Cold Recycling & Bitumen Stabilised Materials BSMs Research and Implementation?

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57th Annual Illinois Bituminous Paving Conference

12th December 2016

Stellenbosch

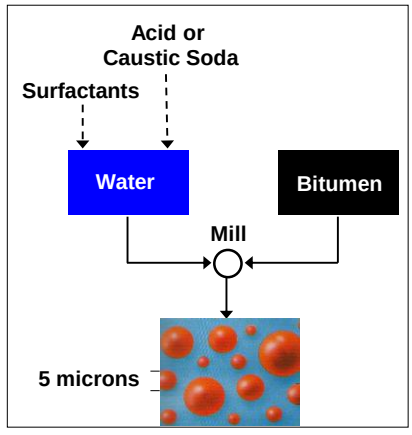
Outline

1. What is BSM?
2. Mix Design
3. Structural Design
4. Application
5. Where to now?

BSM Binder Options

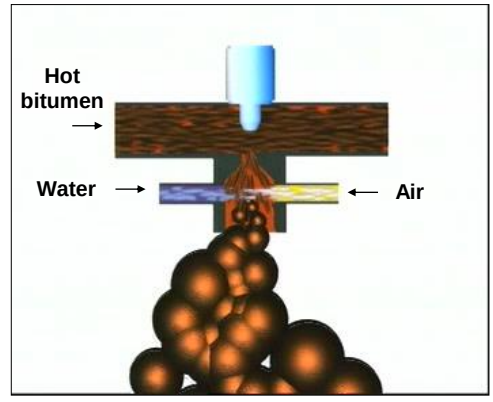
BITUMEN EMULSION

Colloidal Mill

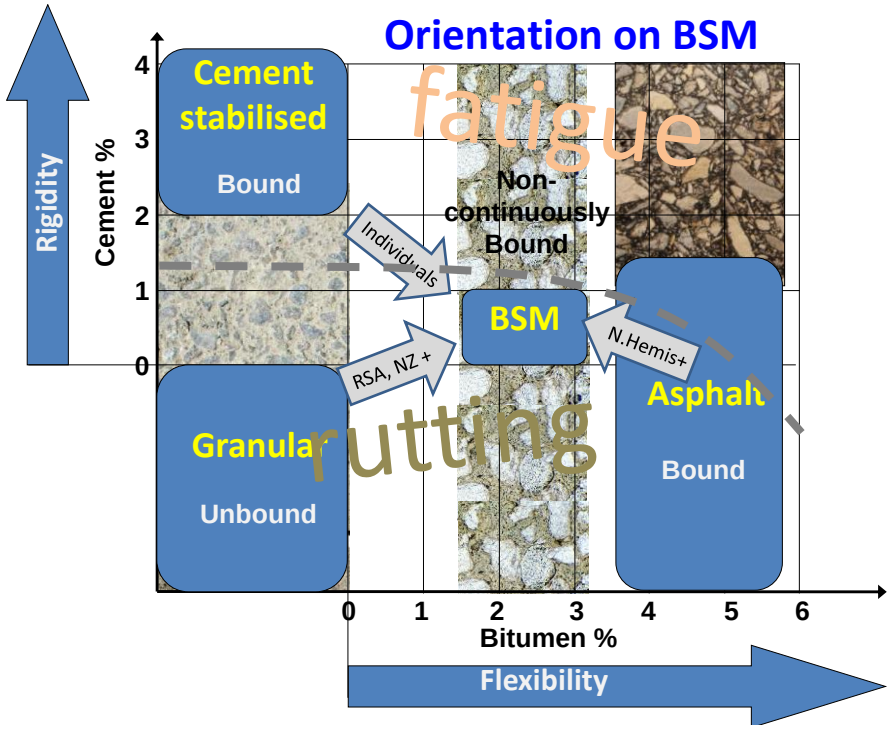


FOAMED BITUMEN

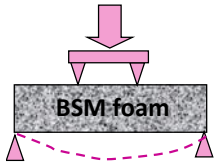
Expansion chamber



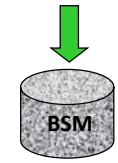
Orientation on BSM

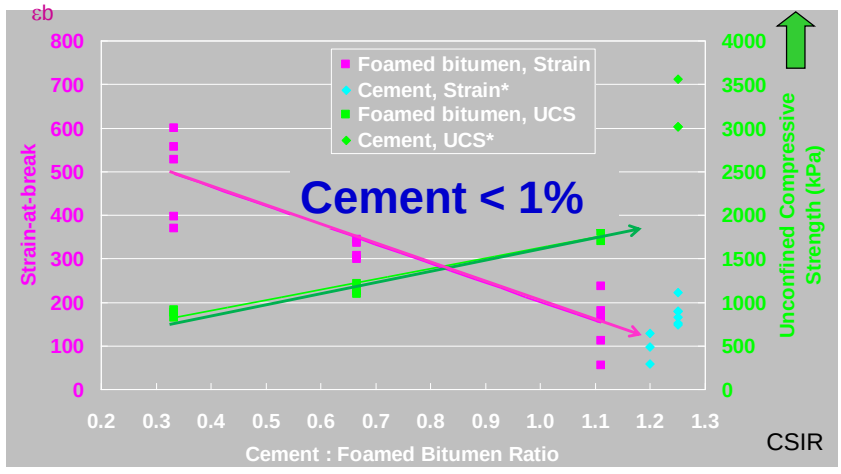


Influence of Active Filler



Strength versus Flexibility

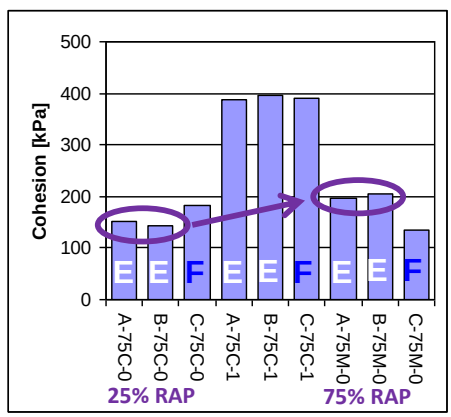




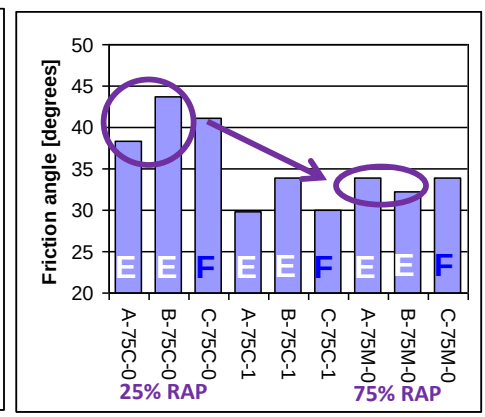
BSM Triaxial Tests Shear properties

(monotonic tests at 25°C)

Cohesion C



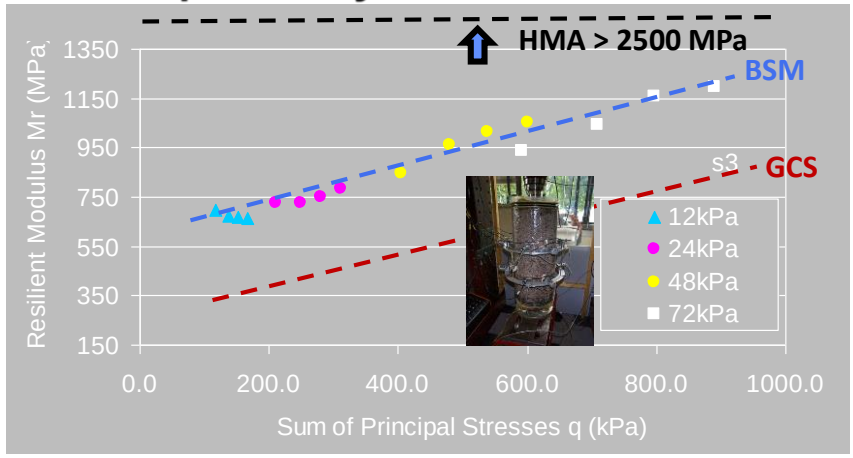
Friction Angle ϕ



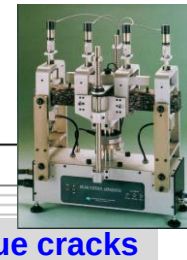
Jenkins, 1999 & Ebels, 2006

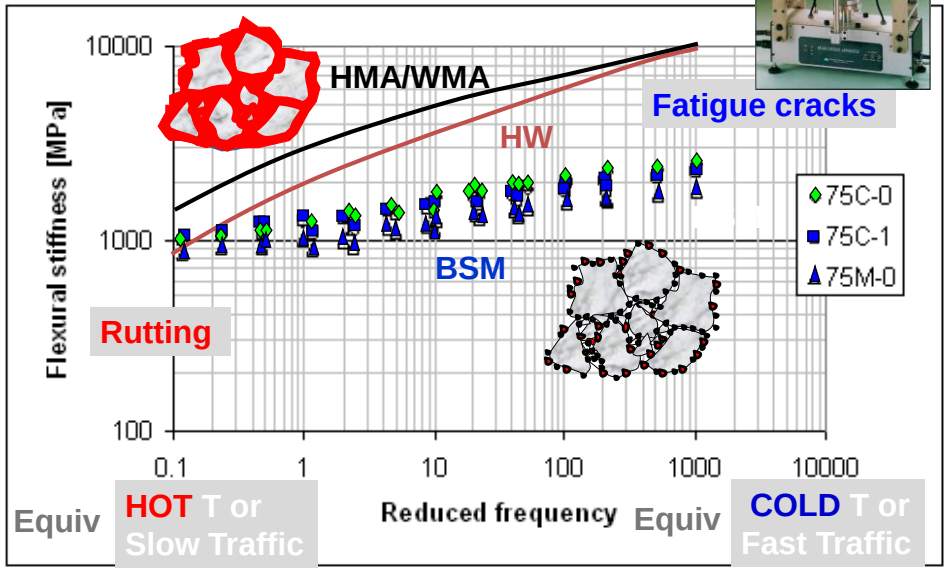
Resilient Modulus of BSM

Stress dependency: Foamed BC = 2%

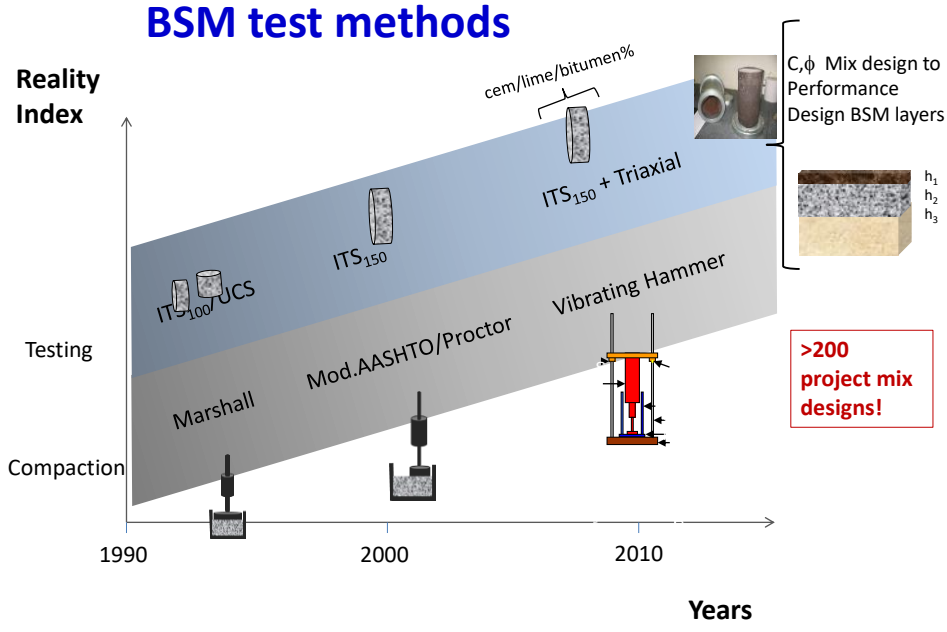


Research: Visco-elasto-plastic & flexural properties on BSM-foam

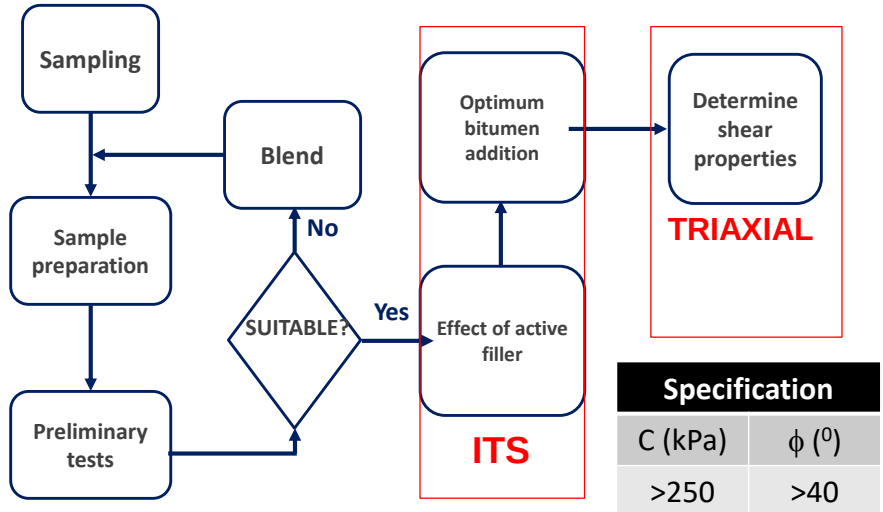




BSM test methods



Mix Design Flowchart



Specification	
C (kPa)	ϕ (⁰)
>250	>40

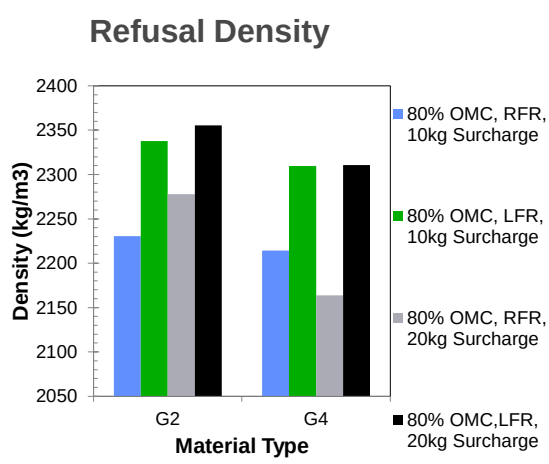
Standardised Mixing Method

Lab Compaction: Vibratory Hammer

Vibratory hammer	Power rating (W)	Frequency (Hz)	Mass (Kg)	Point Energy (J)	
Kango 637®	750	45.83	7.5	27	★
Bosch GSH 11E®	1500	15 - 31.5	10.1	16.8	★
Bosch GSH 11VC®	1700	15 - 30	11.4	23	

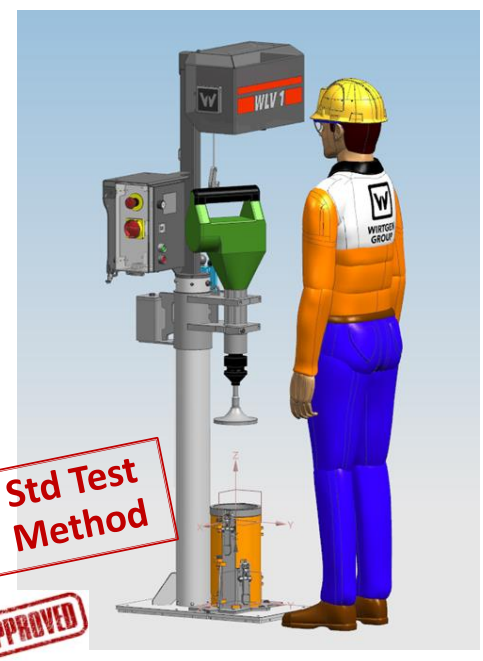
★ For PI >8%, cannot achieve 100% Mod. AASHTO density

Influence of Frame

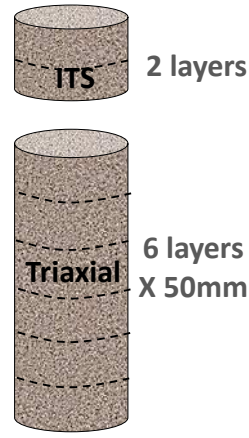


FRAME TYPE
Rigid
Loose
Rigid
Loose

Comparison of refusal density for G2 and G4 material

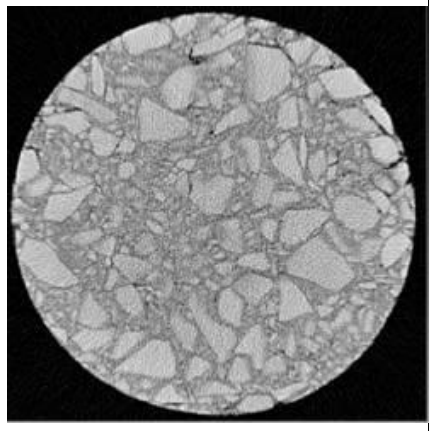


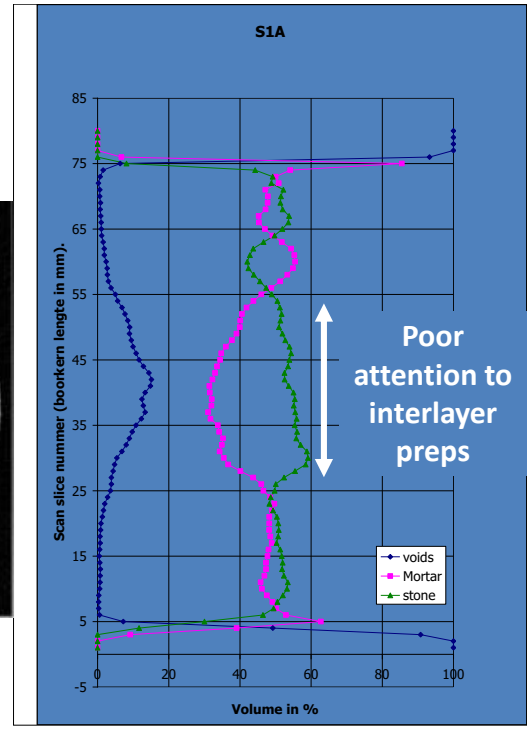
Inter-Layer Roughening (ILR) Device



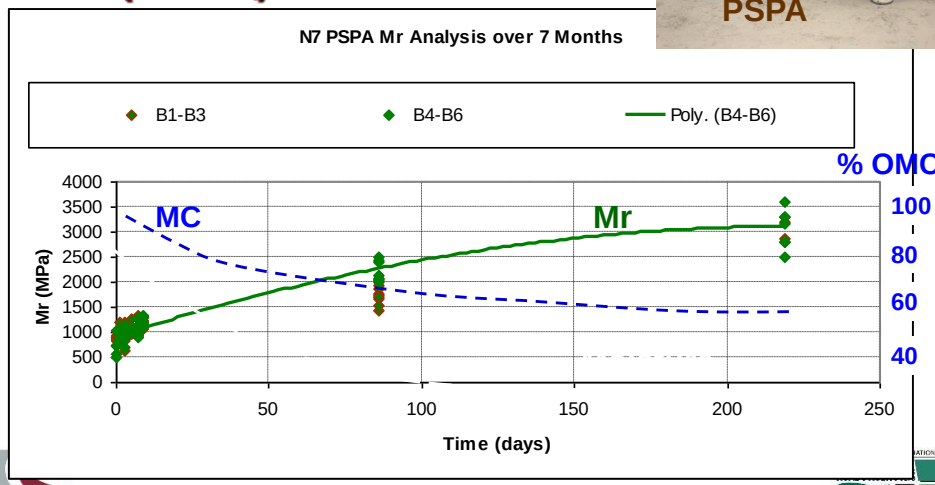
Inventor: Wynand van Niekerk

CT Scans
BSM-emulsion





Why is curing important?
Mr (field) versus cure



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Test at 25°C

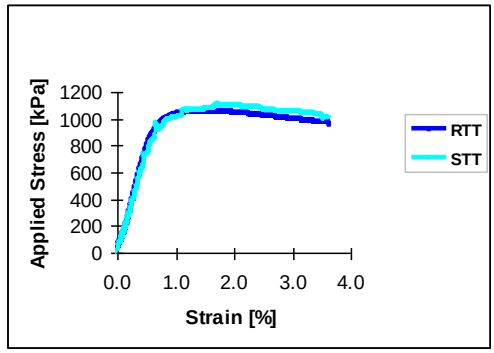
New Triaxial

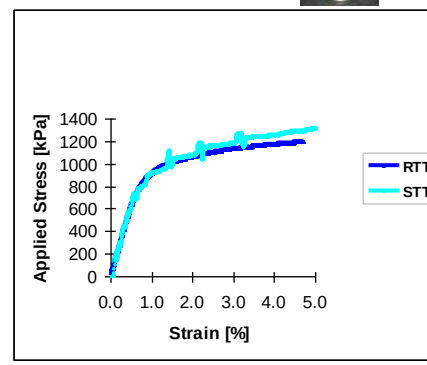
Apply Load (stress σ_1)

Confining Pressure σ_3 (inflate tube)

Validation

Research Triaxial Test RTT versus Simple Triaxial Test STT

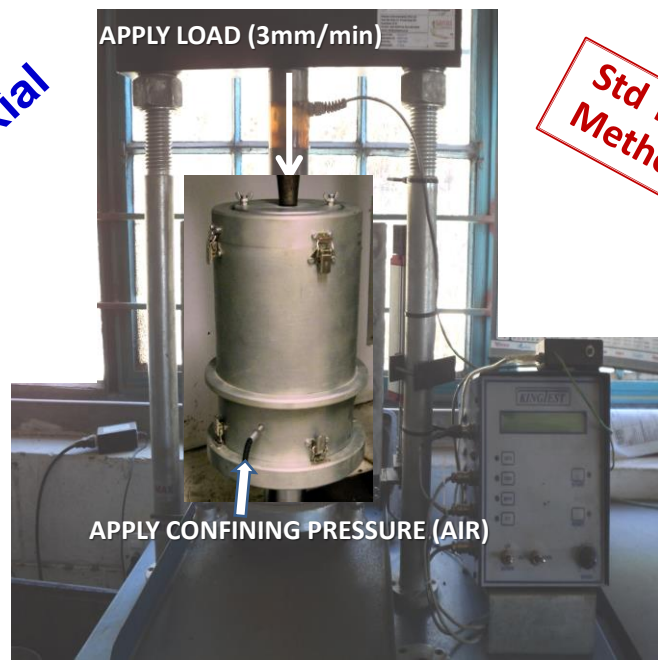




BSM Crushed Hornfels with 3.3% Emulsion

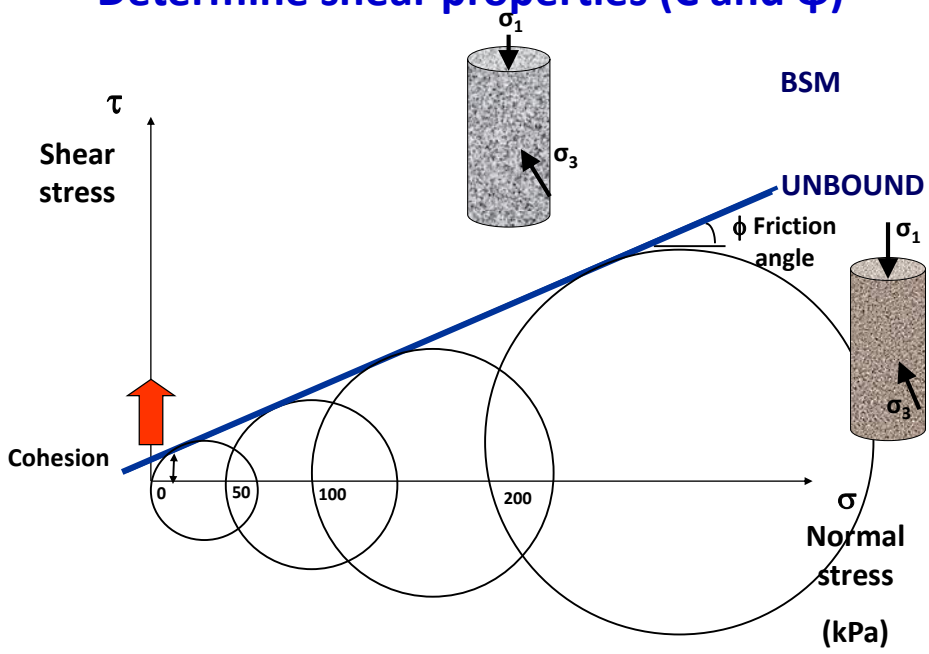
σ_3 =50 kPa and 1% Cement σ_3 = 200 kPa and 0% Cem

Triaxial

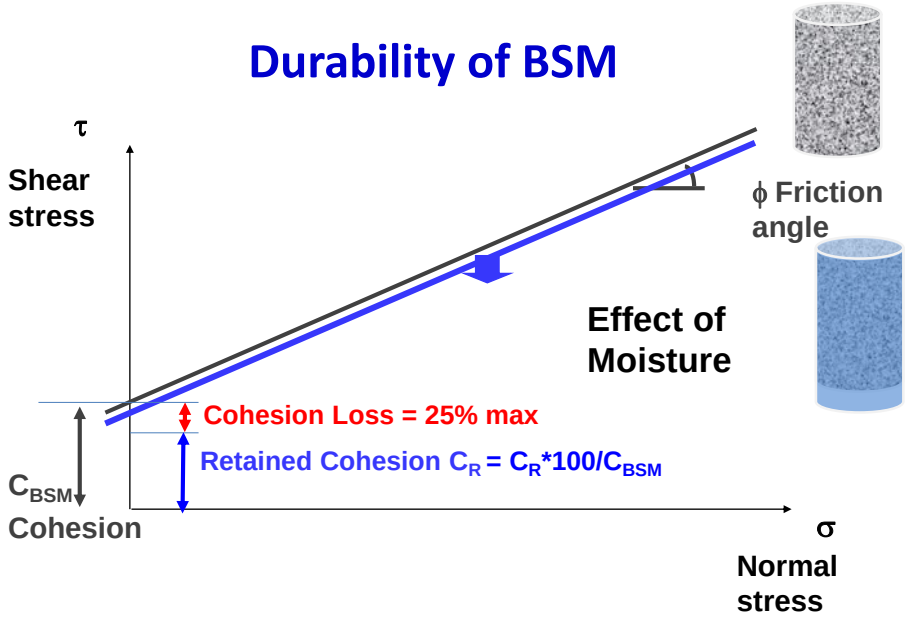


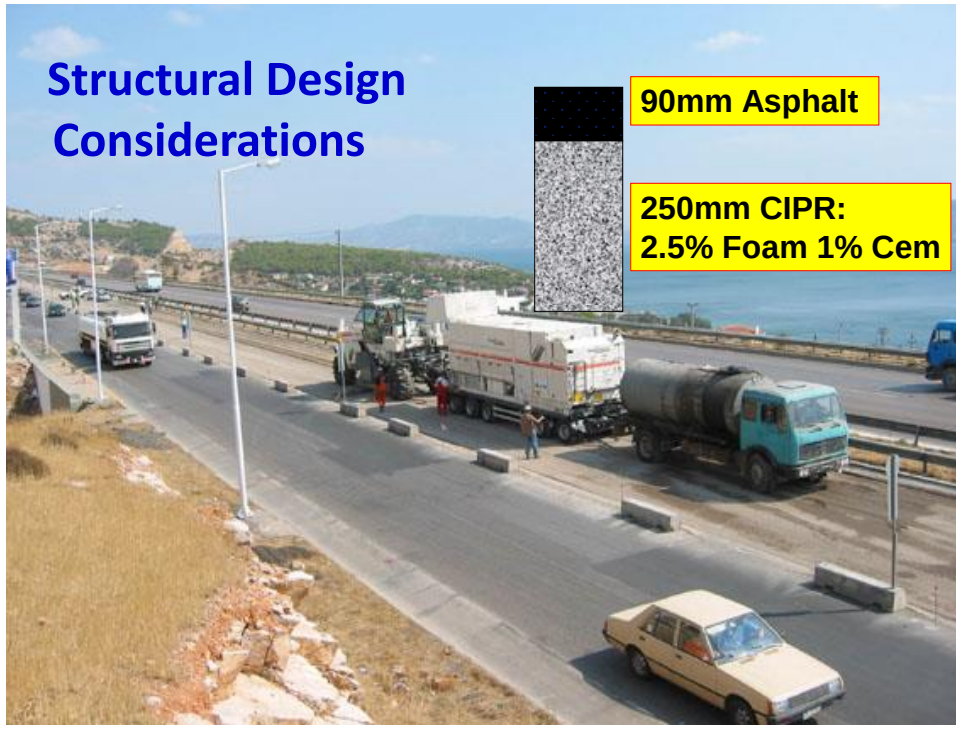
Std Test Method

Determine shear properties (C and ϕ)



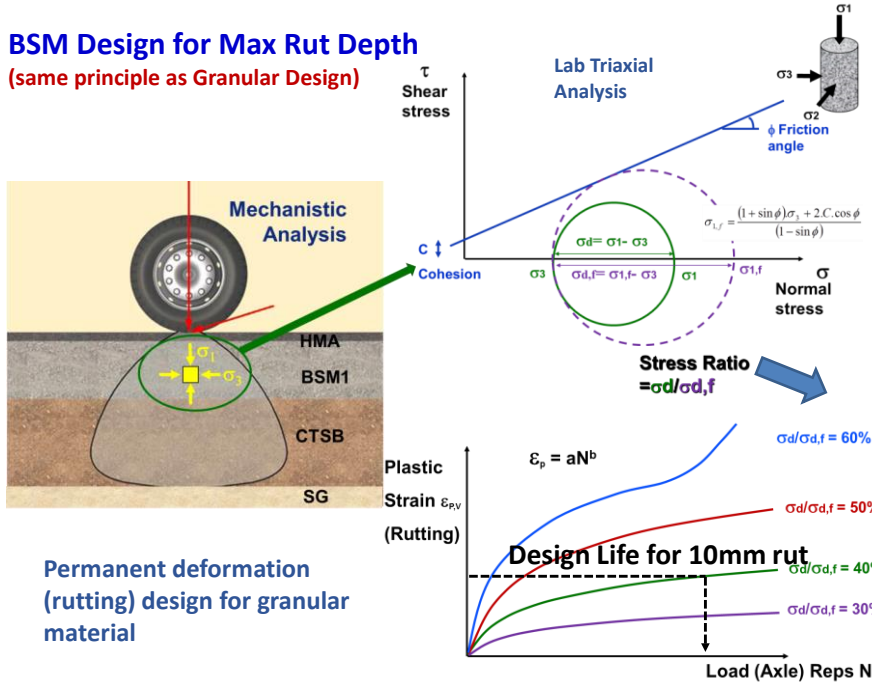
Durability of BSM





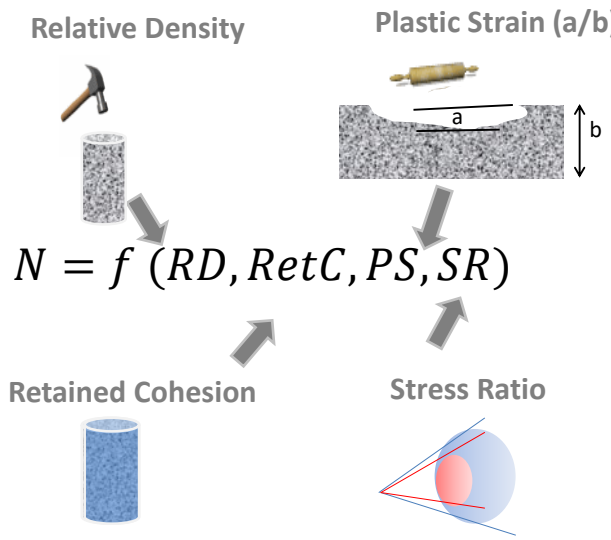
BSM Design for Max Rut Depth

(same principle as Granular Design)

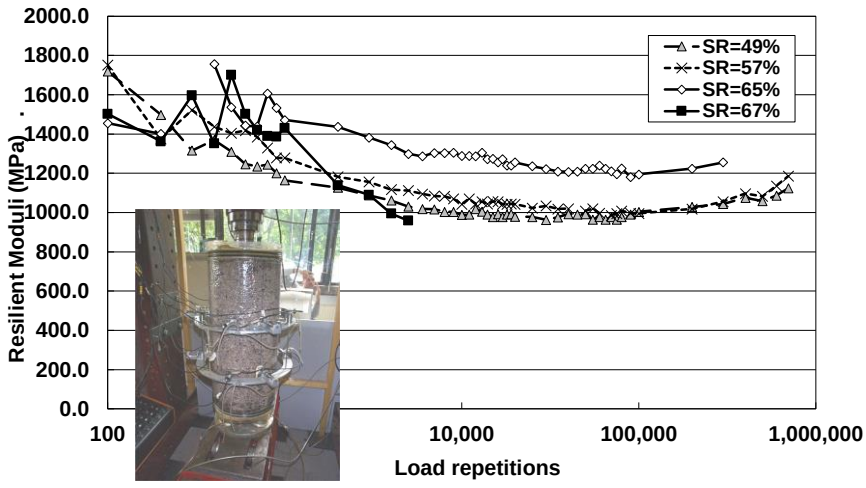


Permanent deformation (rutting) design for granular material

Design Function for BSM



Mr change with trafficking (triaxial)

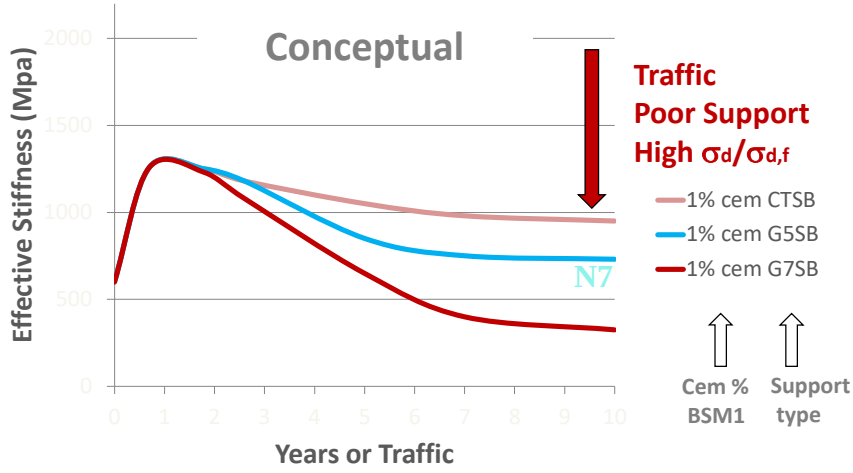


Jenkins et al, IJPE

Jenkins, TU Delft, 1999

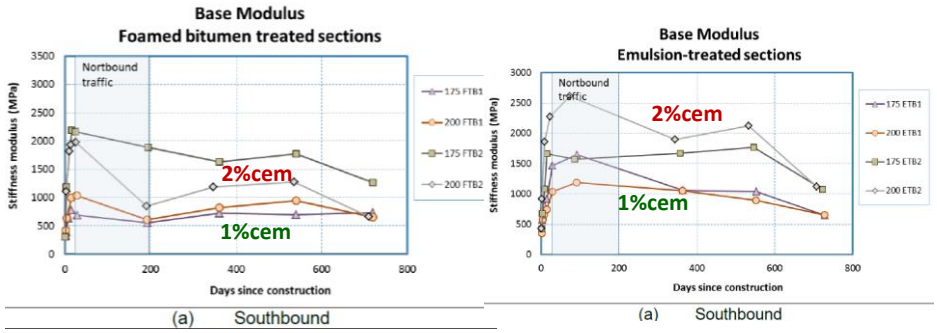
In service behaviour of Mr

Influence of support & traffic



Effective Long Term Mr for BSM base

Mr from FWD back-calcs



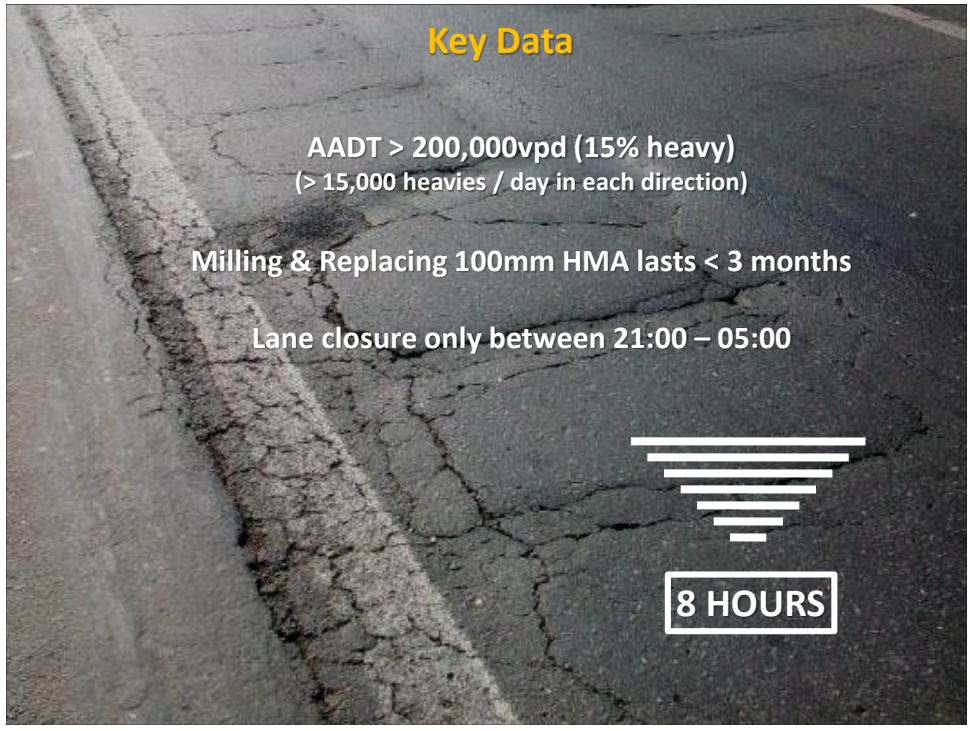
SAPDM - R35 : Theyse, 2015 & Lynch, 2014

Effective Long Term Mr Stiffness (MPa) for BSM base

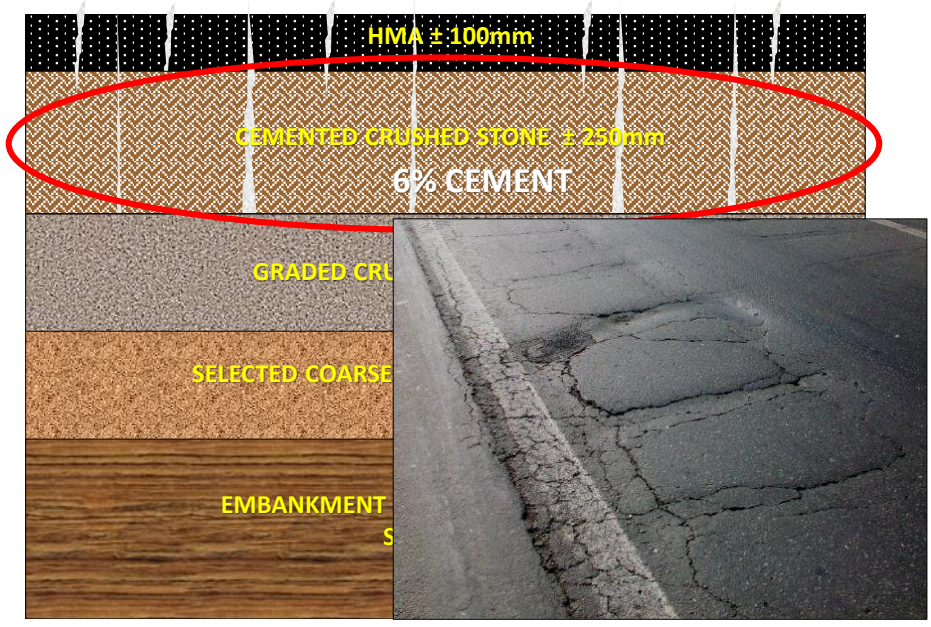
	Supporting Layer	
BSM Class	**Cemented Subbase**	**Granular Subbase**
BSM (RAP + GCS)	**900 – 1750**	**700 – 1200**
BSM (GCS Grade Crushed Stone)	**800 – 1200**	**600 – 900**

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

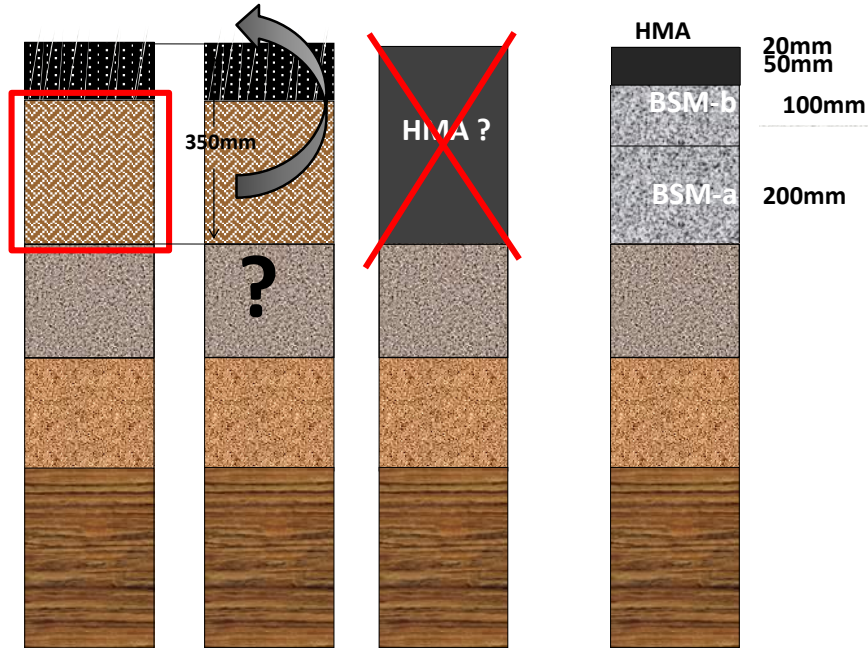
Case Study – Ayrton Senna Highway



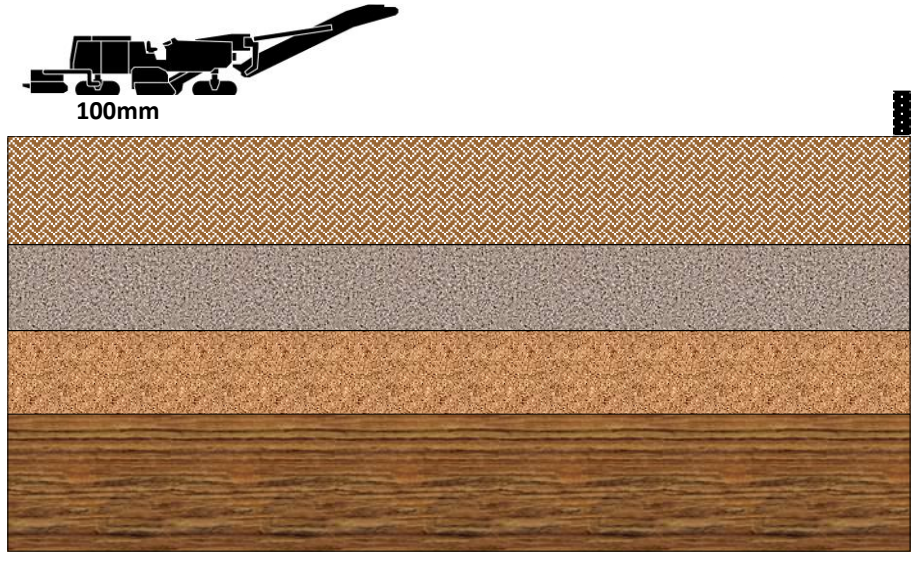
Results from Pavement Investigation



Rehabilitation Options?? (8-hour working window)

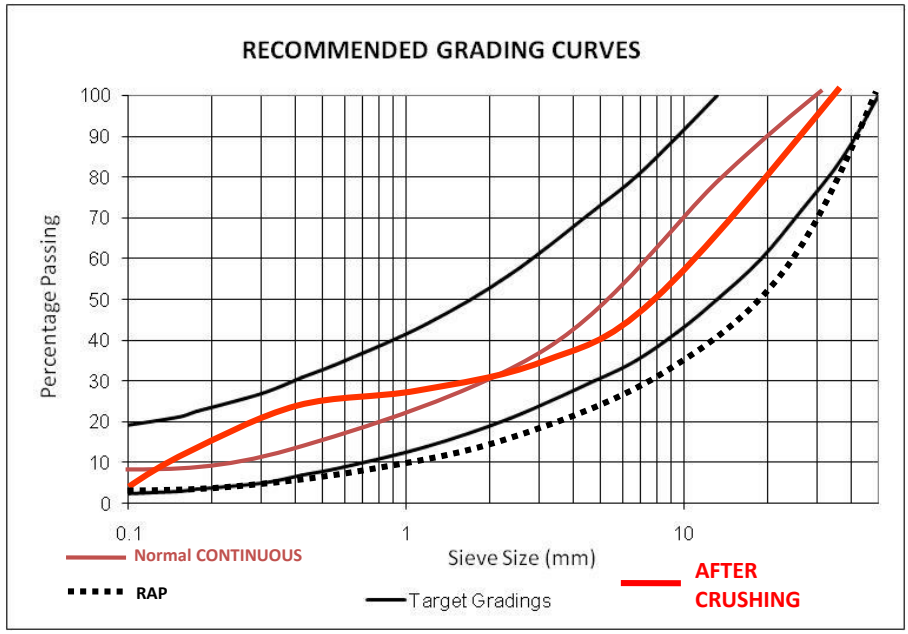


Step 1. Mill off asphalt layers

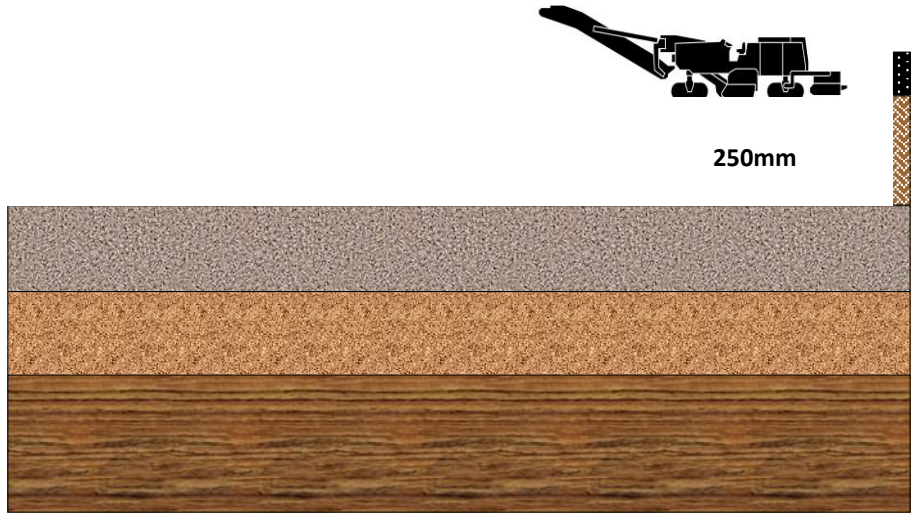


Impact crusher (20mm setting)

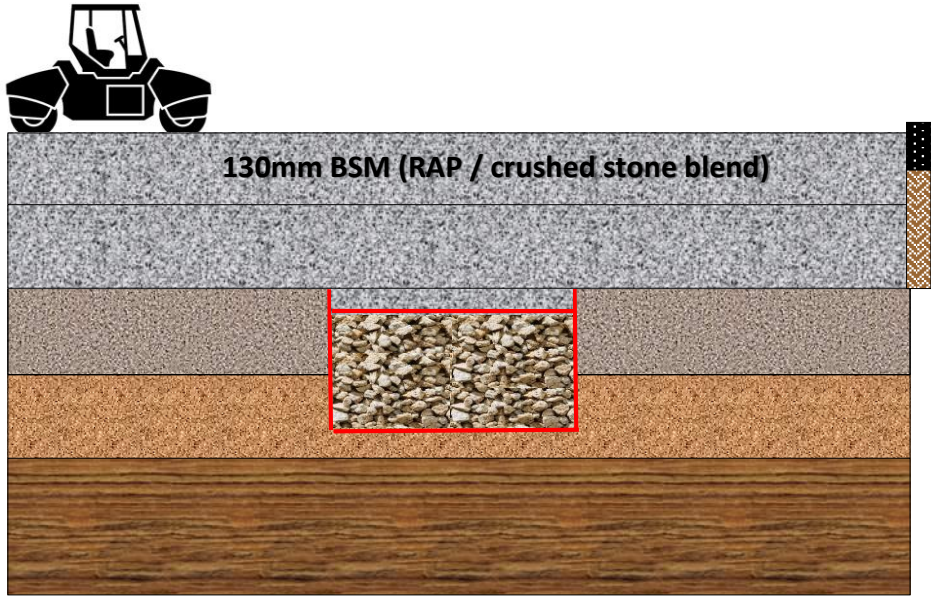
Grading Correction using Single Stage Crushing



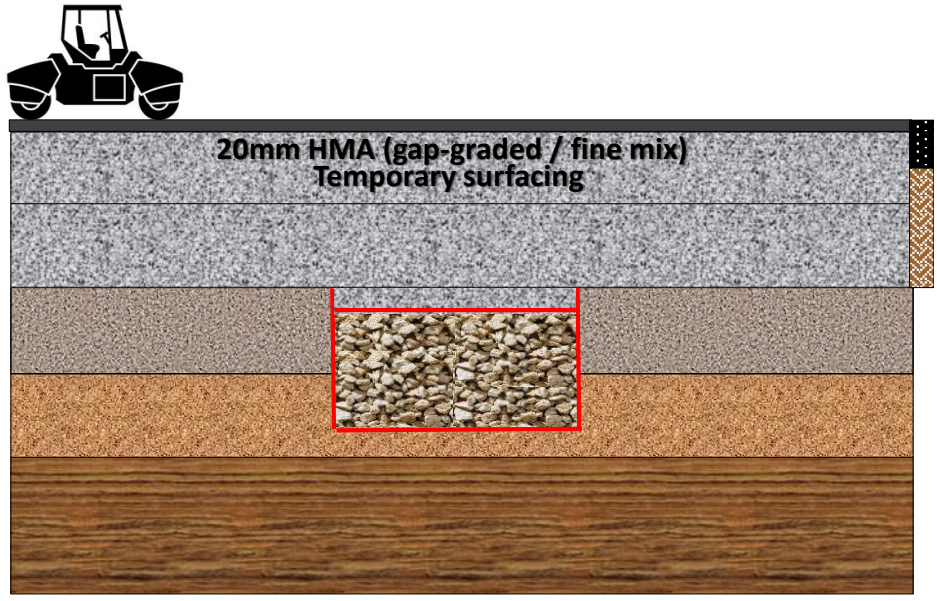
Step 2. Mill and remove CTB layer



Step 5. **Import / pave / compact 130mm BSM layer**



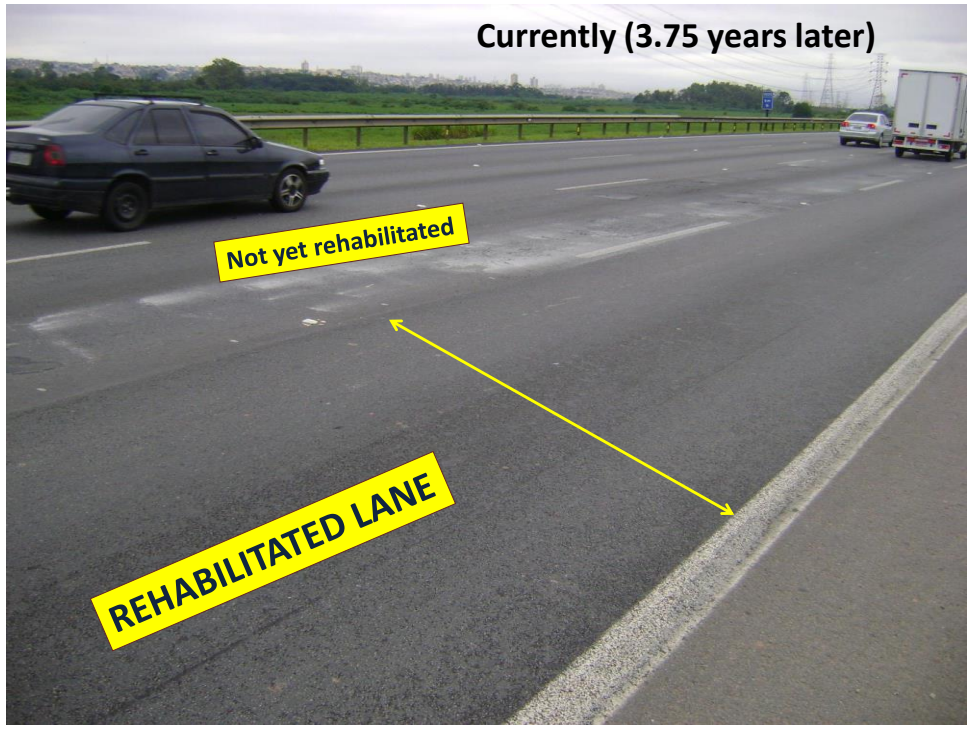
Step 6. Import / pave / compact 20mm HMA




VOGELE
FBS


18th November 2011

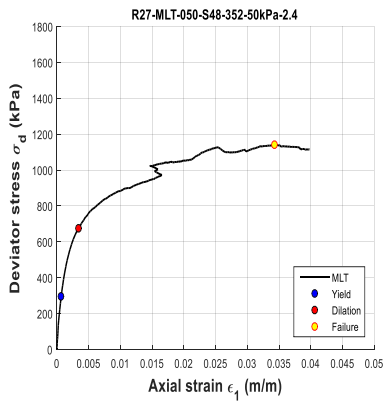

31ST January 2012

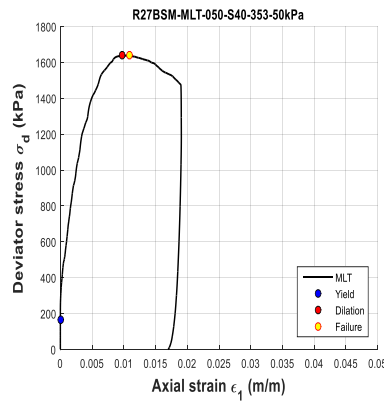

Currently (3.75 years later)
Not yet rehabilitated
REHABILITATED LANE

> 100 lane-km rehabilitated using this method

Way Forward: Research

Monotonic Load Cycle (triaxial)



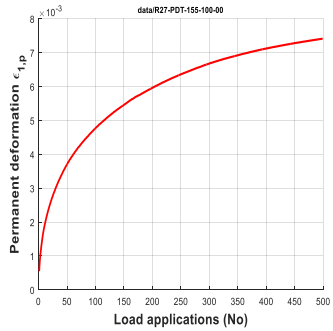


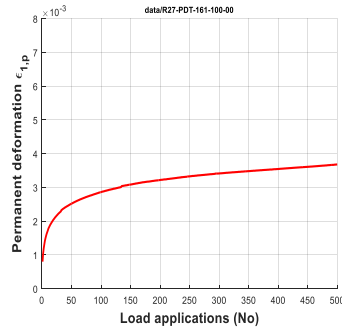
GCS **BSM**

(Bredenhann & Jenkins, 2016)

Way Forward: Research

Dynamic Conditioning (triaxial)



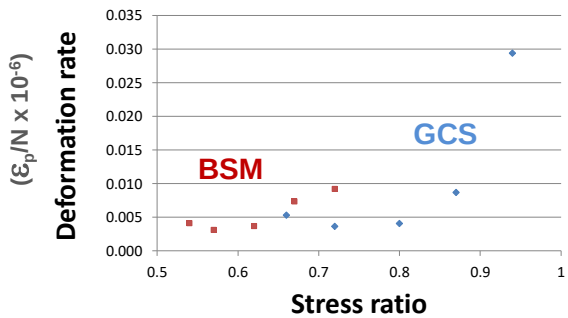


GCS **BSM**

(Bredenhann & Jenkins, 2016)

Way Forward: Research$_{(2)}$

Dynamic Triaxial – Permanent Deformation



(Bredenhann & Jenkins, 2016)

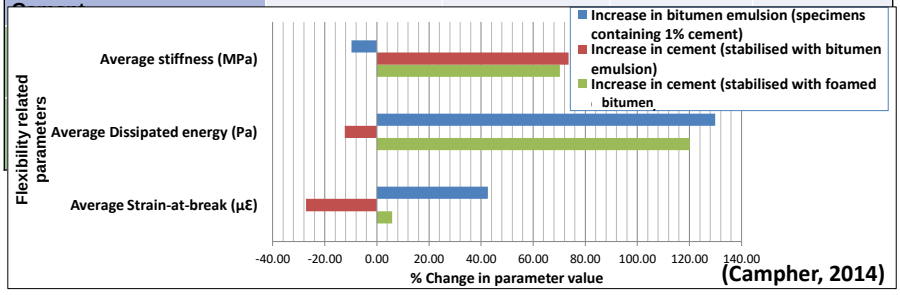
Flexural Strain-at-break

- All beams compacted in a mould
- **Testing temperature: 25°C**
- LVDT on top of the beam to accurately measure displacement in the middle of the beam.

(Campher, 2014)

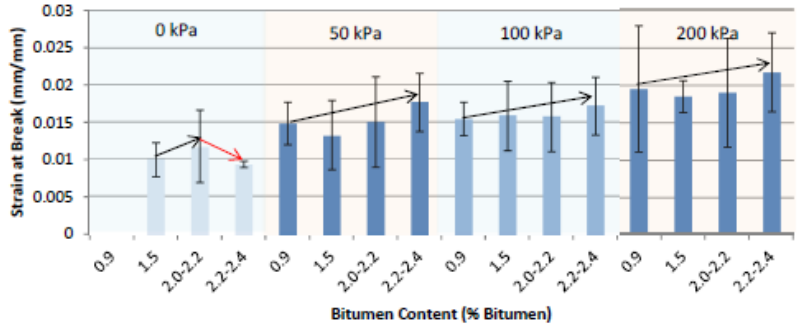
Flexural Strain-at-break & DE

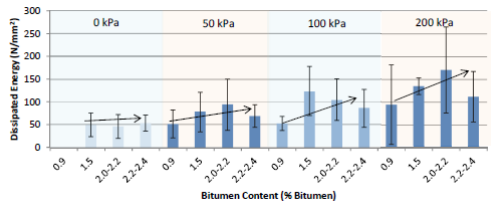
Specimen specification	Material parameter			
	Average Maximum Stress (kPa)	Average Strain-at-break (με)	Average Dissipated energy (Pa)	Average stiffness (MPa)
0.9% Emulsion; 1% Cement	**174.4**	**376.5**	**39.1**	**524.2**
2.4% Emulsion; 1% Cement	**254.9**	**537.2**	**89.8**	**473.1**
2.4% Emulsion; 2%				



(Campher, 2014)

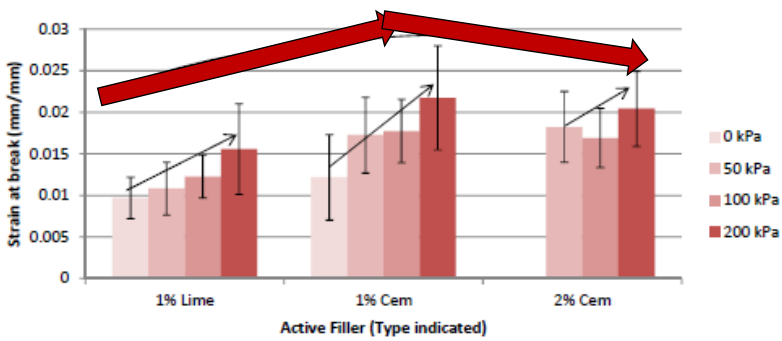
Flexibility (triaxial)

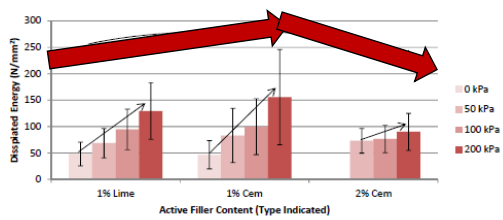




(Llewellyn, 2016)

Flexibility (triaxial)



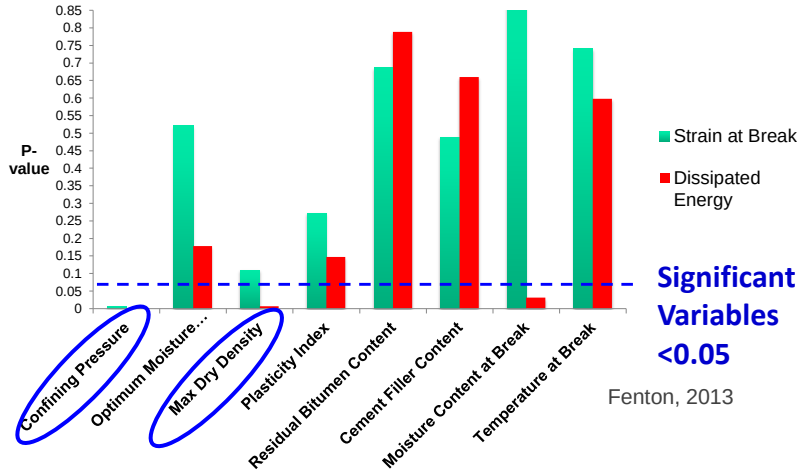


(Llewellyn, 2016)

Factors Influencing BSM Flexibility

Analysis of Variance

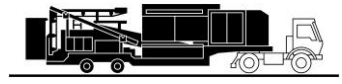
Summary of P values for variables in ANOVA analysis



Fenton, 2013

Conclusions

- **Mix design system in place**
  - Aim for flexibility **not** high strength
  - Update of equipment (vib hammer & triax)
- **Pavement design**
  - New ME design function
  - Link of mix- and pavement-design (C & ϕ)
- **Application (field performance data)**
- **Way forward: flexibility focus**



The sky's the limit!

Thank you!

Stellenbosch

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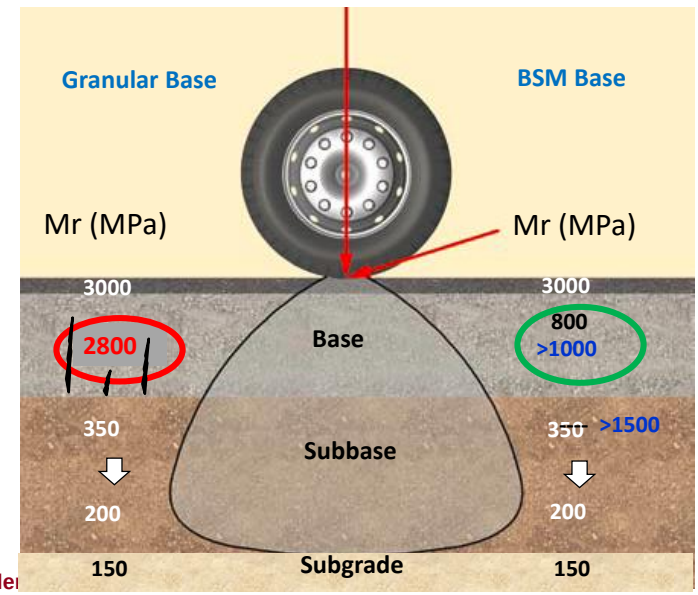
Pavement Balance



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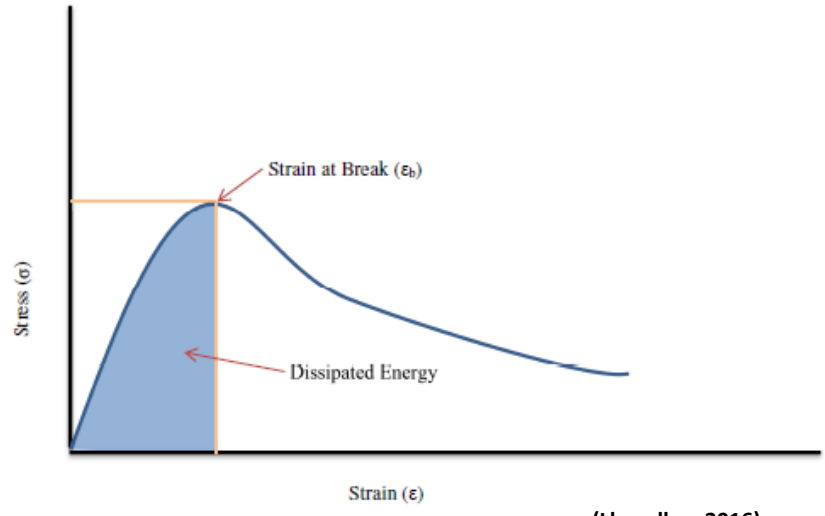
Research on BSM Flexibility

How can we benefit from?



(Llewellyn, 2016)

Strain-at-break vs Fatigue

25%RA & 0%Cem