Bitumen Stabilised Materials
MIX DESIGN OVERVIEW

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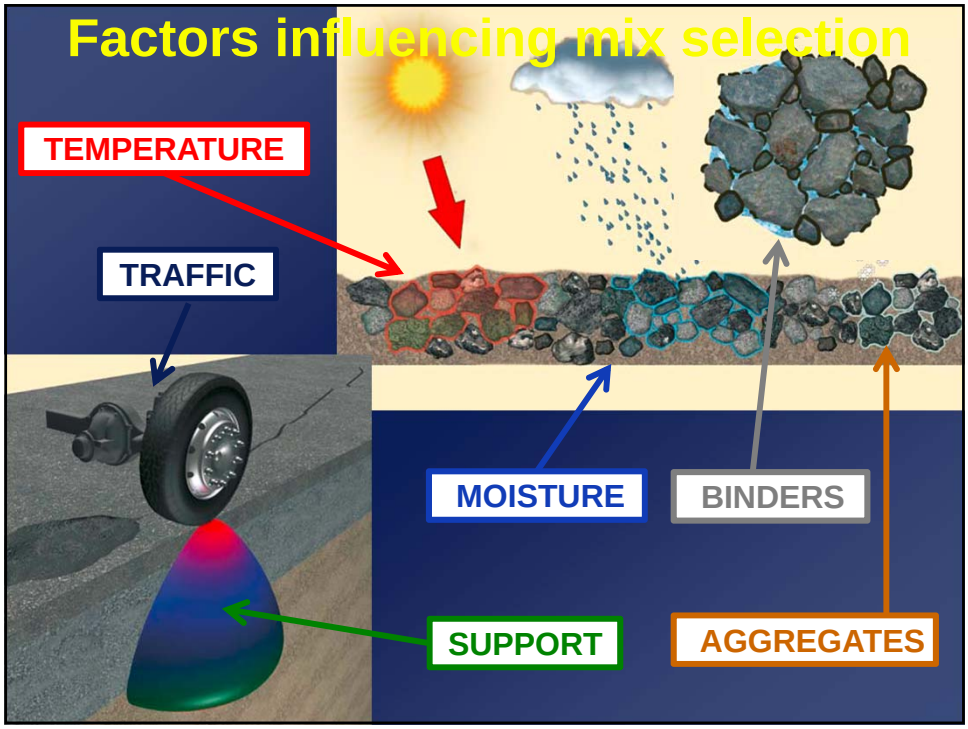
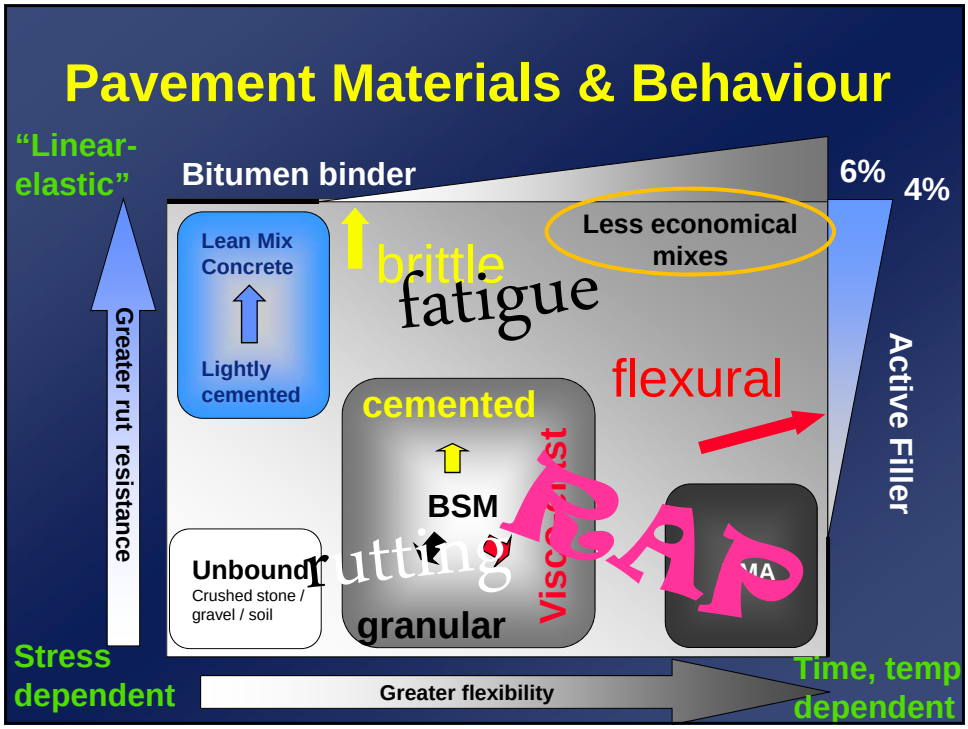
Pre-Conference Course

ISAP 2012, Fortaleza

30 Sep 2012

Stellenbosch


Factors influencing mix selection
TEMPERATURE
TRAFFIC
MOISTURE
BINDERS
SUPPORT
AGGREGATES

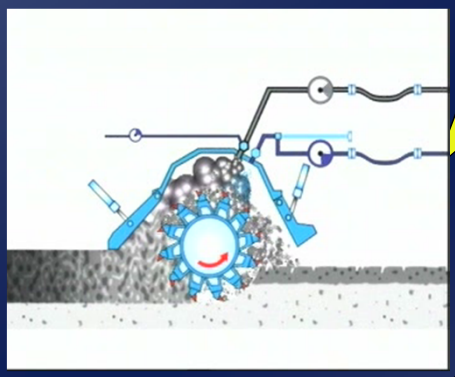

Pavement Materials & Behaviour
"Linear-elastic"
Bitumen binder
6%
4%
Lean Mix Concrete
Lightly cemented
brittle
fatigue
Less economical mixes
flexural
cemented
BSM
Unbound
Crushed stone / gravel / soil
granular
rutting
GAP
Active Filler
Greater rut resistance
Stress dependent
Greater flexibility
Time, temp dependent

Primary Design Objectives

- Load spreading
  - Resilient Modulus (Mr)
- Rut resistance
  - Shear Strength
- Flexibility
  - Displacement at Ultimate Strength
- Durability
  - Moisture resistance

BINDERS

Recycling Additives



Granular and RAP Materials

Aggregate

Bitumen Emulsion

Chemical Additives

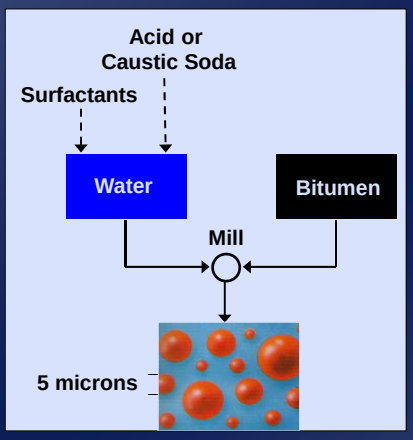
Active Filler

Foamed Bitumen

BSM Binder

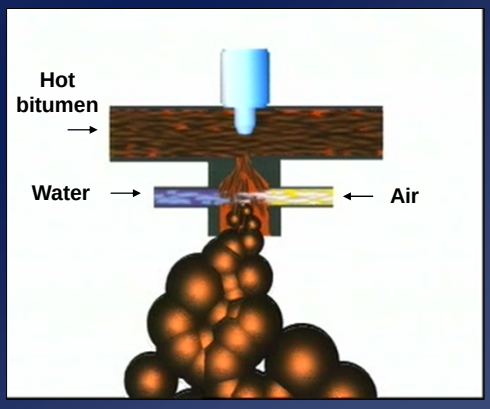
BITUMEN EMULSION

Colloidal Mill



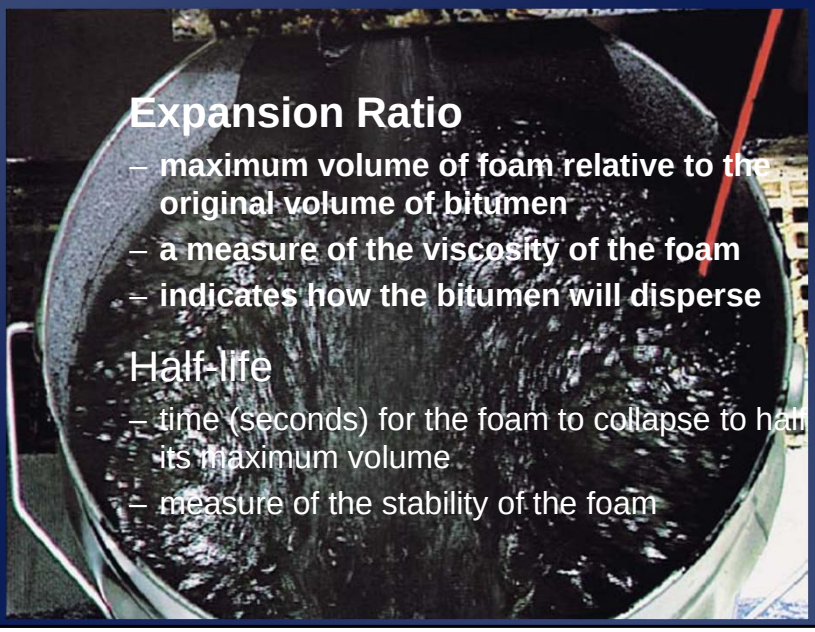
FOAMED BITUMEN

Expansion chamber



Foaming in laboratory

Foamed bitumen characteristics



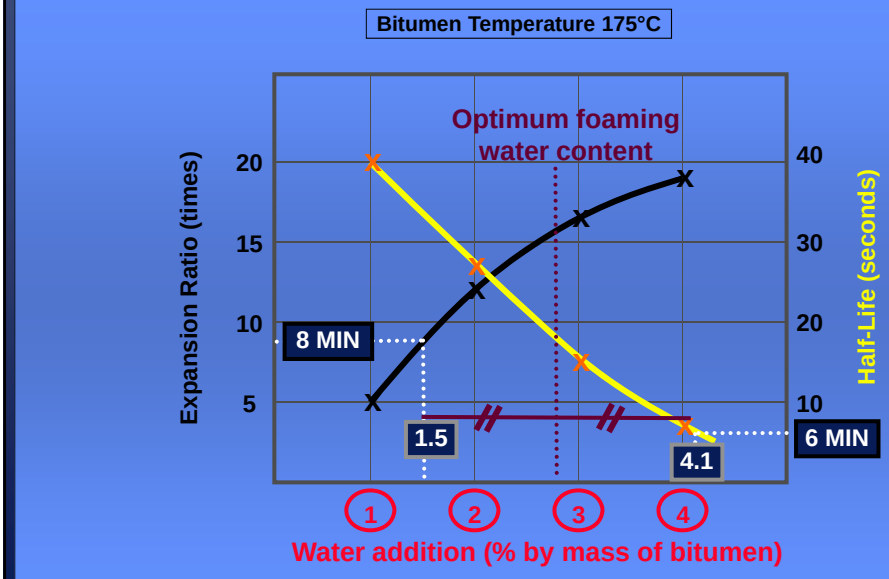
Expansion Ratio

- **maximum volume of foam relative to the original volume of bitumen**
- **a measure of the viscosity of the foam**
- **indicates how the bitumen will disperse**

Half-life

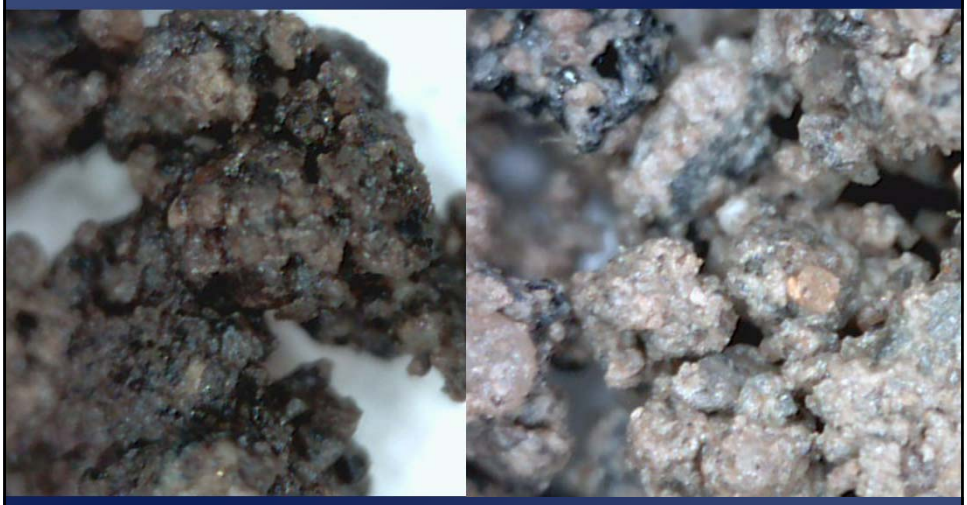
- time (seconds) for the foam to collapse to half of its maximum volume
- measure of the stability of the foam

FOAMING CHARACTERISTICS



AGGREGATES

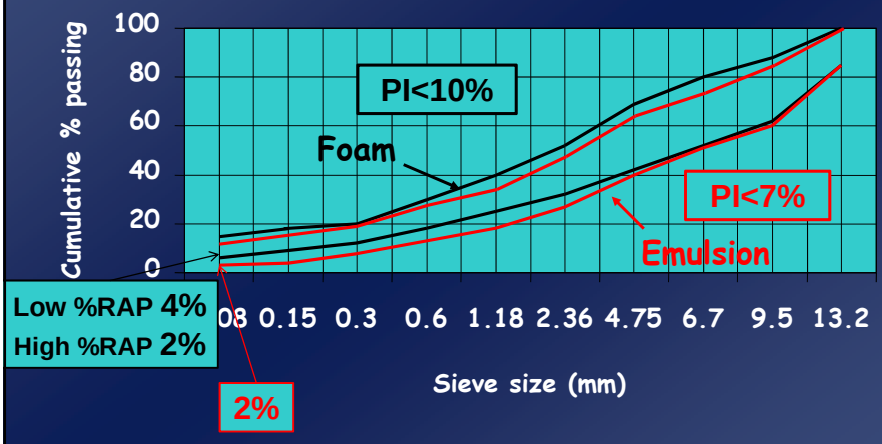
Microscopic Analysis



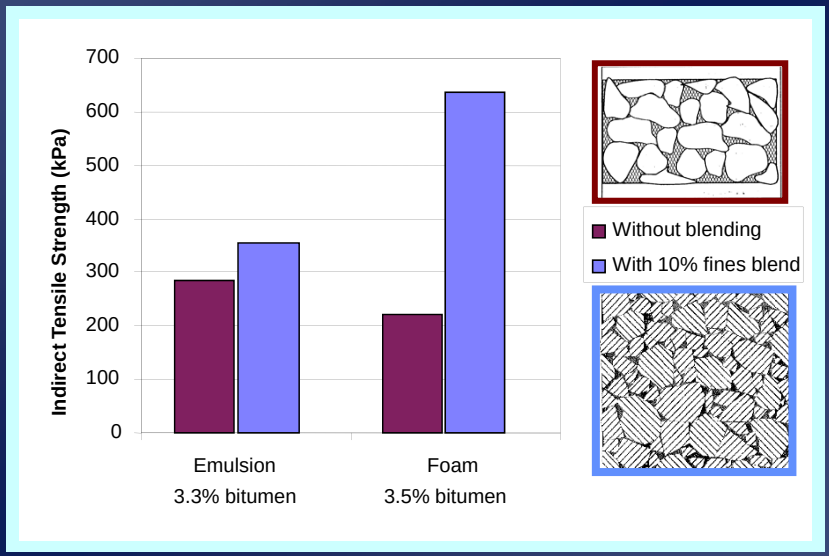
BSM-emulsion

BSM-foam

Grading and PI requirements



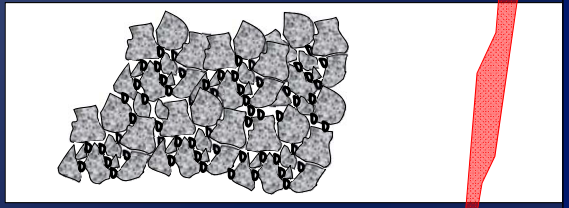
Optimisation of grading curve



BSM: RAP Influence

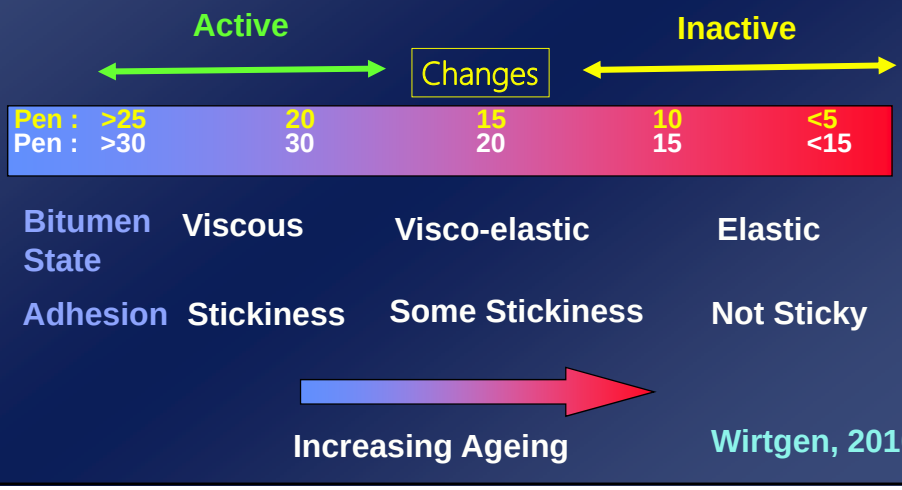
Bitumen Stabilised

Non-continuously bound

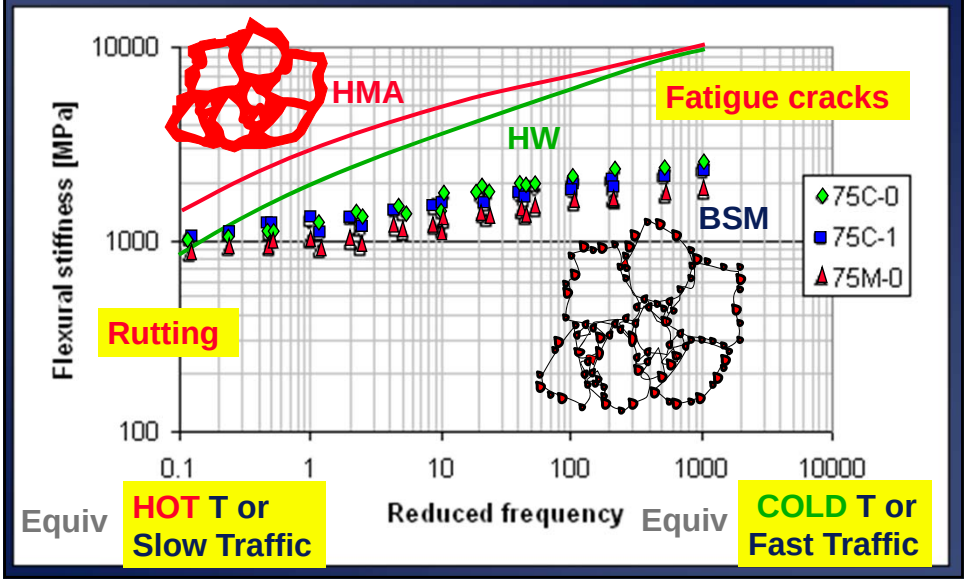


<30	RAP: Recovered pen
<5%	RAP: Recovered BC(%)
<2%	Emulsion Residual BC
No	Rejuvenating Agent
TG2/Wirtgen	Mix Design

Classes of RAP

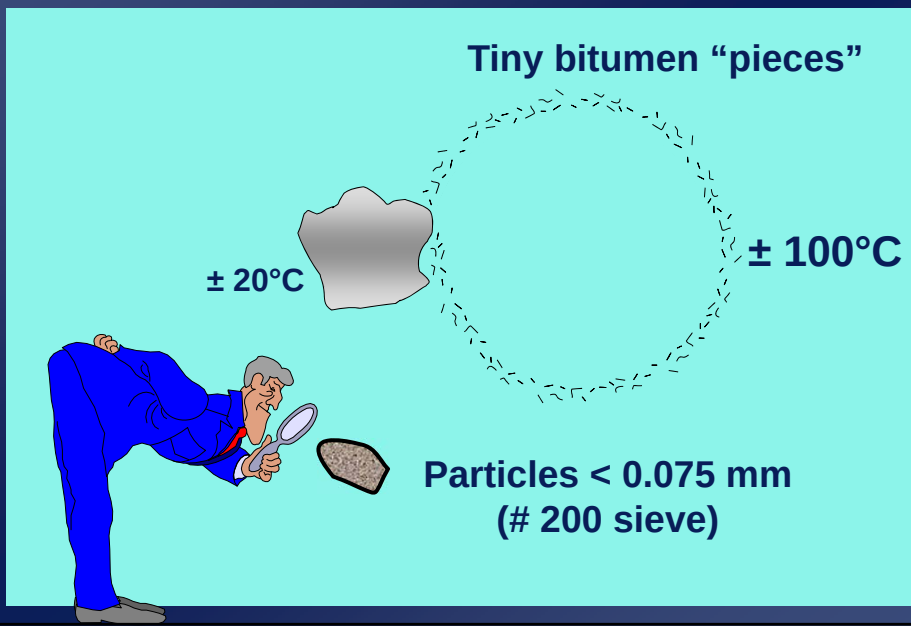


Visco-elastic properties
Beam tests on BSM-foam Tref = 20C

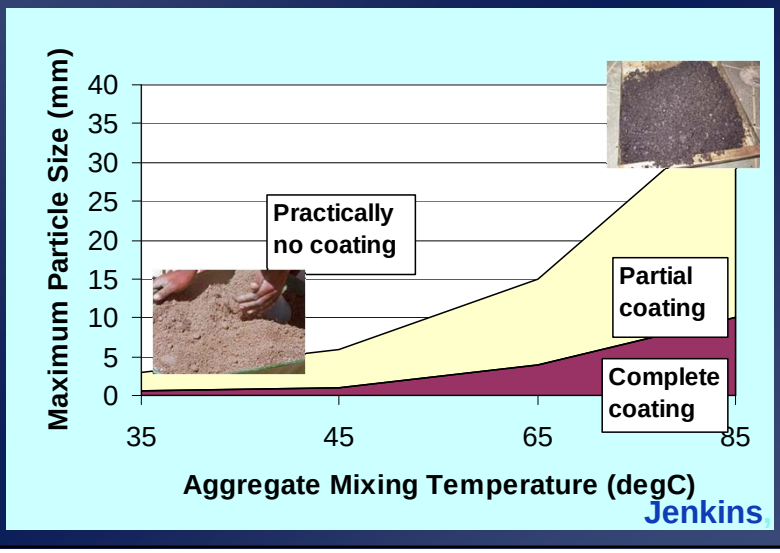


TEMPERATURE

BITUMEN DISPERSION



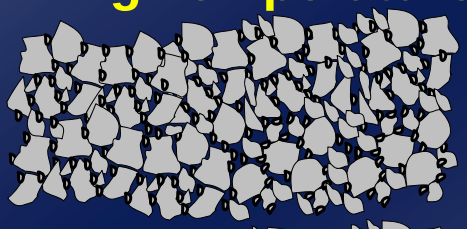
Aggregate Temperature vs Particle coating (BSM-foam)



Jenkins, 2000

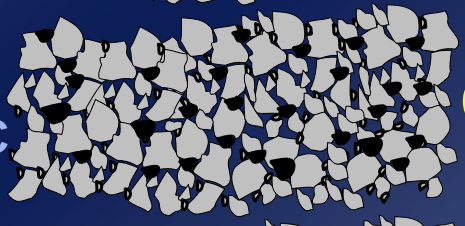
Aggregate Mixing Temperature

Foam > 25ºC



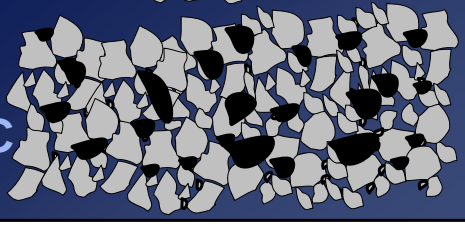
√

Foam 15ºC
Emulsion 10ºC



OK

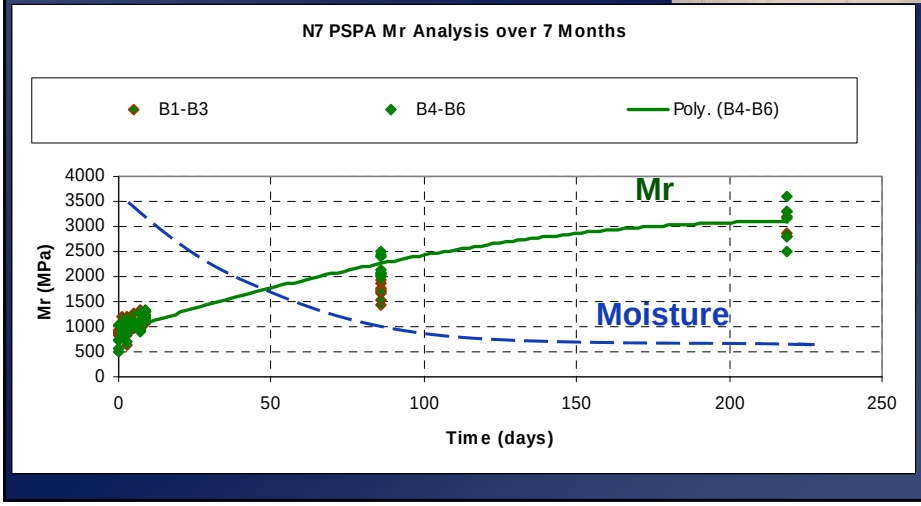
Foam <15ºC
Emulsion<10ºC



X

MOISTURE

Mr (field) versus cure



MOISTURE DAMAGE

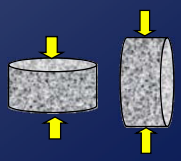
HVS Cape Town on BSM

MIX DESIGN

BSM Mix Design & Classification

Level 1

100mmϕ



Aggregate blend

Compaction fluids

Act filler – type & cont

Level 2

150mmϕ

Strength & moisture resistance

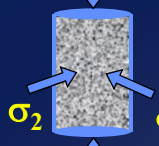
σ_1

Binder cont 0.2% inc

Level 3

150mmϕ

300mmH



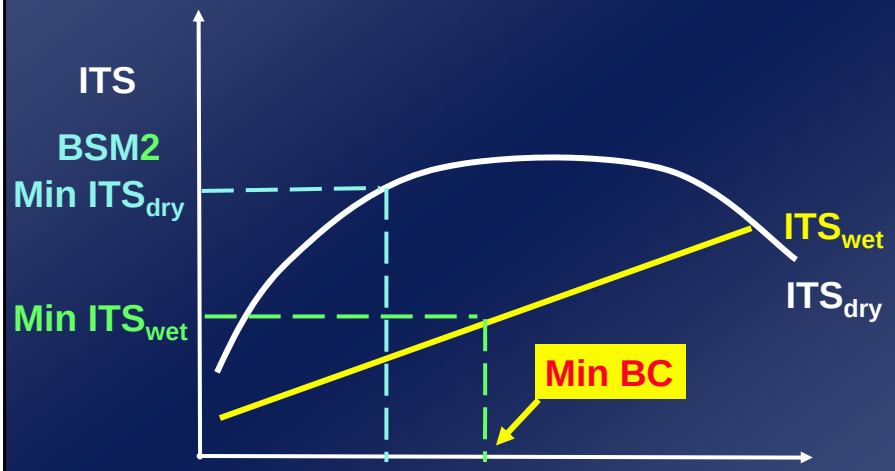
Final mix selection

Reliable performance related properties

Shear properties & resilient modulus

Flexibility?

Binder type & content – Level 1

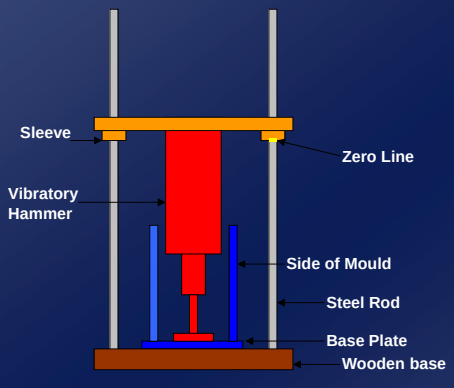


Level 1 and 2 Classification

Test	Dia ϕ mm	BSM1 (kPa)	BSM2 (kPa)	BSM3 (kPa)	Comments
ITS_{dry}	100	>225	175 to 225	125 to 175	Indicates OBC
ITS_{wet}	100	>100	75 to 100	50 to 75	Indicates active filler type & amt
TSR	100	Not applicable			Prob mat TSR < 50 % ITS_{dry} > 400 kPa
ITS_{equil}	150	>175	135 to 175	95 to 135	OBC refined
ITS_{soaked}	150	>100	75 to 100	50 to 75	Adjusted to ITS_{wet}

Vibratory Compaction Hammer

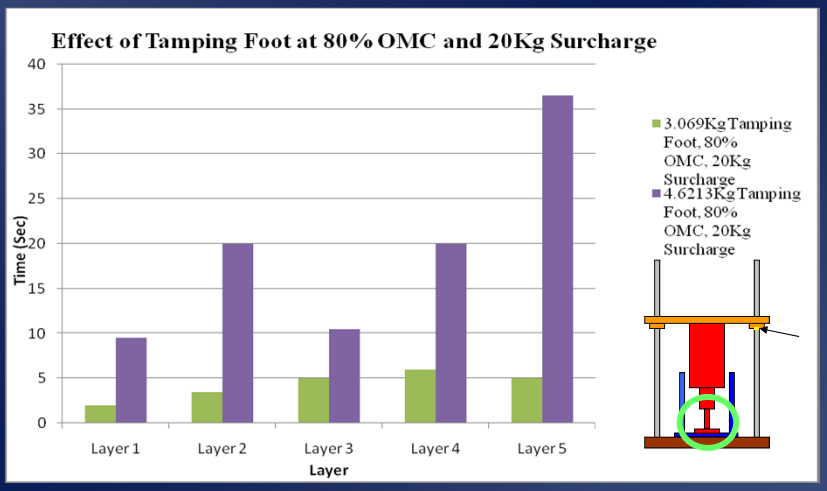
To prepare specimens



Kelfkens

Rear View of Frame

Influence of Tamping Foot



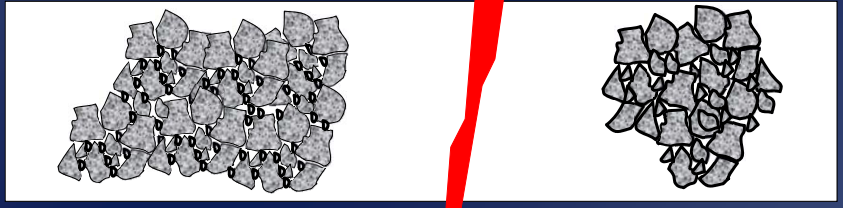
Compaction time (vibratory)

Comp Time

Phase	Level 1		evel 3
Test	ITS		riaxial
Foot ϕ	100mm	15	50mm
Height	65mm	95	0mm
Layers	1	2	
Surchg	5 kg	10	0 kg
Foam	10 sec	25	5 sec
Emuls	10 sec	15	5 sec

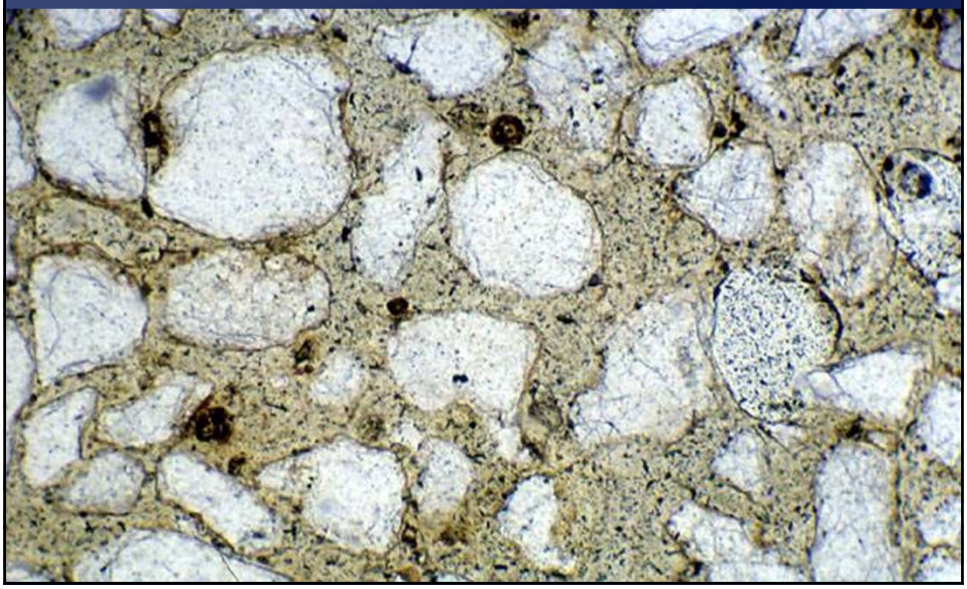
Testing the Material

Bitumen Stabilised Material	Asphalt
Non-continuously bound	Continuously bound



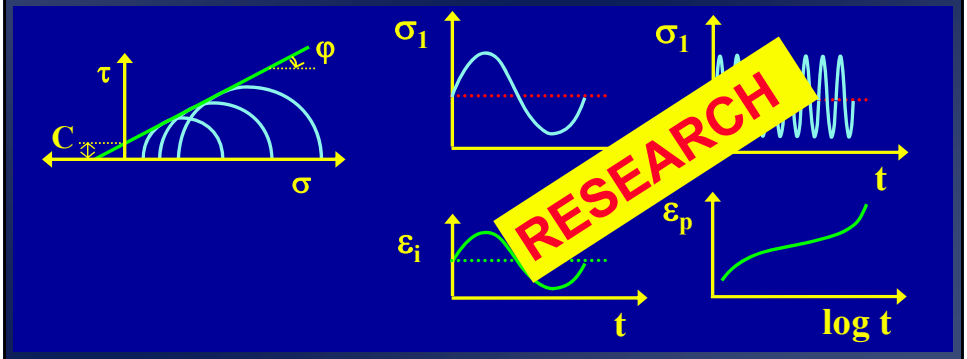
DIFFERENT BEHAVIOUR PATTERNS

Nature of BSM e.g. foam



Critical Material Properties

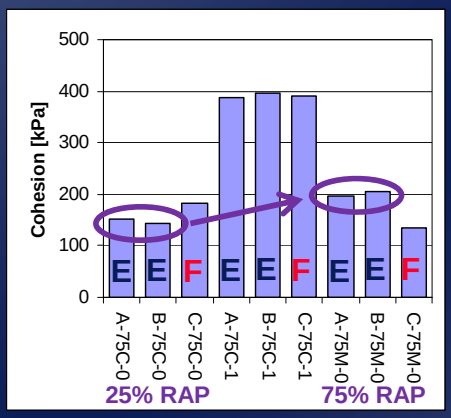
- Tri-axial test to determine:
  - Shear parameters (C & φ)
  - Resilient modulus (M_r)
  - Permanent deformation behaviour



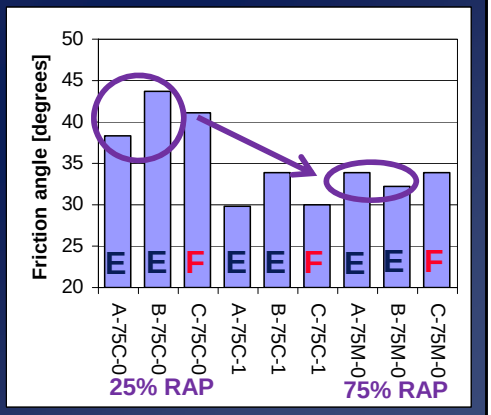
Triaxial Testing

Shear properties (monotonic triaxial at 25°C)

Cohesion C



Friction Angle ϕ



Ebels

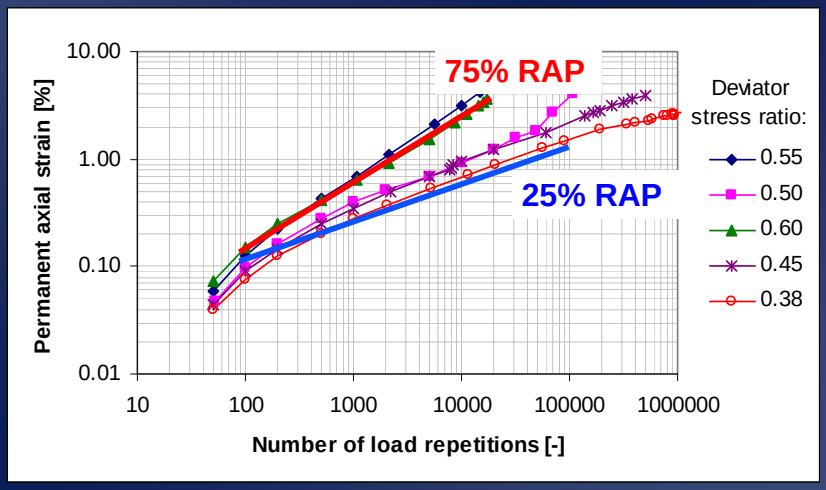
New "Simple triaxial"

BSM Classification ito Shear Properties

Equivalent BSM Class	Angle of Internal Friction (º)	Cohesion (kPa)
BSM 1	> 40	> 250
BSM 2	30 to 40	100 – 250
BSM 3	< 30	50 – 100

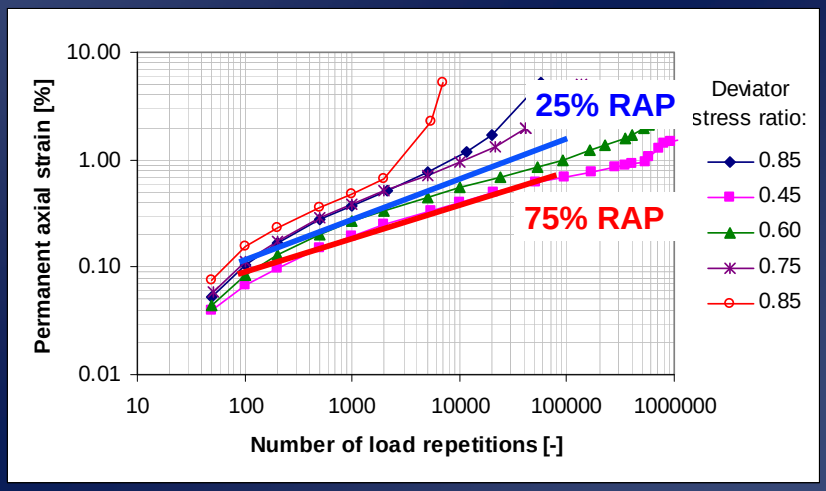
Permanent Deformation (Triaxial)

BSM-emulsion with 75% RAP (A-75M-0)

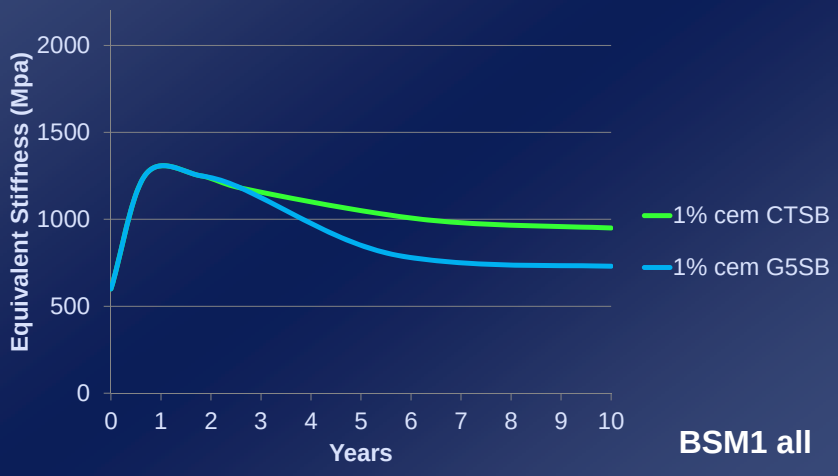


Permanent Deformation (Triaxial)

BSM-foam with 75% RAP (C-75M-0)

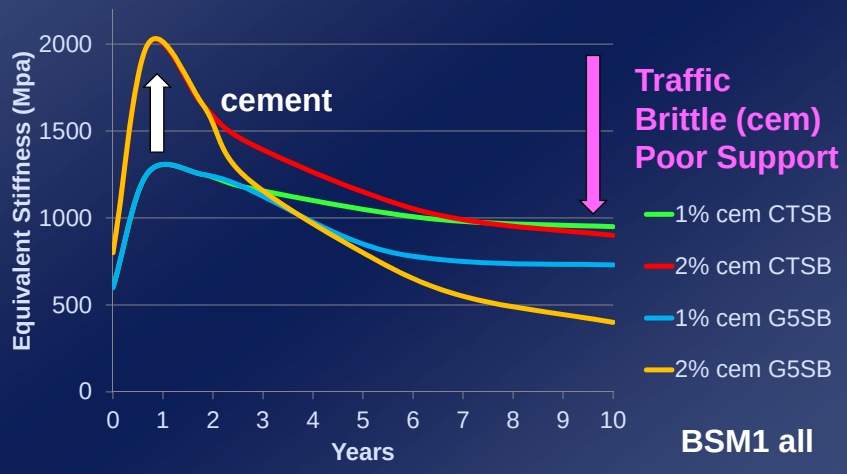


BSMs Mr change: Effective Long Term Stiffness



BSM1 all

BSMs Mr change: Effective Long Term Stiffness



(Prelim) Effective Long Term Mr for BSM base

BSM Class	C3 Subbase	G5/G6 Subbase
BSM 1 (RAP + G1 or G2)	**900 – 1750**	**700 – 1200**
BSM 1 (G1 or G2)	**800 – 1200**	**600 – 900**
BSM 2	**400 – 750**	**300 – 500**
BSM 3	**Not in use**	**Not in use**

ELT Mr = f (aggregate type and quality, RAP %, bitumen %, support, traffic, climate)

FLEXIBILITY

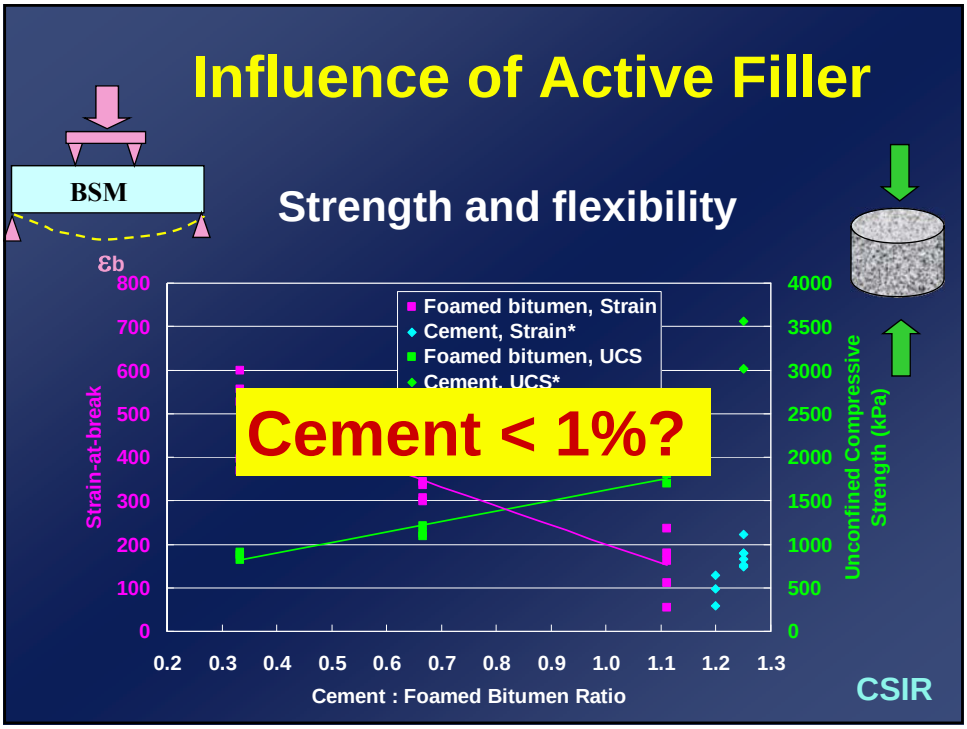
Purpose of Active Filler

- Improve adhesion — PRIMARY
- Improve dispersion — REASONS
- Modify plasticity
- Increase stiffness & strength
- Accelerate curing

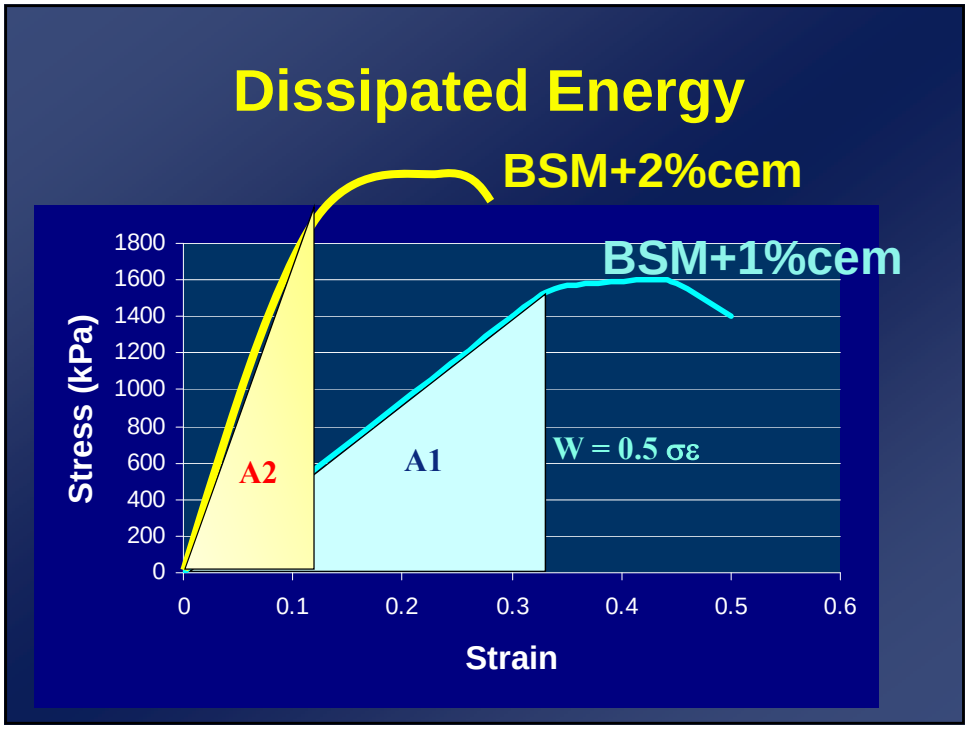
Emulsion — Foam

- Breaking time — Dispersion!
- Improve workability

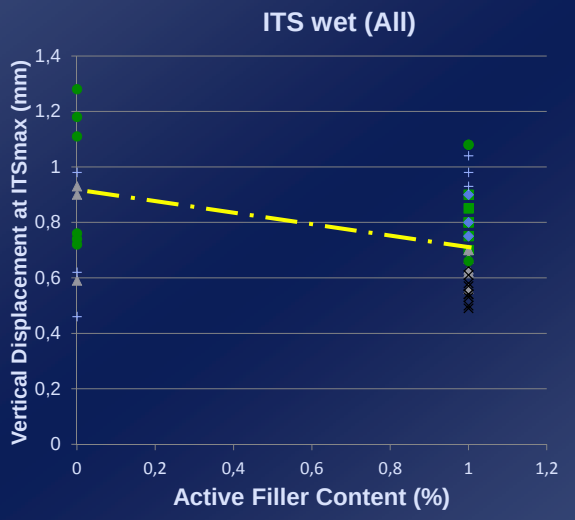
Influence of Active Filler




全面开通

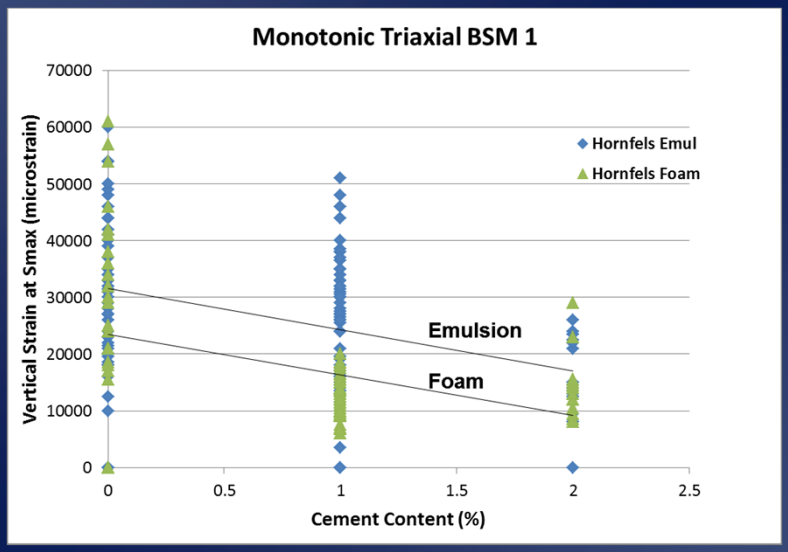

Dissipated Energy
BSM+2%cem
BSM+1%cem
Stress (kPa)
1800
1600
1400
1200
1000
800
600
400
200
0
0
0.1
0.2
0.3
0.4
0.5
0.6
Strain
A2
A1
W = 0.5 σε

ITS displacement at σ_{max}
(from Mix Design)



Similar trend for triaxial On Foam & Emulsion Mixes

Triaxial data from Mix Design



Can refine by separating data based on σ_3

Conclusions

- Understanding of material behaviour of BSMs has increased significantly
- Flexibility is NB! Active filler versus bitumen content!!
- More advanced test evaluation (triaxial = shear properties)
- Mix Design is linked to Structural Design method for BSMs

Thank you

WHOLE OF LIFE ENERGY & COST

Resilient Modulus of BSM

- **Granular Type Behaviour:** Foamed BC = 2%