STABILISATION MIX DESIGNS CEMENT AND BITUMEN BINDERS

RPF Port Elizabeth Kim Jenkins

3 July 2019

Outline – Understanding Stabilisation Mix Designs

1. **Cement Stabilisation**
2. **Bitumen Stabilisation**
    - Material characterisation
    - Blending
    - Compaction
    - Curing
    - ITS tests
    - Triaxial
3. **Conclusions**

Material Stabilisation

STABILISATION

Stabilising agents are used to improve the performance of materials

The pavement structure shown here is not able to spread the load sufficiently

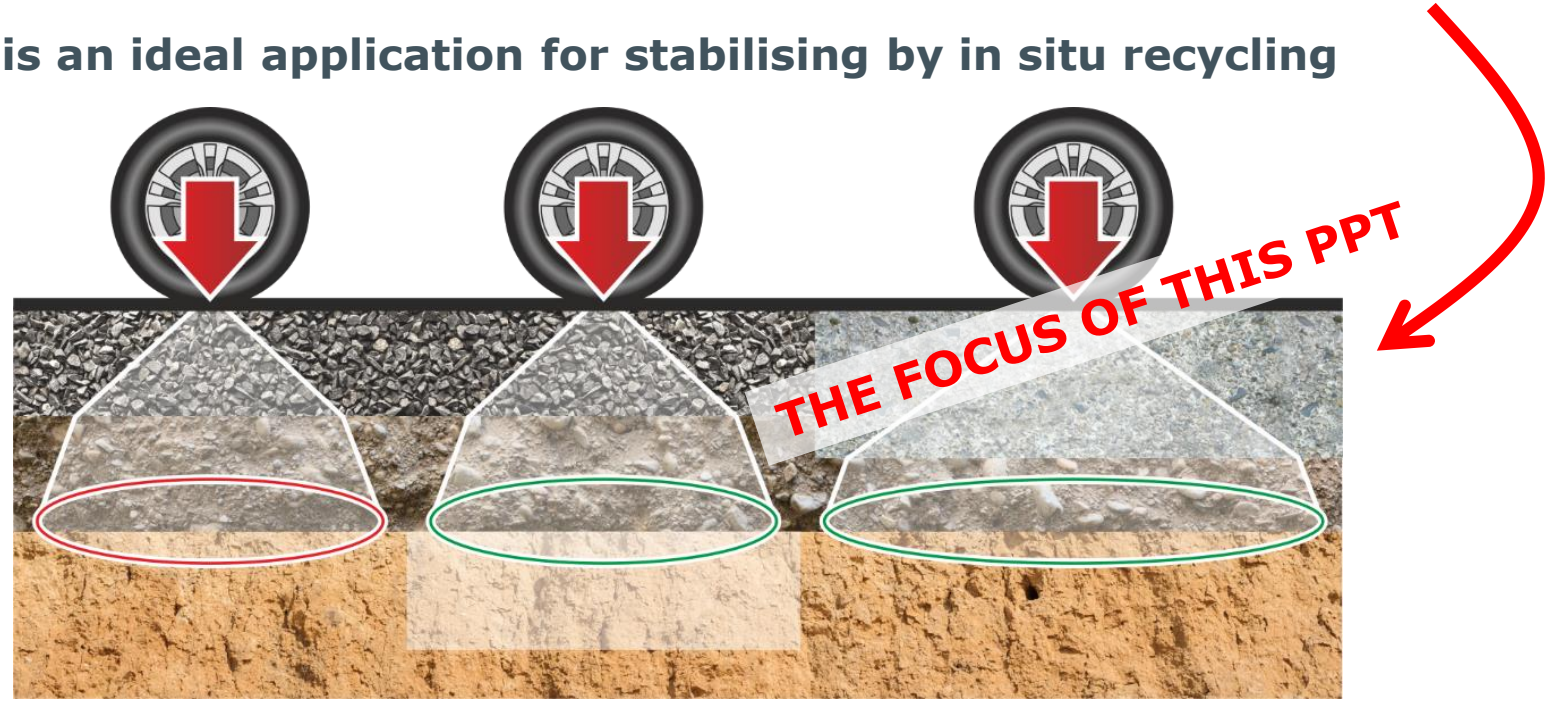
The subgrade is overstressed

How can we use stabilising agents to address this situation ??

Material Stabilisation

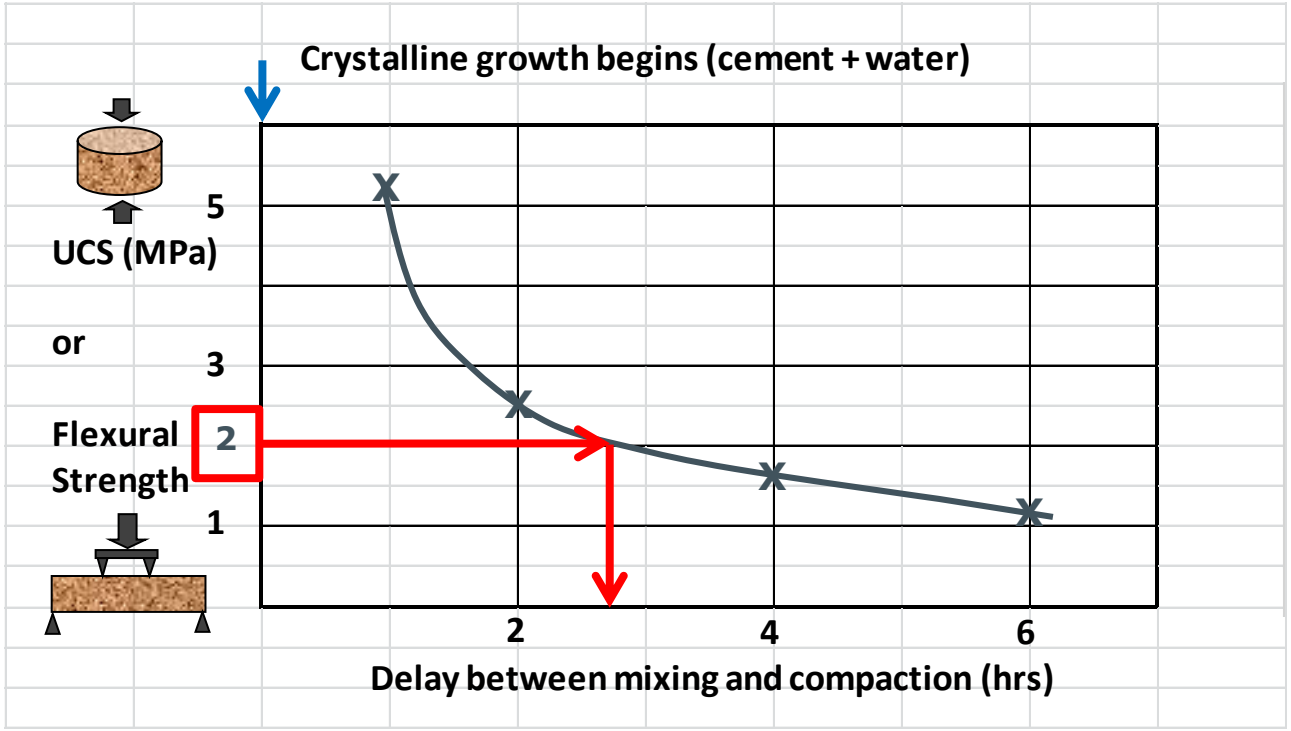
Stabilise (strengthen and stiffen) the upper pavement

This is an ideal application for stabilising by in situ recycling



Stabilisation Mix Designs

Time limitation from mixing to compaction



Stabilisation Mix Designs

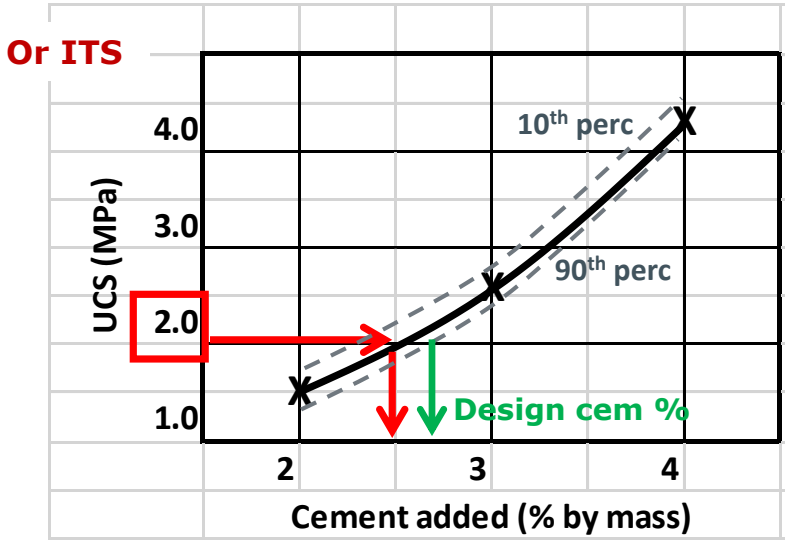
Cement stabilisation mix design (contd.)

The results for strength are then plotted against cement addition

The cement addition that provides the target strength is then read off the graph

Target strength ??

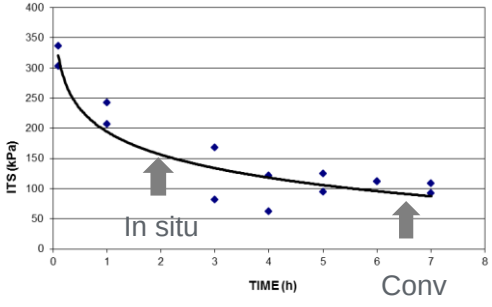
From Project Specifications



Extra cement for variability: 0.5 to 1.0 %
(spreading, field mixing, depth, windrows, testing)

Conventional

Cement

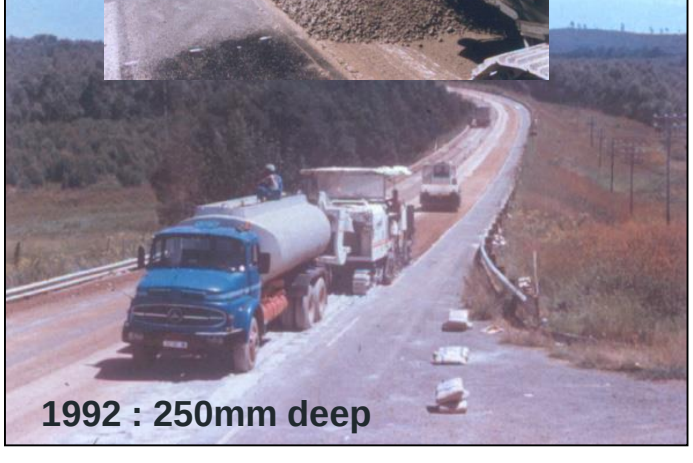


Benefits

- Quality
- Thickness t^3
- Production
- Performance
- Cost

But…shrinkage

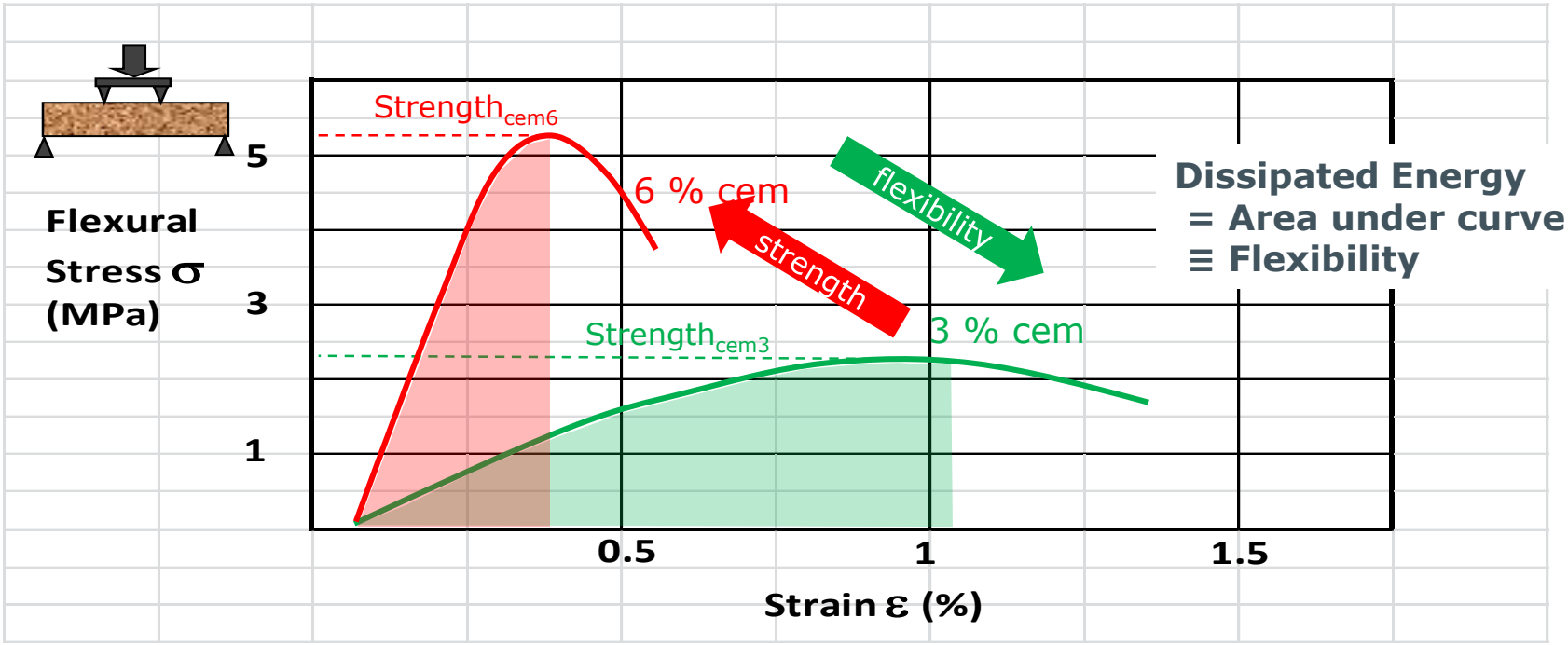
In situ recycling



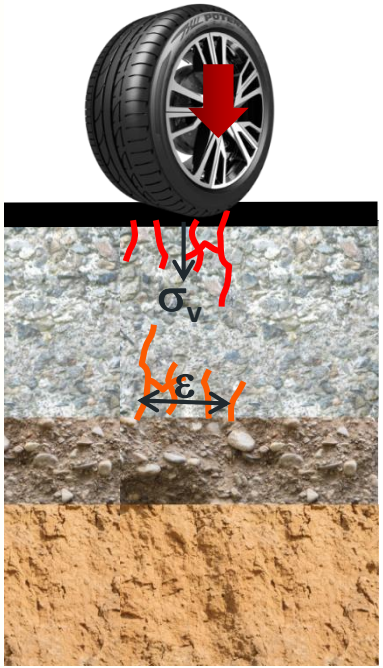
Spreading Cement

Material Damage: Dissipated Energy

Strength, Stiffness & Flexibility Of Cement Stabilised Material



Remember: Failure Mechanisms!!



Asphalt surfacing

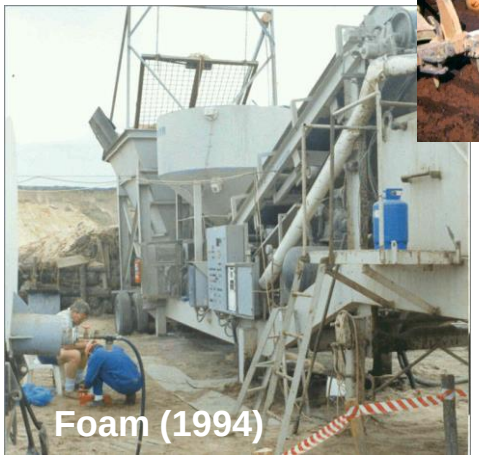
Crushing & Shrinkage

Cement stabilised base

Fatigue Cracking

Bitumen Stabilisation

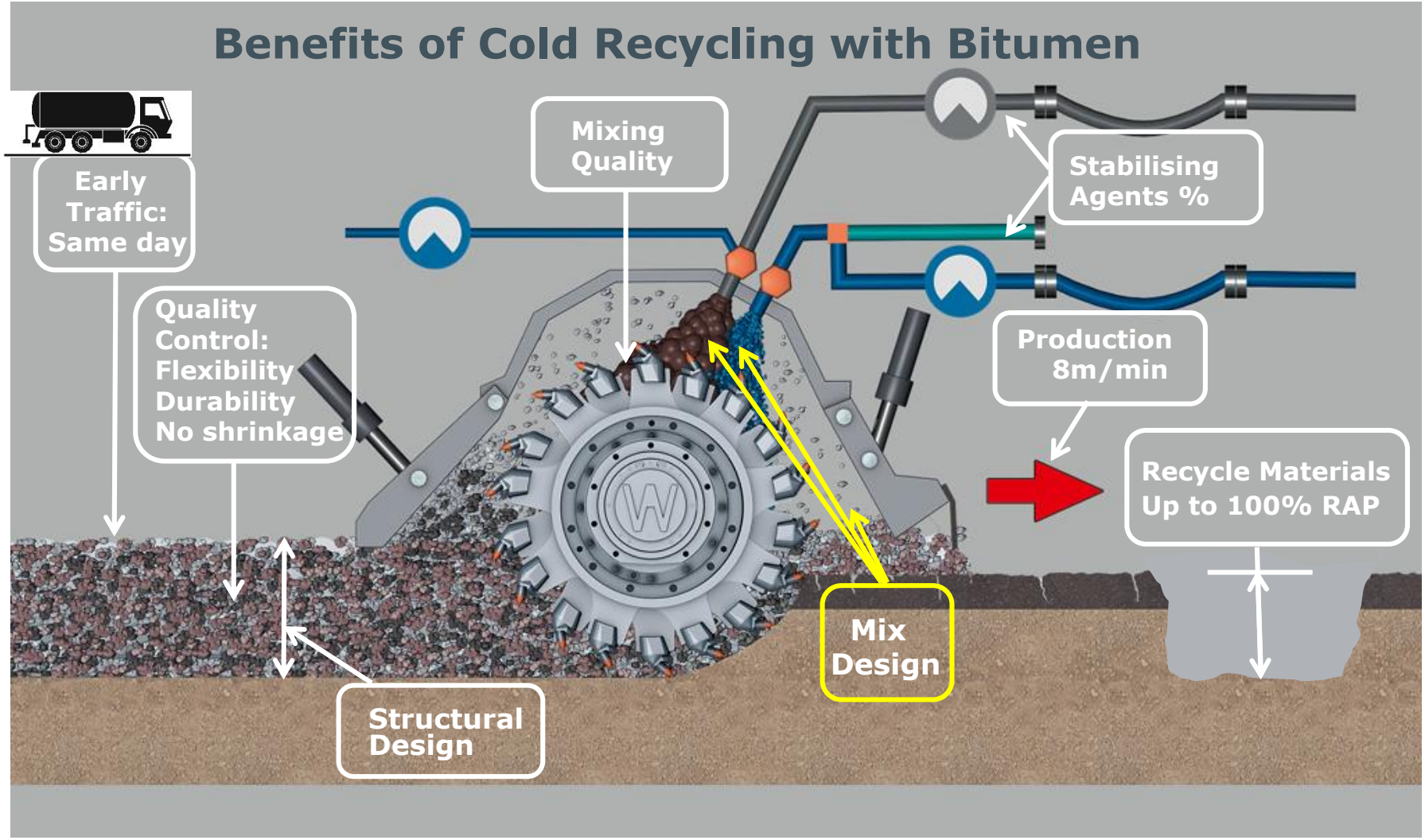
Conventional



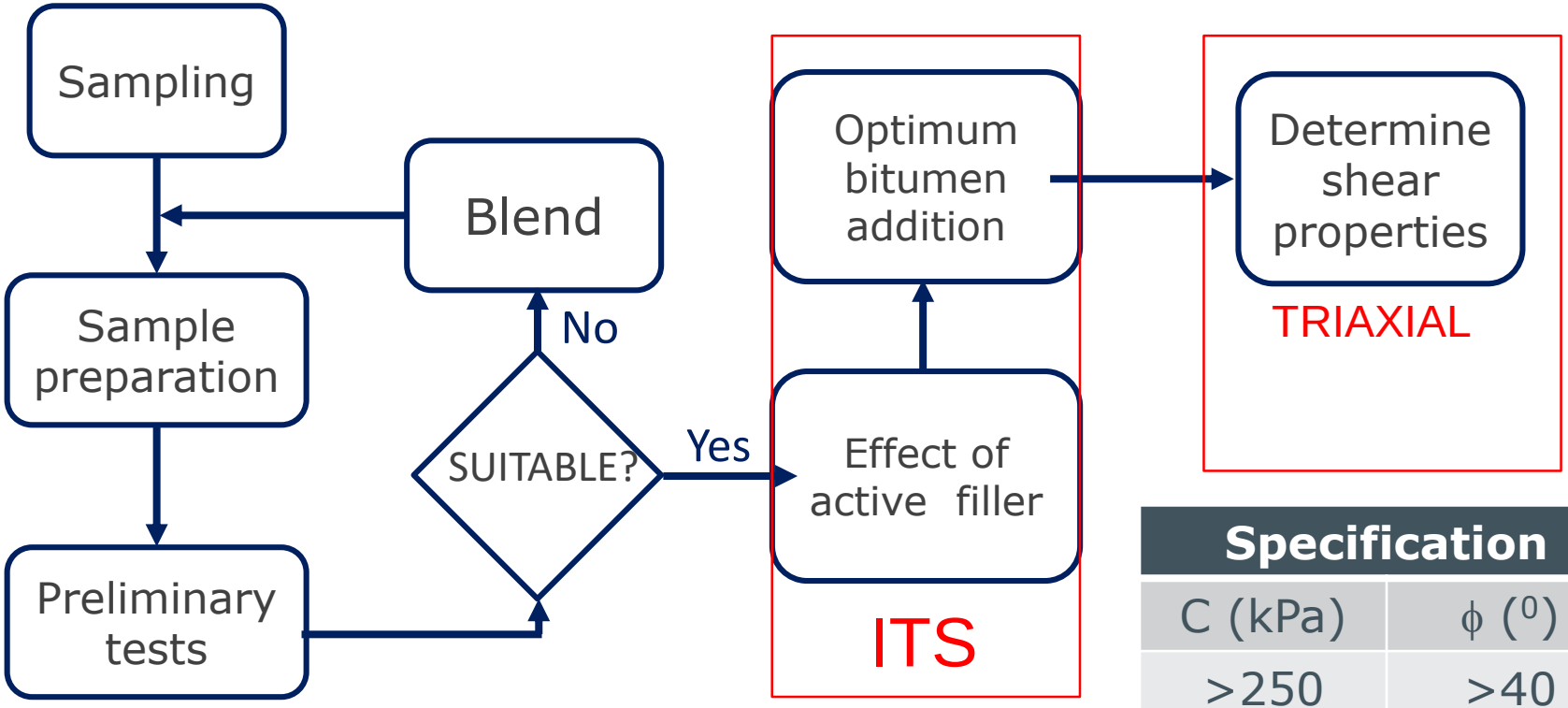
Currently (2019)

In situ recycling

Benefits of Cold Recycling with Bitumen



Mix Design Flowchart

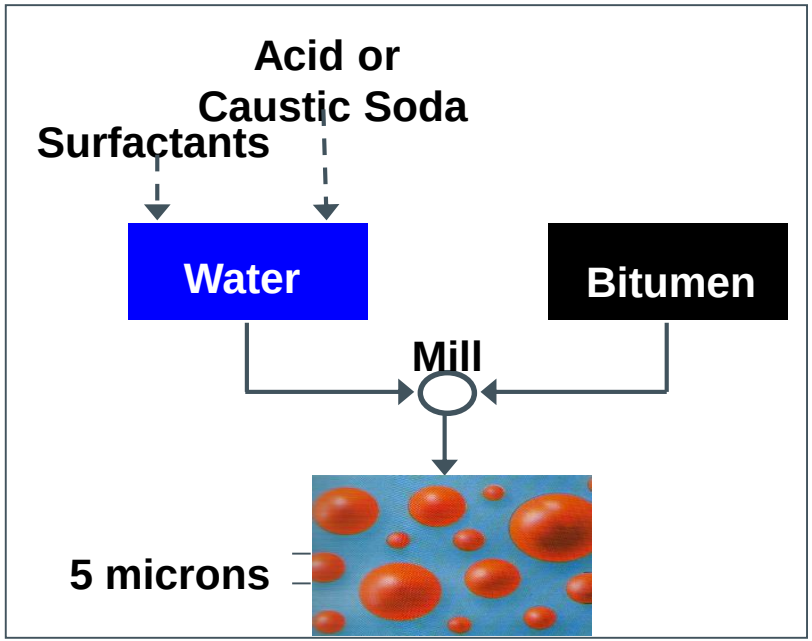


Specification	
C (kPa)	ϕ (^{0})
>250	>40

Bitumen Stabilisation Agents

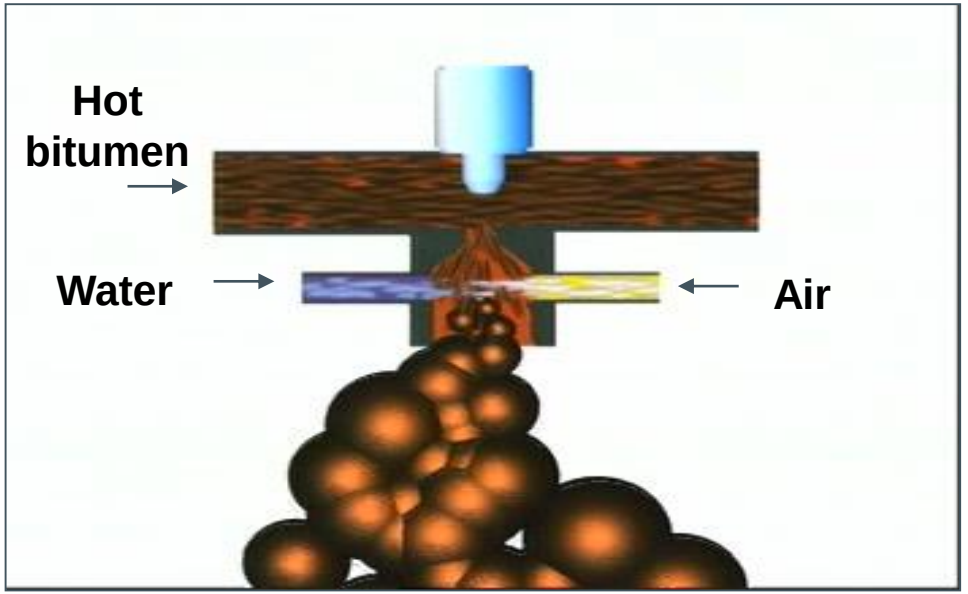
BITUMEN EMULSION

Colloidal Mill



FOAMED BITUMEN

Expansion chamber



Standardised Mixing Method

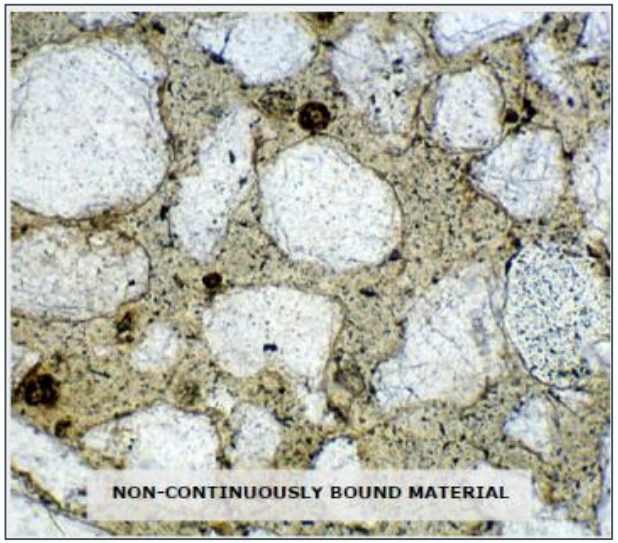
How do these stabilising agents work ?

Bitumen viscosity is reduced, allowing bitumen emulsion and foamed bitumen to be mixed with cold moist aggregate

Millions of independent black dots (bitumen "splinters") dispersed amongst the white (sand) particles

In compaction, tiny bitumen splinters stick to aggregate particles to produce a "**non-continuously bound**" material

White beach sand + foamed bitumen



Lab Compaction: Vibratory Hammer

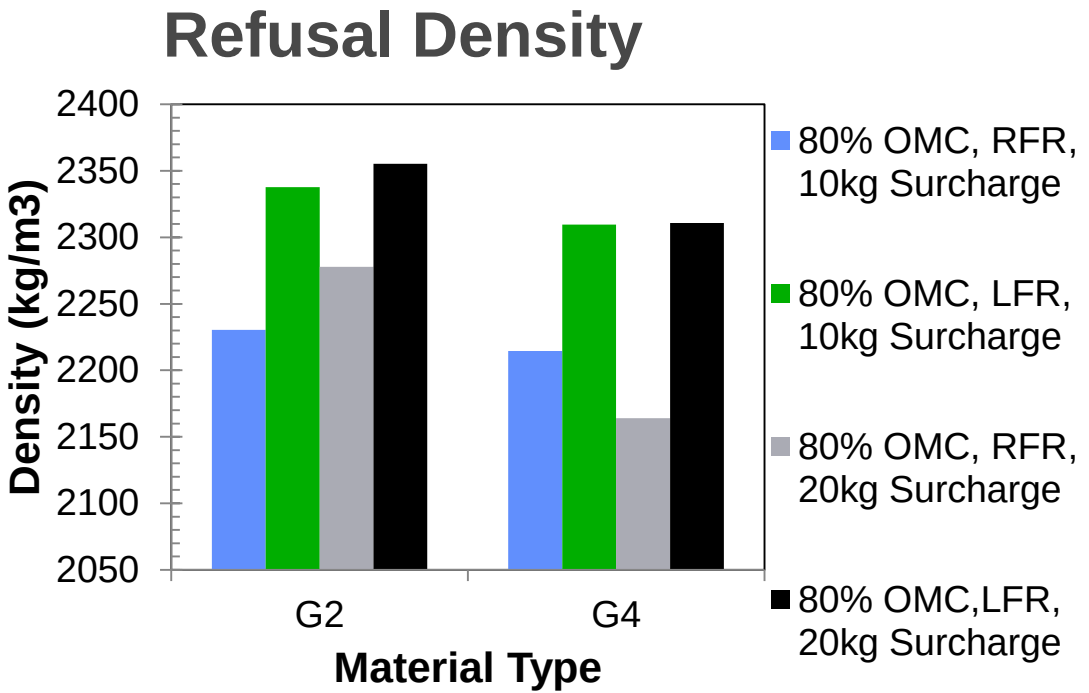
Vibratory hammer	Power rating (W)	Frequency (Hz)	Mass (Kg)	Point Energy (J)	
Kango 637®	750	45.83	7.5	27	★
Bosch GSH 11E®	1500	15 - 31.5	10.1	16.8	★
Bosch GSH 11VC®	1700	15 - 30	11.4	23	

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

Influence of Compactor Frame


Rigid Frame


Loose Frame

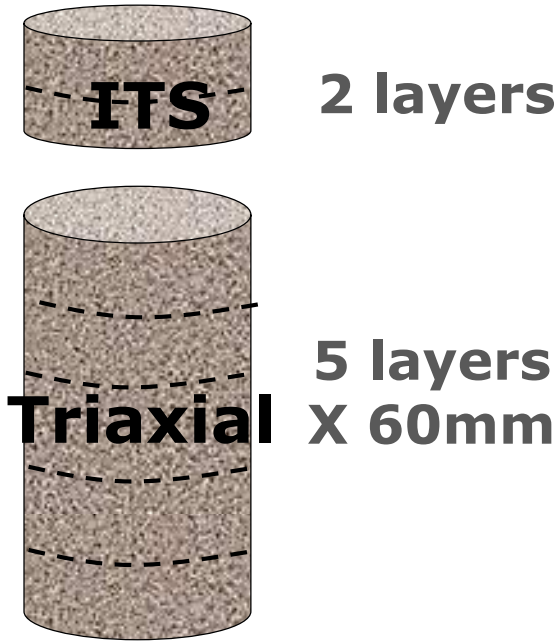


FRAME TYPE
Rigid
Loose
Rigid
Loose

Comparison of refusal density for G2 and G4 material

Industry Standard for Compaction

Inter-Layer Roughening (ILR) Device

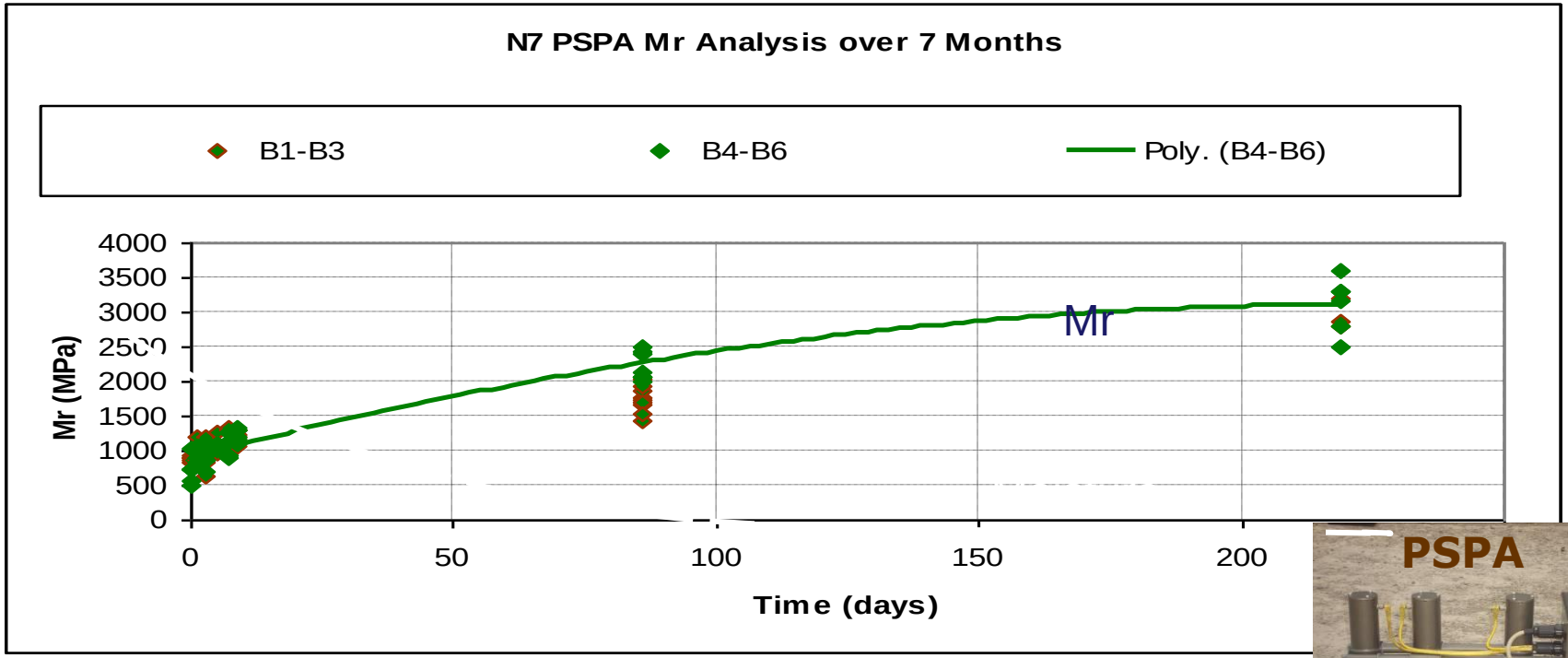


Inventor: Wynand van Niekerk

Curing of BSM material

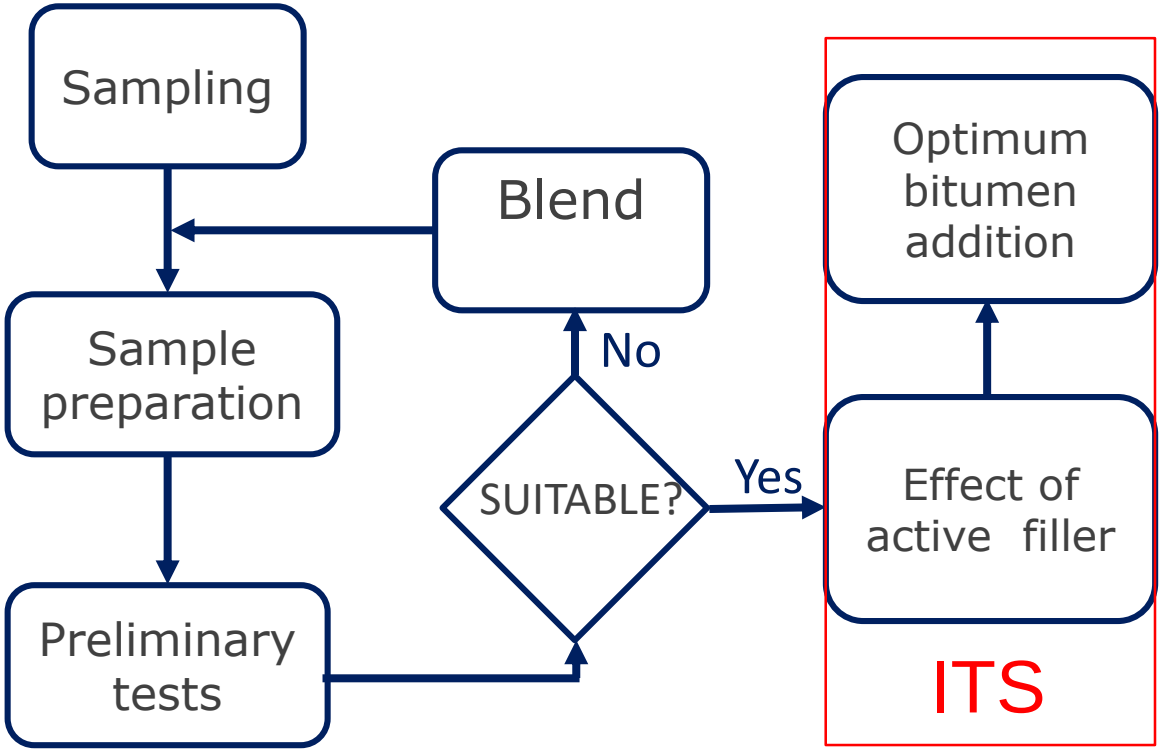
Why is curing important?

Mr (field) versus lab cure



BSM Stabilisation Mix Design Procedure

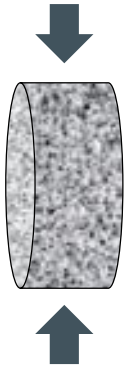
Phase 1: Material Selection + Binders (ITS)



Specification	
ITS_{dry} (kPa)	ITS_{wet} (kPa)
>225	>125

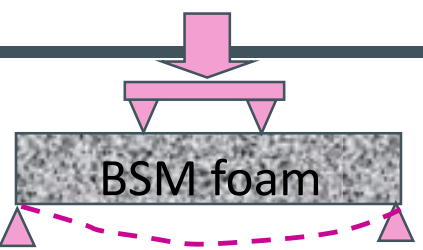
Active Filler Selection

Bitumen addition	(%)	**2.2**	**2.2**	**2.2**
Type / amount of active filler	(%)	1% Lime	None	1% Cement
Moulding moisture content	(%)	8.5	8.4	8.5
TEST RESULTS				
ITS_{DRY}	(kPa)	**267**	**243**	**259**
Moisture content at break	(%)	2.5	2.4	2.5
Dry density	(kg/m^3)	2248	2257	2248
Temperature at break	(°C)	24.9	25.1	24.9
Displacement	(mm)	2.3	2.1	1.7
ITS_{WET}	(kPa)	**184**	**58**	**126**
Moisture content at break	(%)	6.1	6.3	6.1
Dry density	(kg/m^3)	2247	2254	2247
Temperature at break	(°C)	25.0	24.9	25.0
Displacement	(mm)	3.1	2.8	2.3



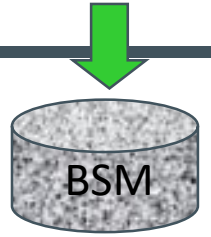
Select bitumen addition range

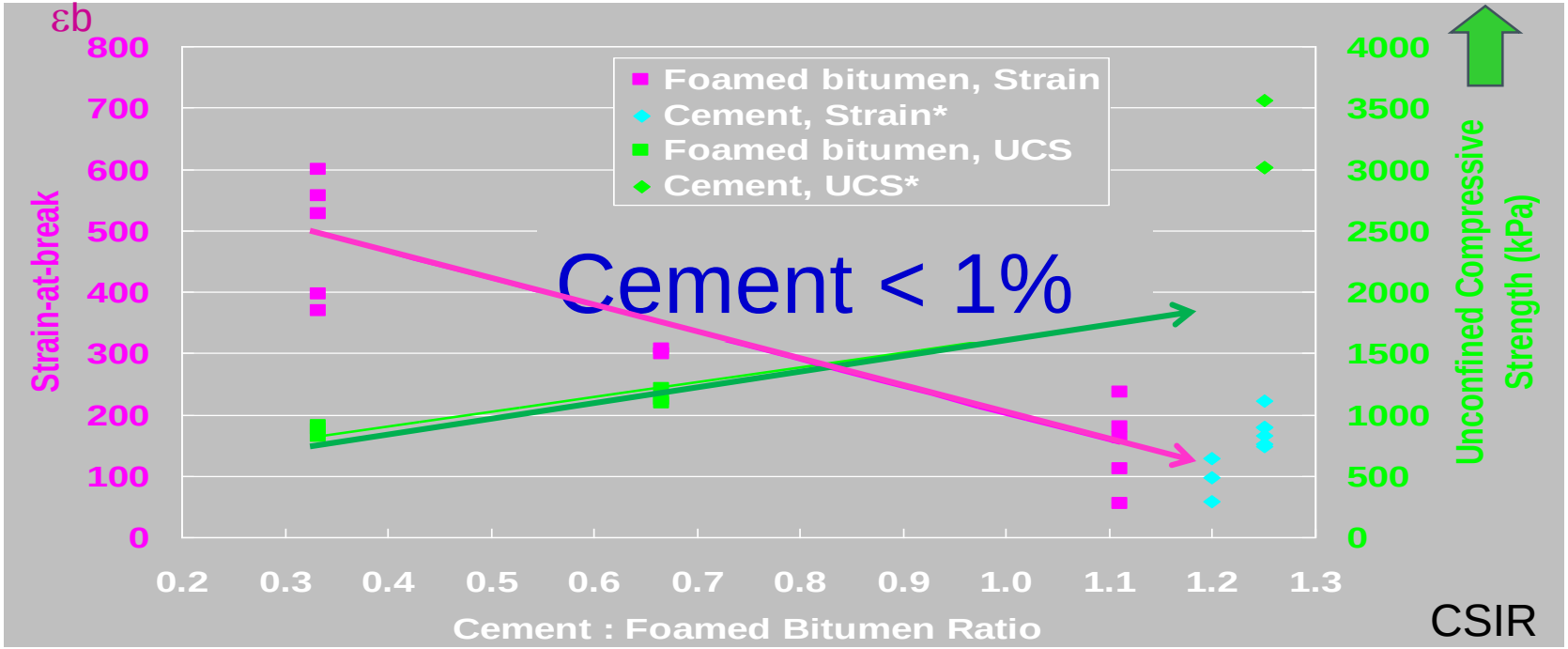
Guidelines for estimating Optimum Bitumen Addition			
Fraction < 0.075mm (%)	Bitumen addition (% by mass of dry aggregate)		Typical material
	Fraction < 4.75mm		
	< 50%	>50%	
< 4	**1.8**	**2.0**	Recycled asphalt (RA)
4 – 7	**2.2**	**2.4**	RA / Graded crushed stone / Natural gravel / blends
7 – 10	**2.4**	**2.6**	
> 10	**2.6**	**3.0**	Gravels / sands



Influence of Active Filler

Strength versus Flexibility





Stabilisation Mix Designs

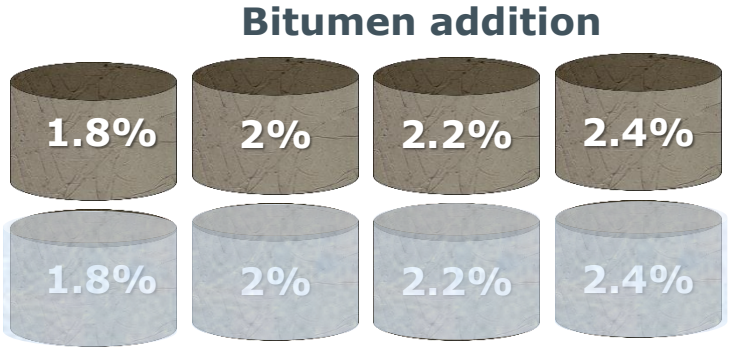
How much bitumen should be added for effective stabilisation ?

i.e. a "Mix Design"

Test specimens with varying bitumen quantities

Specimens "cured" for 3 days (moisture loss)

Soak half the specimens in water for 24 hours



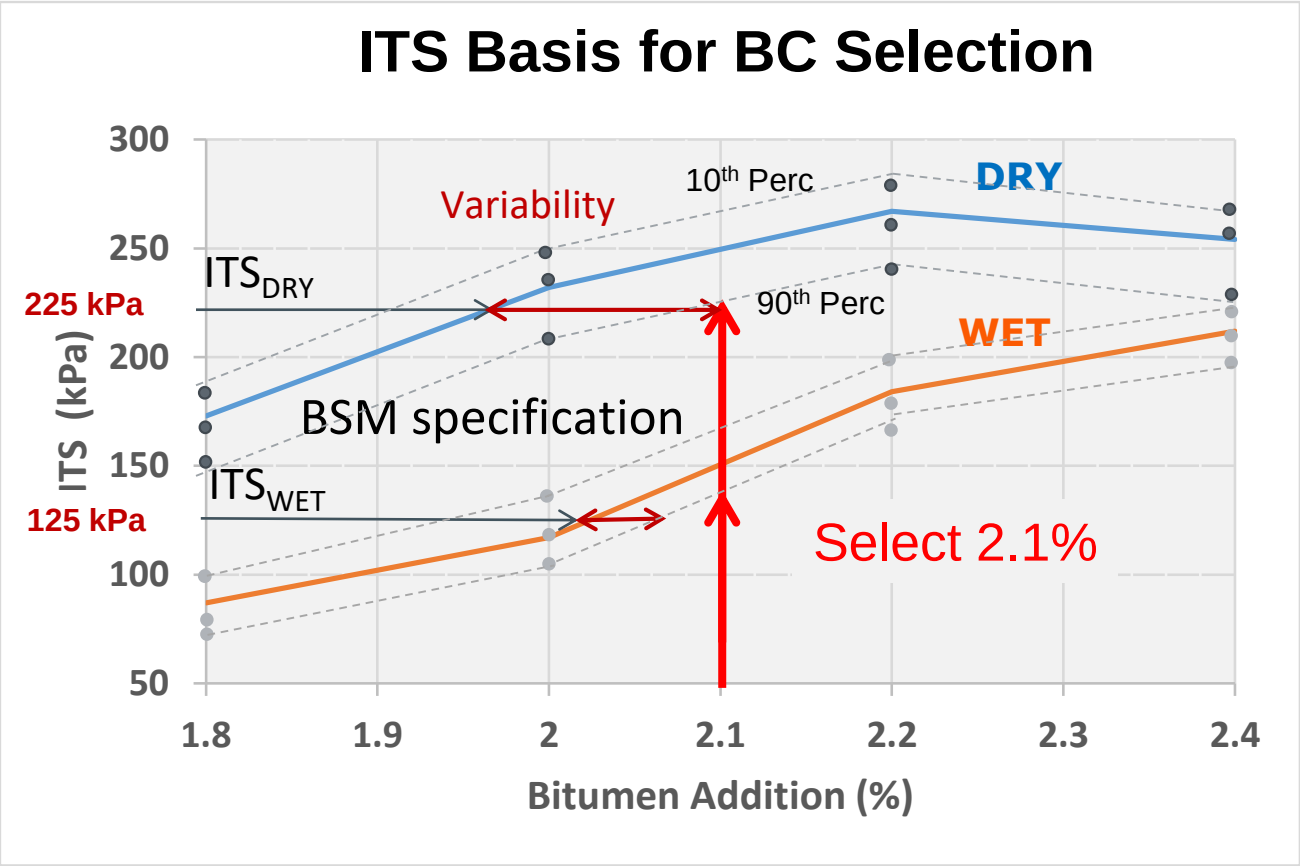
Indirect Tensile Strength (ITS)

Bitumen Content Selection

Bitumen addition	(%)	**1.8**	**2**	**2.2**	**2.4**
Type / amount of active filler	(%)	1% Lime	1% Lime	1% Lime	1% Lime
Moulding moisture content	(%)	8.6	8.4	8.5	8.6
TEST RESULTS					
ITS_{DRY}	(kPa)	**173**	**232**	**267**	**254**
Moisture content at break	(%)	2.6	2.4	2.5	2.4
Dry density	(kg/m^3)	2255	2257	2248	2239
Temperature at break	(°C)	24.9	25.1	24.9	25.0
Displacement	(mm)	2.1	2.1	2.3	2.7
ITS_{WET}	(kPa)	**87**	**117**	**184**	**212**
Moisture content at break	(%)	6.3	6.3	6.1	6.0
Dry density	(kg/m^3)	2256	2254	2247	2241
Temperature at break	(°C)	24.9	24.9	25.0	24.9
Displacement	(mm)	2.9	2.8	3.1	2.9

Plot it!!!

Optimisation of Bitumen Application Rate



Mix Design Flowchart

Sampling

Sample preparation

Preliminary tests

Blend

No

SUITABLE?

Yes

Effect of active filler

Optimum bitumen addition

ITS

Determine shear properties

TRIAXIAL

Specification	
C (kPa)	ϕ (^{0})
>250	>40

New Triaxial

Test at 25°C

Apply Load (stress σ_1)

Confining Pressure σ_3 (inflate tube)

Curing Triaxial Specimens

Curing of BSM

40°C curing temperature

Triaxial specimens – 24 hrs in mould+ 8hrs @ 40^0C + seal and 48 hrs @ 40^0C (equilibrium m/c)

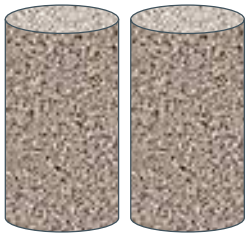
Soaking: 24 hours submerged

Specimen Preparation for Triaxial Testing of Shear Properties

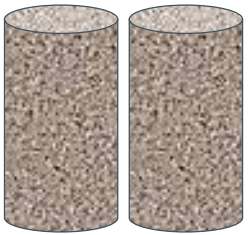
Develop Tools

Specimen Pairs
Tested at 4 different confining pressures

0kPa



50kPa



100kPa

200kPa

Example			
Spec	X_0	T_0	Outlier?
X_{O1}	2407	0.65	No
X_{O2}	2449	2.19	Yes
X_{O3}	2419	0.16	No
X_{O4}	2434	1.18	No
X_{O5}	2404	0.99	No
X_{O6}	2418	0.09	No
X_{O7}	2412	0.31	No
X_{O8}	2407	0.65	No
X_{O9}	2403	0.92	No
X_{O10}	2415	0.11	No
X_n	2416		
S_n	14.78		

Outlier Test for Density

Soaked

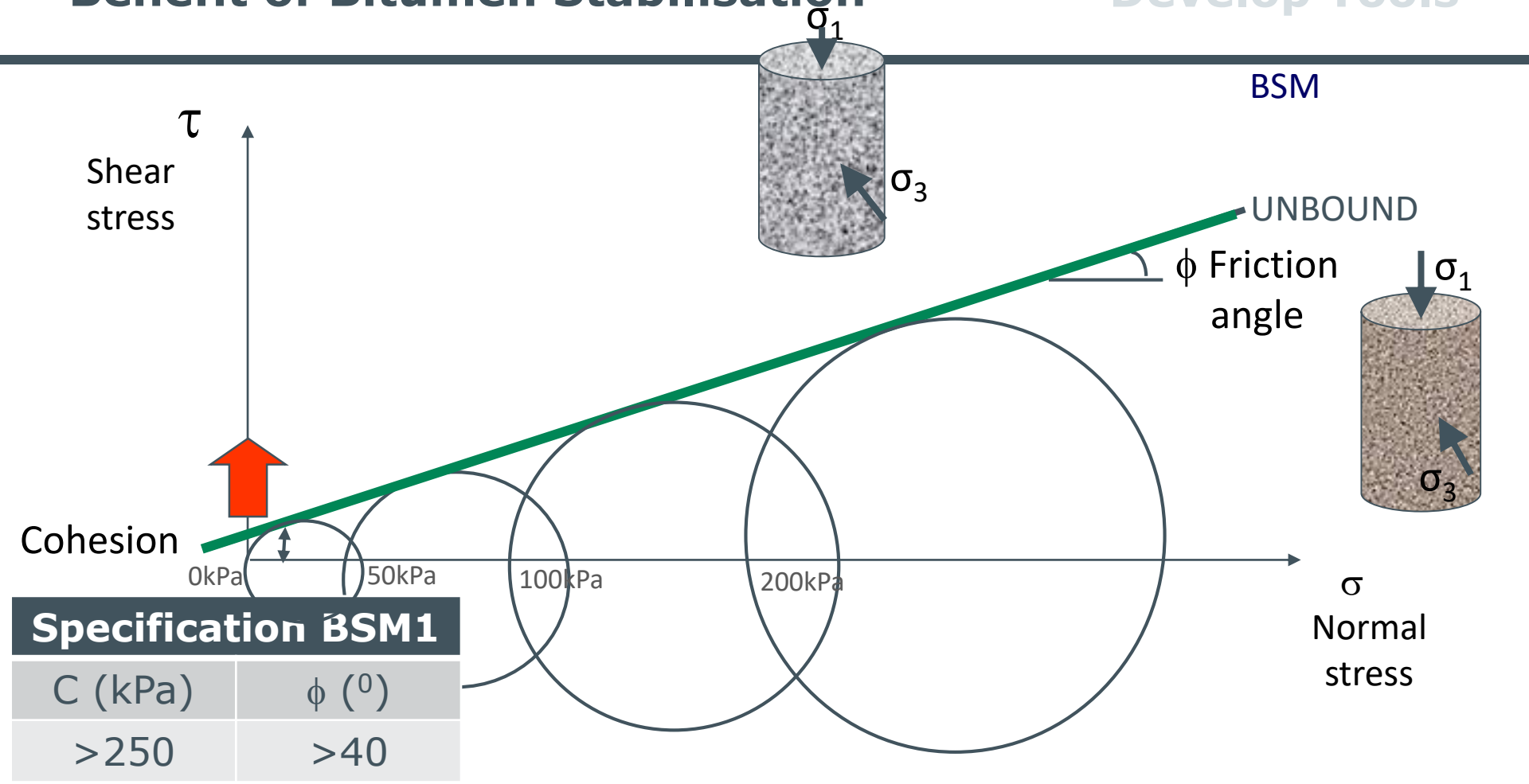
100kPa

Triaxial Cell & Membrane

Test at 25^0C

Confining Pressure
0 kPa 50 kPa
100 kPa 200kPa

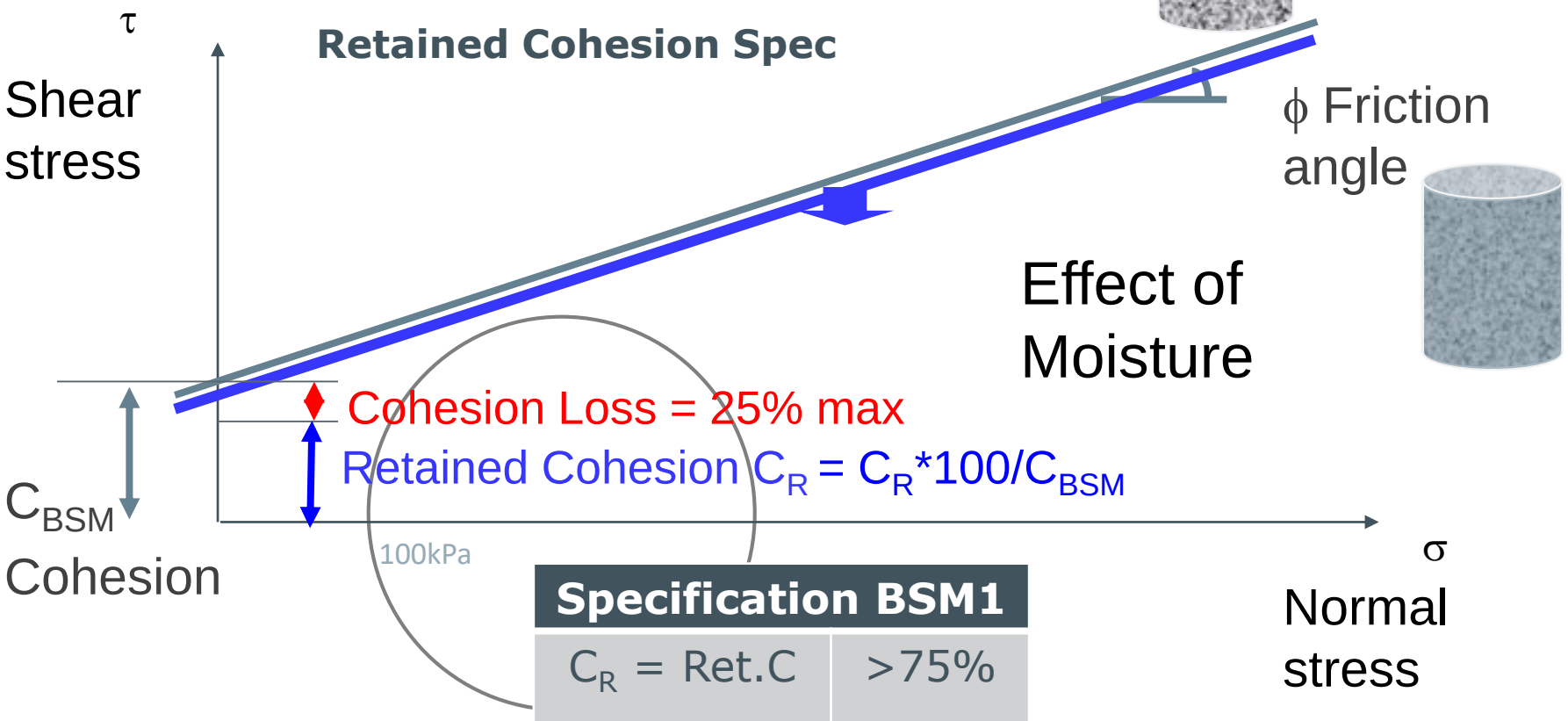
Benefit of Bitumen Stabilisation



Specification BSM1	
C (kPa)	ϕ (⁰)
>250	>40

Triaxial Analysis of Moisture Damage

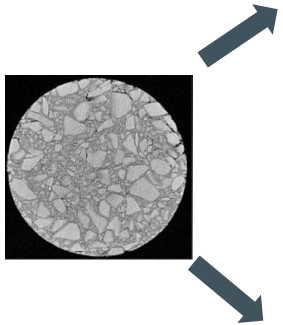
Develop Tools

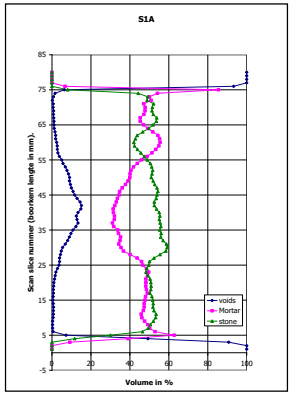


Specification BSM1	
C_R = Ret.C	>75%

Spin-offs from Vibratory Hammer Compaction and Triaxial Testing$_1$

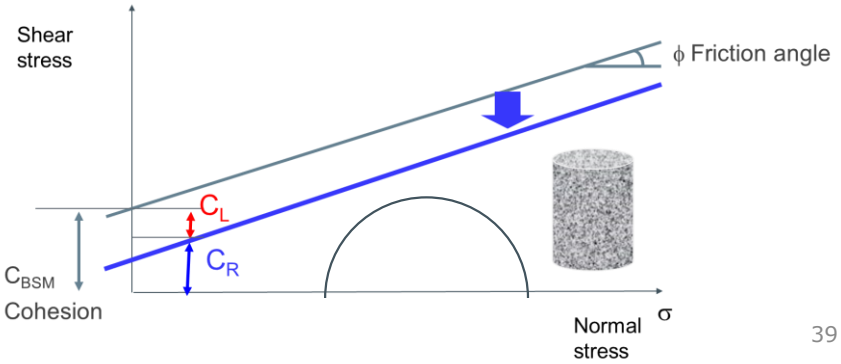
- Representative packing and density
  - CT scans showing void distribution
  - Interlayer bond





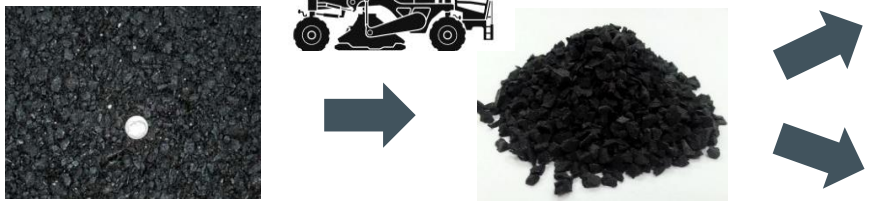
- Direct links between Mix Design and Pavement Design
- Moisture damage insights
  - TSR = ITS_{WET}/ITS_{DRY} has higher COV
  - Direct link of Cohesion Loss to Performance

    (increase in deviator stress ratio)



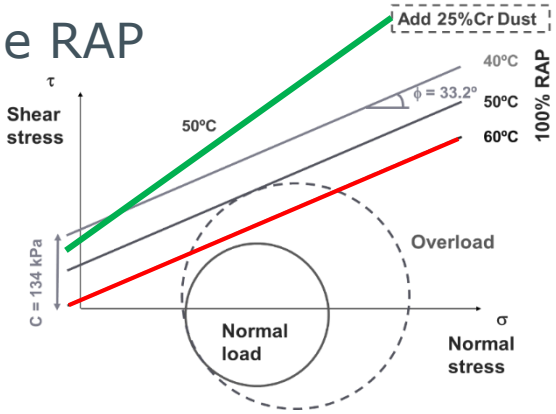
Spin-offs from Vibratory Hammer Compaction and Triaxial Testing$_2$

- Identifying true behaviour of recycled materials
  - Bitumen-Rubber Asphalt RAP (M4 example)



Spec result

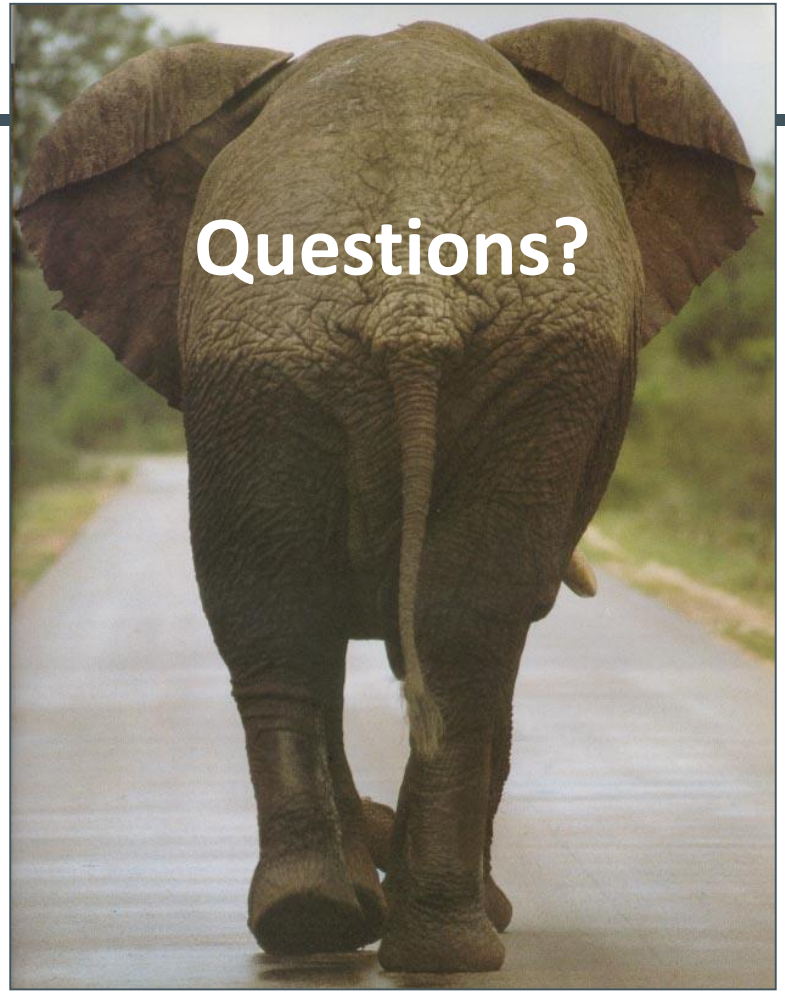
  - Soft bitumen in the RAP



Adjust mix to achieve desired shear properties

Conclusions

- Vibrating hammer compaction – more realistic, **less variable**
- Cement stabilisation – be aware of **shrinkage** (less cement)
- Cement % - account for **variability** and delay to compaction
- BSM – ITS is used to select **binder %** (cement & bitumen)
- **Triaxial** testing gives shear properties
  - More **reliable** mix design (repeatability)
  - Cohesion and friction angle is used in **structural design**



Thank you!