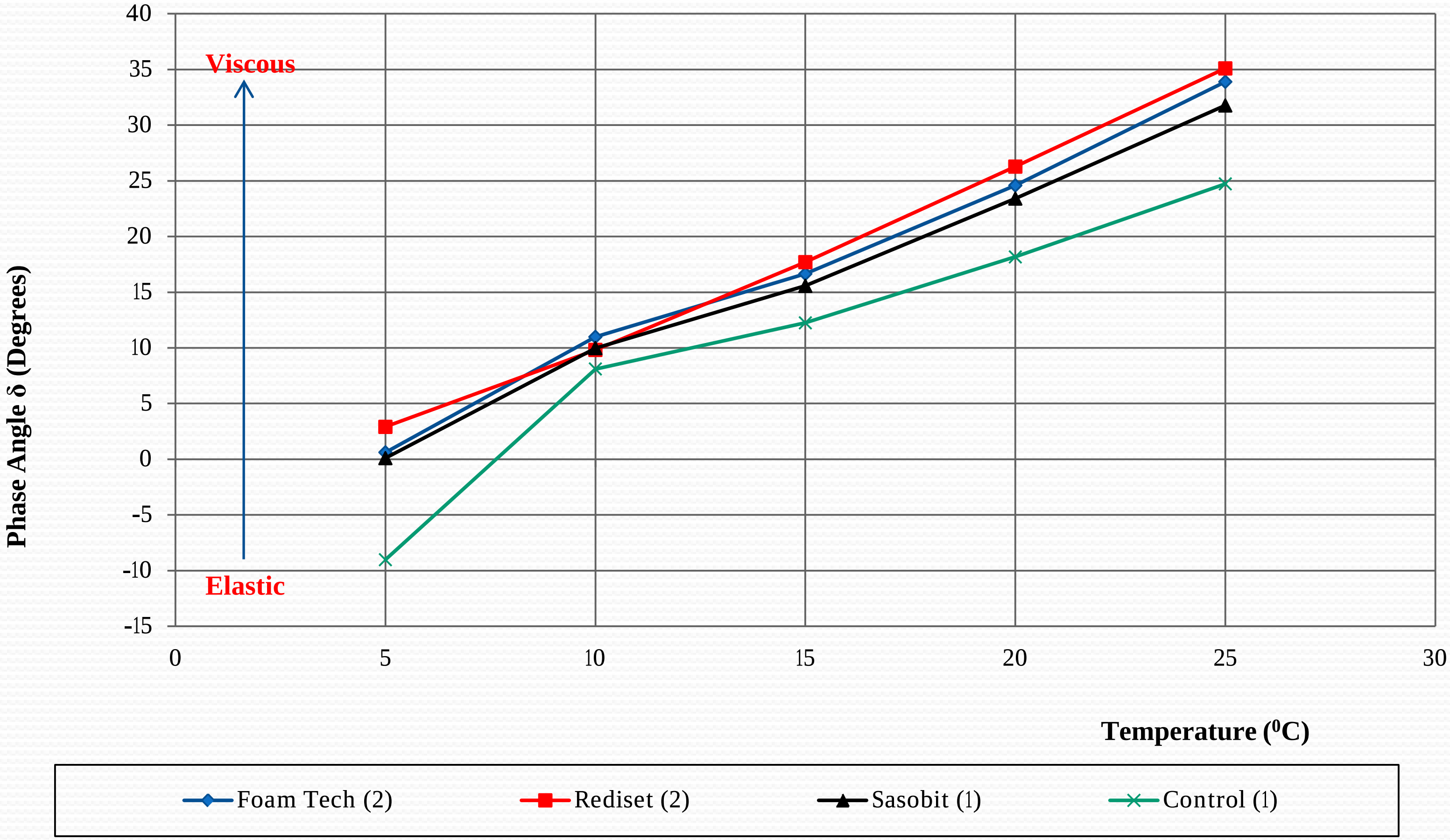
Graph 9 Type B 10% & 40% RA 60/70 Base Mixes

LABORATORY RESULTS – Fatigue



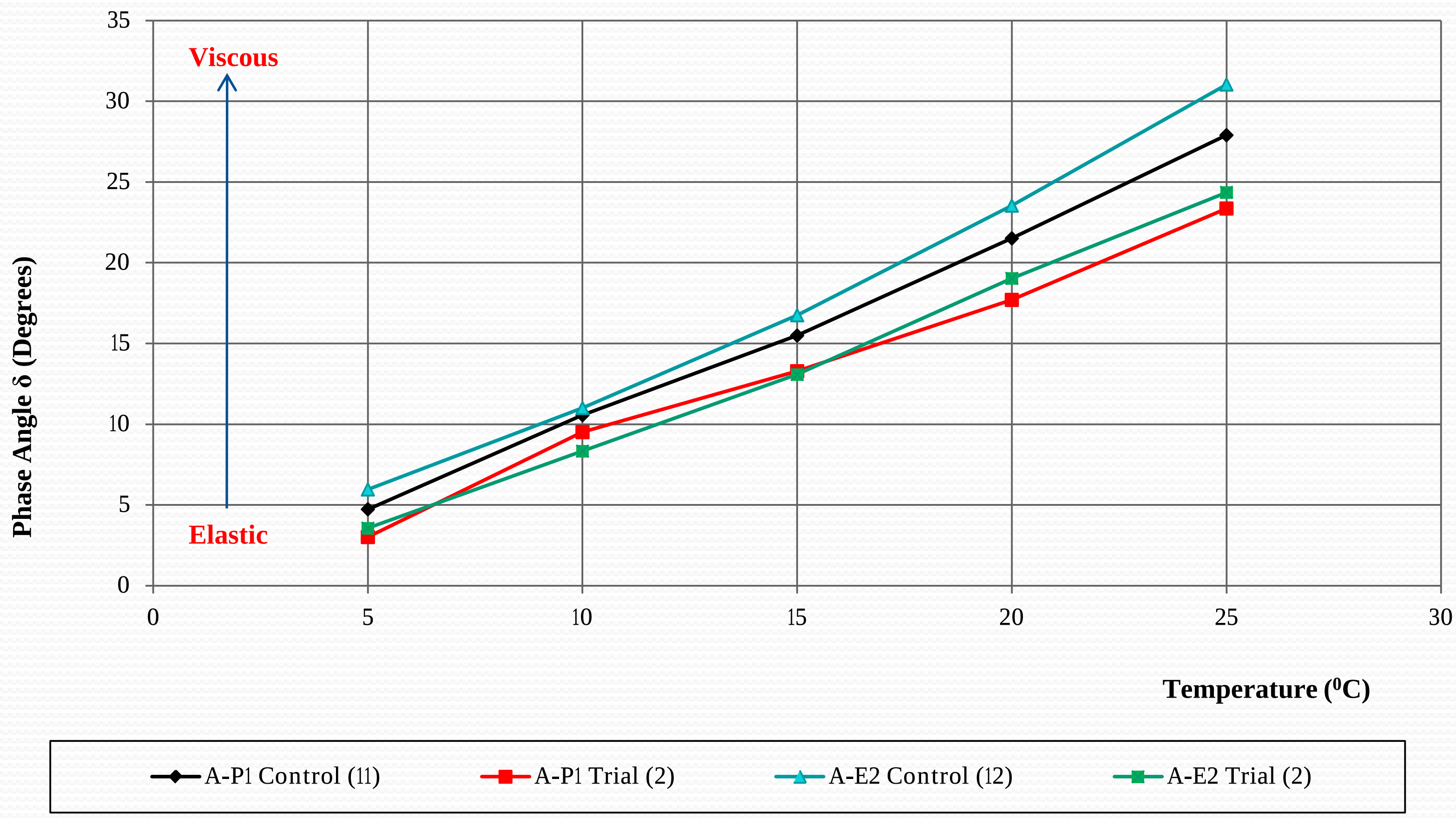
Graph 10 Type B 40% RA 80/100 Base Mixes

LABORATORY RESULTS – Visco-elastic



Graph 11 Type D 10% RA 60/70 Surfacing Mixes (Freq. 10Hz)

LABORATORY RESULTS – Visco-elastic



Graph 12 Type D 20% RA 80/100 Surfacing Mixes (Freq. 10Hz)

CONCLUSIONS – Flexural stiffness

- Surfacing (no SBS or EVA) with 10% RA 60/70 for plant versus final trial mixes
  - no consistent trend, sometimes higher, sometimes lower
  - (Control) HMA = WMA
  - Sasobit > Rediset for WMA
- Surfacing (SBS or EVA) with 20% RA 80/100
  - Plant > final field trial mixes for both SBS and EVA
  - Sasoflex WMA = EVA + Rediset
- Bases with 10% RA 60/70
  - SBS WMA > HMA
  - EVA HMA > WMA
  - EVA + Foam similar to EVA + Rediset
- Bases with 40% RA 80/100 + EXP1655
  - SBS HMA slightly > WMA (Sasobit)
  - EVA HMA > WMA (+ Rediset)

CONCLUSIONS – Additives and Elasticity

- Elastomer and Plastomer, Flexural Stiffness
  - For SBS the WMA generally >or= Control (HMA)
  - For EVA the WMA generally < Control (HMA)
- Visco-elastic Behaviour Surfacing 10% RA 60/70
  - Elastic HMA – WMA – Viscous
  - Elastic - Sasobit – Foamtech – Rediset - Viscous
- Behaviour Surfacing 20% RA 80/100 + SBS or EVA
  - EVA = SBS with variability

CONCLUSIONS – Fatigue

- Surfacing 10% RA 60/70
  - HMA > WMA (plant& final)
  - For WMA overall Foamtech > Sasobit > Rediset
- Surfacing 20% RA 80/100
  - HMA > WMA Sasoflex (plant) > Sasoflex (final)
  - WMA EVA+Rediset (plant) > (final) > HMA
- Base 60/70 + SBS (all)
  - HMA (10%) > HMA (40% RA) > WMA (10% and 40% RA)
- Base 40% RA 80/100 + SBS or EVA
  - HMA (SBS) > WMA (EVA) > WMA (SBS)

RECOMMENDATIONS

- Laboratory and full scale trial??
- Further analysis - WMA technology vs. Rheology
  i.e. lubrication vs. technology, cohesive and adhesive
- Local materials and WMA technologies