3rd International Symposium on Asphalt Pavements & Environment

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Mix Design of Bitumen Stabilised Materials (BSMs)

South Africa and Abroad

Kim Jenkins: Stellenbosch University

Dave Collings: BSM Laboratories (Pty) Ltd

TOPICS

Design criteria

What answers do we want from a mix design?

Tooling up for BSM mix design testing

Determining the required treatment

Determining the key performance properties

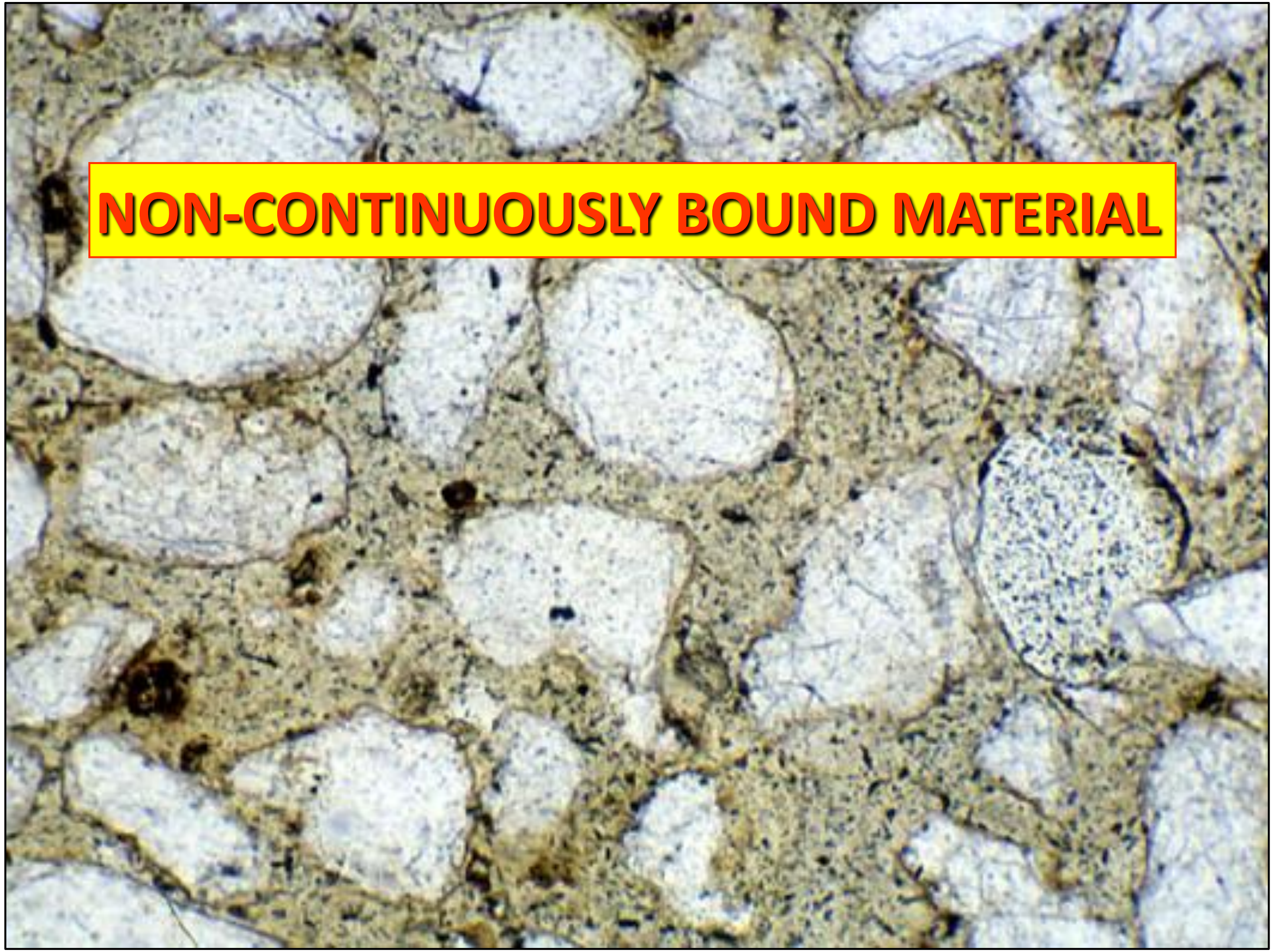
Design Criteria

Failure mechanism of BSMs

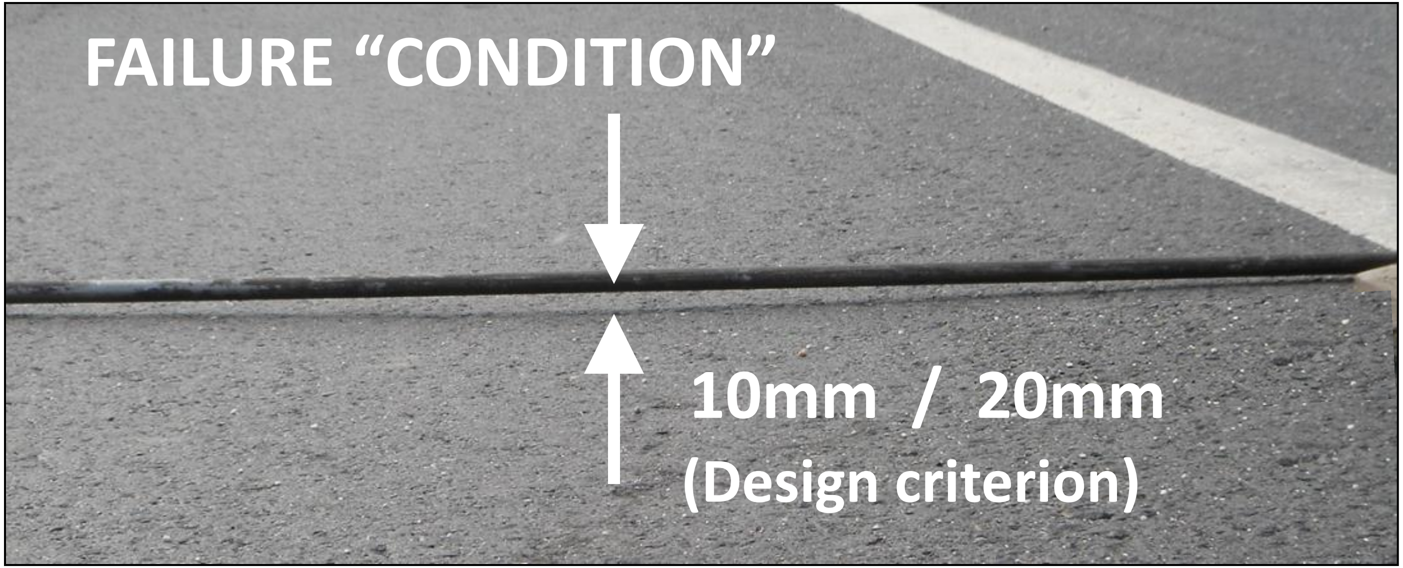
Characteristics of the parent material

Key performance parameters

Mix Design of BSMs – South Africa

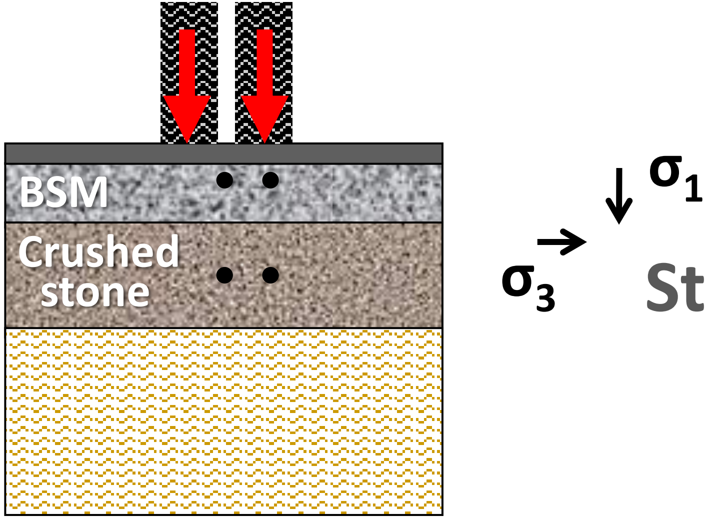


Mix Design of BSMs – South Africa



- BSMs are granular materials "on steroids"
- Shear properties dictate performance

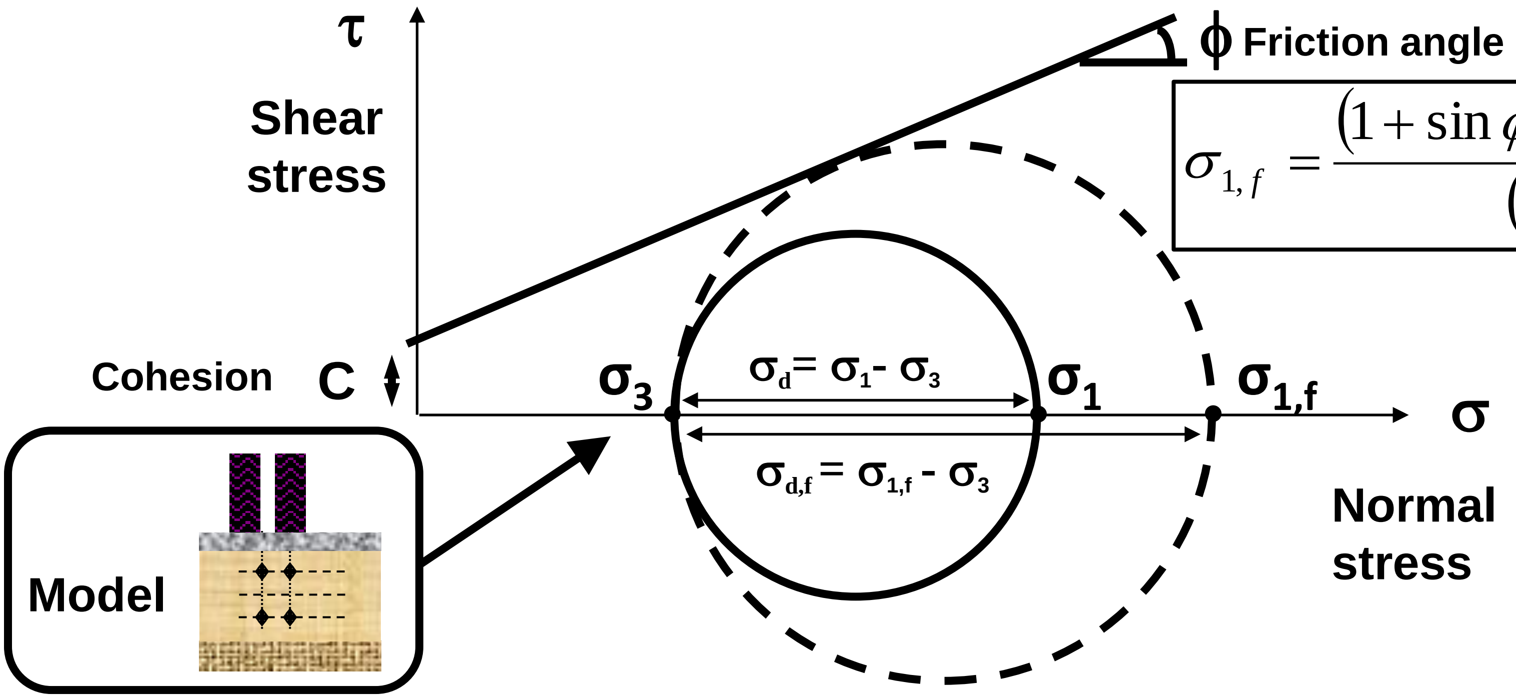
DESIGNING BSM AND GRANULAR LAYERS



Stress state

Deviator stress (σ_d) = $\sigma_1 - \sigma_3$

Deviator Stress Ratio: $\frac{\sigma_d}{\sigma_{d,f}}$ ➡ TRANSFER FUNCTION



$$\sigma_{1,f} = \frac{(1+\sin\phi).\sigma_3 + 2.C.\cos\phi}{(1-\sin\phi)}$$

Mix Design of BSMs – South Africa

$$\sigma_{1,f} = \frac{(1+\sin\phi).\sigma_3 + 2.C.\cos\phi}{(1-\sin\phi)}$$

σ_3 : Confining pressure → MODEL

C : Cohesion

ϕ : Friction angle

} **TRIAXIAL TEST**

MIX DESIGN → SHEAR PROPERTIES

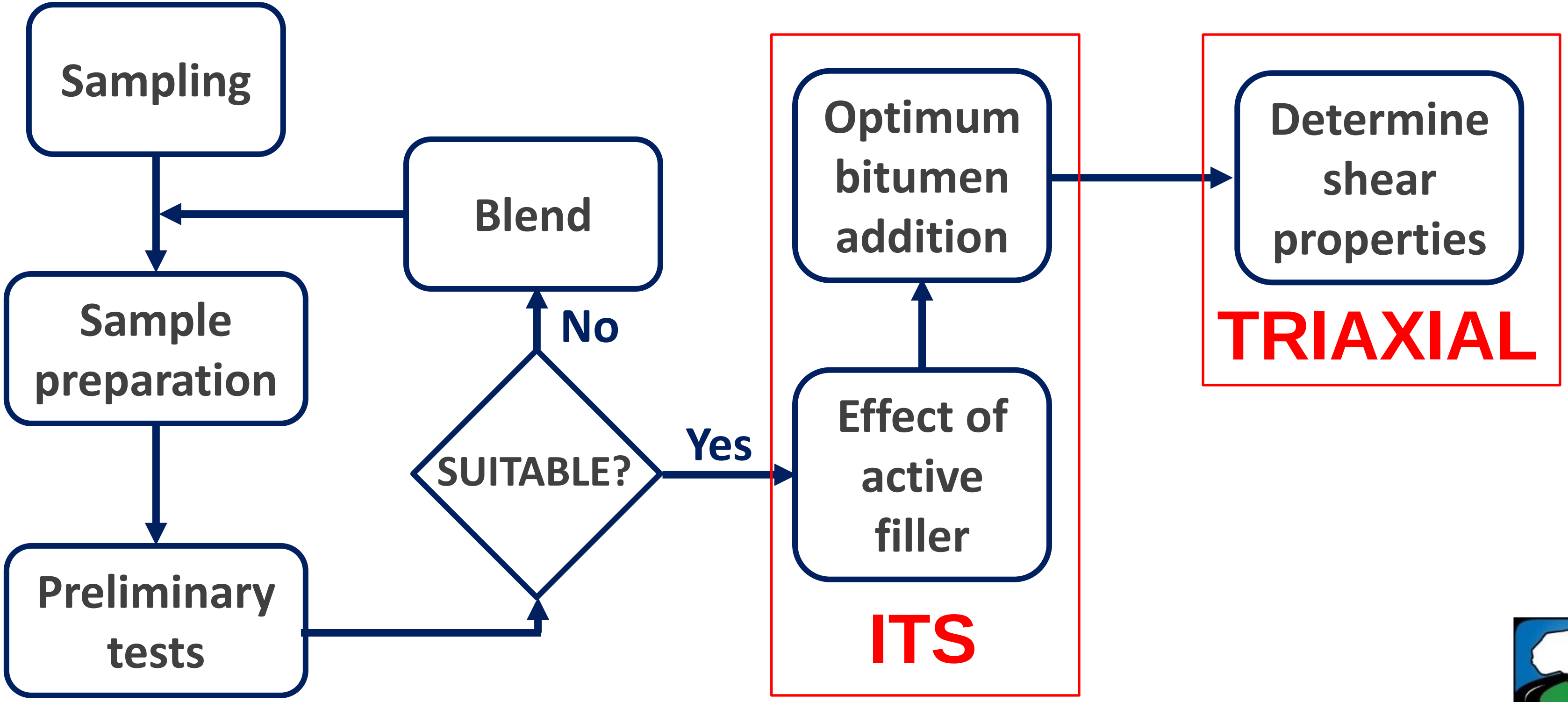
PRELIMINARY STEPS:

Is the material suitable for stabilising with bitumen?

How much bitumen must be added?

Is an active filler required?

MIX DESIGN FLOWCHART



TEST SPECIMENS

Mixing (simulate field conditions)

Density (100% of mod AASHTO density)

Curing regime (40°C / dry / soaked / equilibrium)

Temperature of specimens when tested (25°C)

Tooling up for BSM mix design testing

Material separator (4 fractions)

Laboratory crusher (>19mm reduced to <19mm / >13mm)

Unit for producing foamed bitumen

Twin-shaft pugmill mixer (elimination of injection losses)

Specimen manufacture (vibrating hammer compaction)

Applying confining pressure (triaxial testing)

Mix Design of BSMs – South Africa

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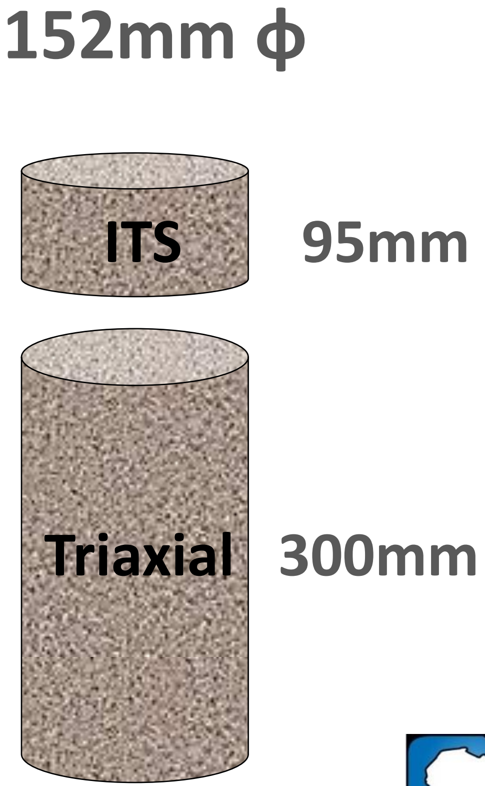
SPECIMEN MANUFACTURE

Vibratory hammer compaction

(Split moulds)



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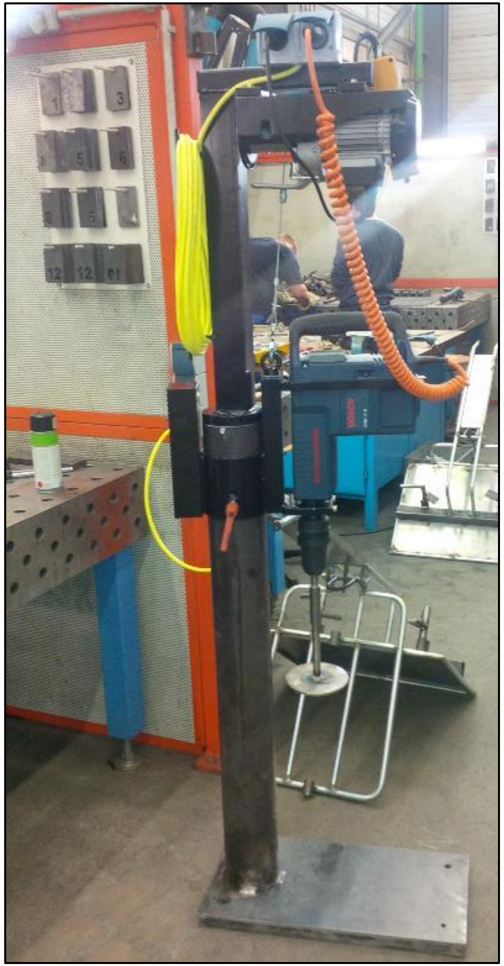
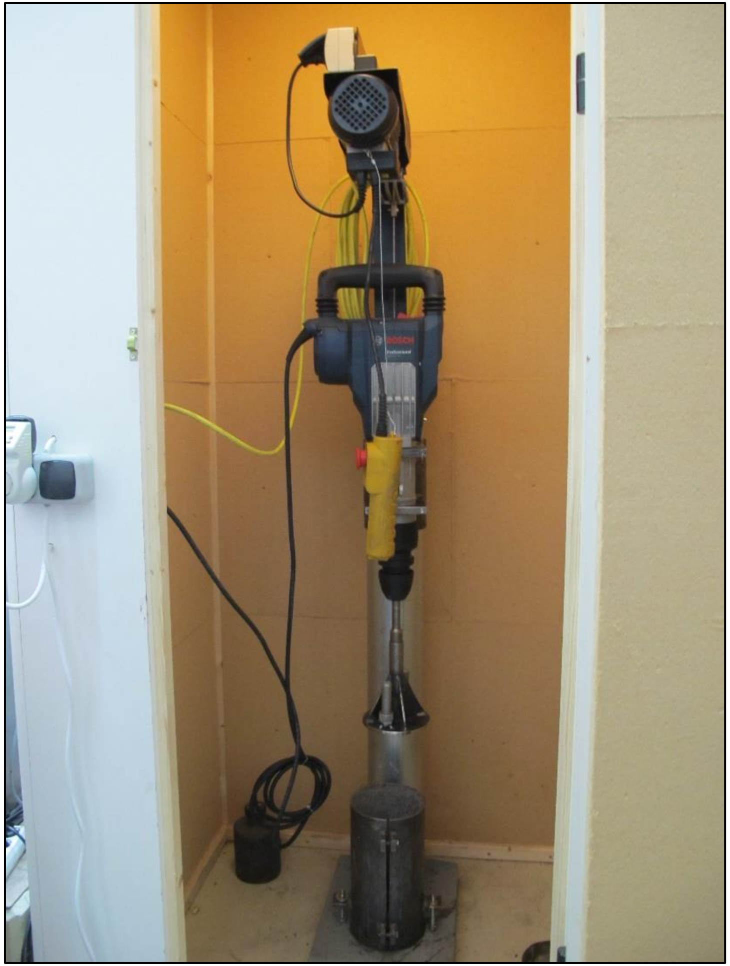
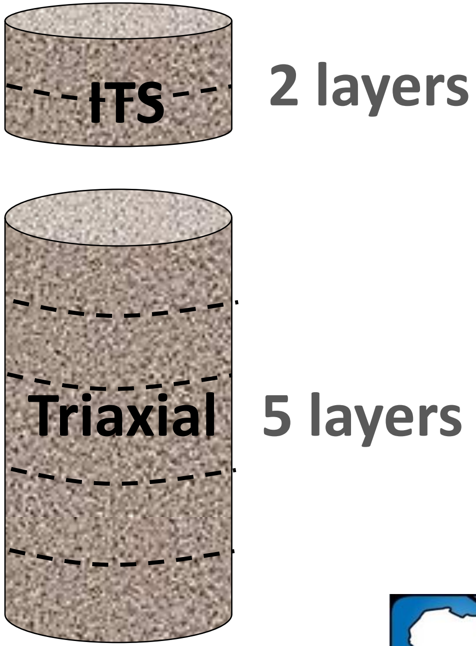




Inter-Layer Roughening (ILR) Device



Curing regimes

40°C curing temperature

ITS specimens – dry to constant mass

Triaxial specimens – equilibrium m/c

Soaking: 24 hours submerged

Mix Design # 1. Preliminary Tests (material suitability)

Grading (sieve analysis – washed method)

Atterberg Limits (plasticity)

Moisture / density relationship (modified AASHTO)

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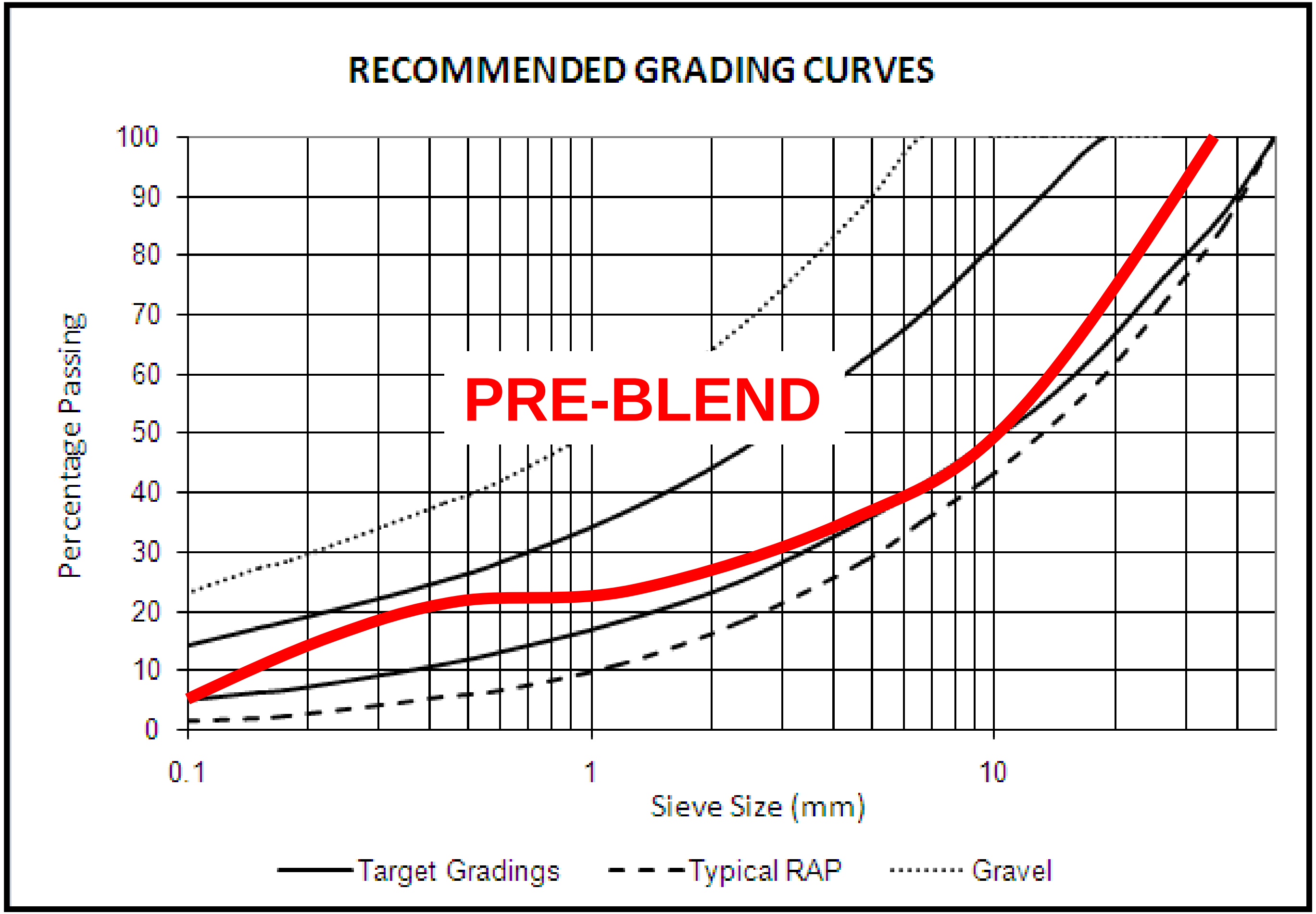


Mix Design # 2. Determine the effect of Active Filler

Estimate the optimum bitumen application rate

Apply / mix 3 batches with identical bitumen addition + different active fillers (1% by mass)

Specimen manufacture / curing

ITS testing

Interpreting the results

Mix Design of BSMs – South Africa

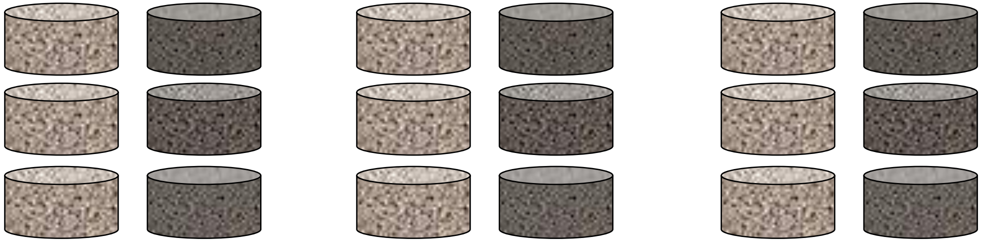
Guidelines for estimating Optimum Bitumen Addition *			
Fraction < 0.075mm (%)	Bitumen addition (% by mass of dry aggregate)		Typical material
	Fraction < 4.75mm		
	< 50%	>50%	
< 4	**1.8**	**2.0**	Recycled asphalt (RA)
4 – 7	**2.2**	**2.4**	RA / Graded crushed stone / Natural gravel / blends
7 – 10	**2.4**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

*** Wirtgen Cold Recycling Technology Manual (2012), Page 245**

Mix Design of BSMs – South Africa

3 mixes: Same bitumen application rate (e.g. 2.2%)

Active Filler: 1% Lime | None | 1% Cement



ITS_{DRY} ITS_{WET} ITS_{DRY} ITS_{WET} ITS_{DRY} ITS_{WET}

Mix Design of BSMs – South Africa

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

Mix Design # 3. Determine the Optimum Bitumen Application rate

Selecting the amount / range of bitumen to be applied

Specimen manufacture / curing

ITS testing

Interpreting the results

Select bitumen addition range

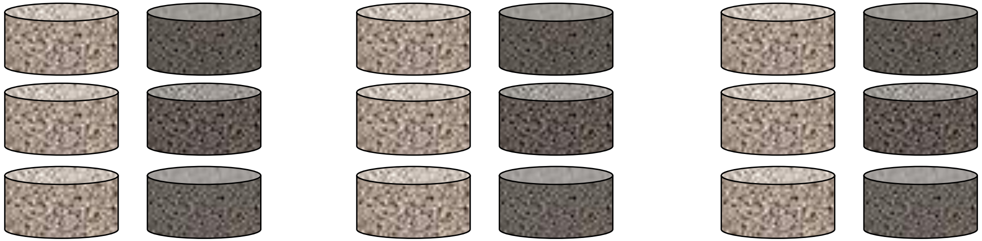
1.8 2.0 **2.2** 2.4

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

Mix Design of BSMs – South Africa

3 mixes: Same active filler addition (e.g. 1.0% lime)

Bitumen addition: 1.8% 2.0% 2.4%

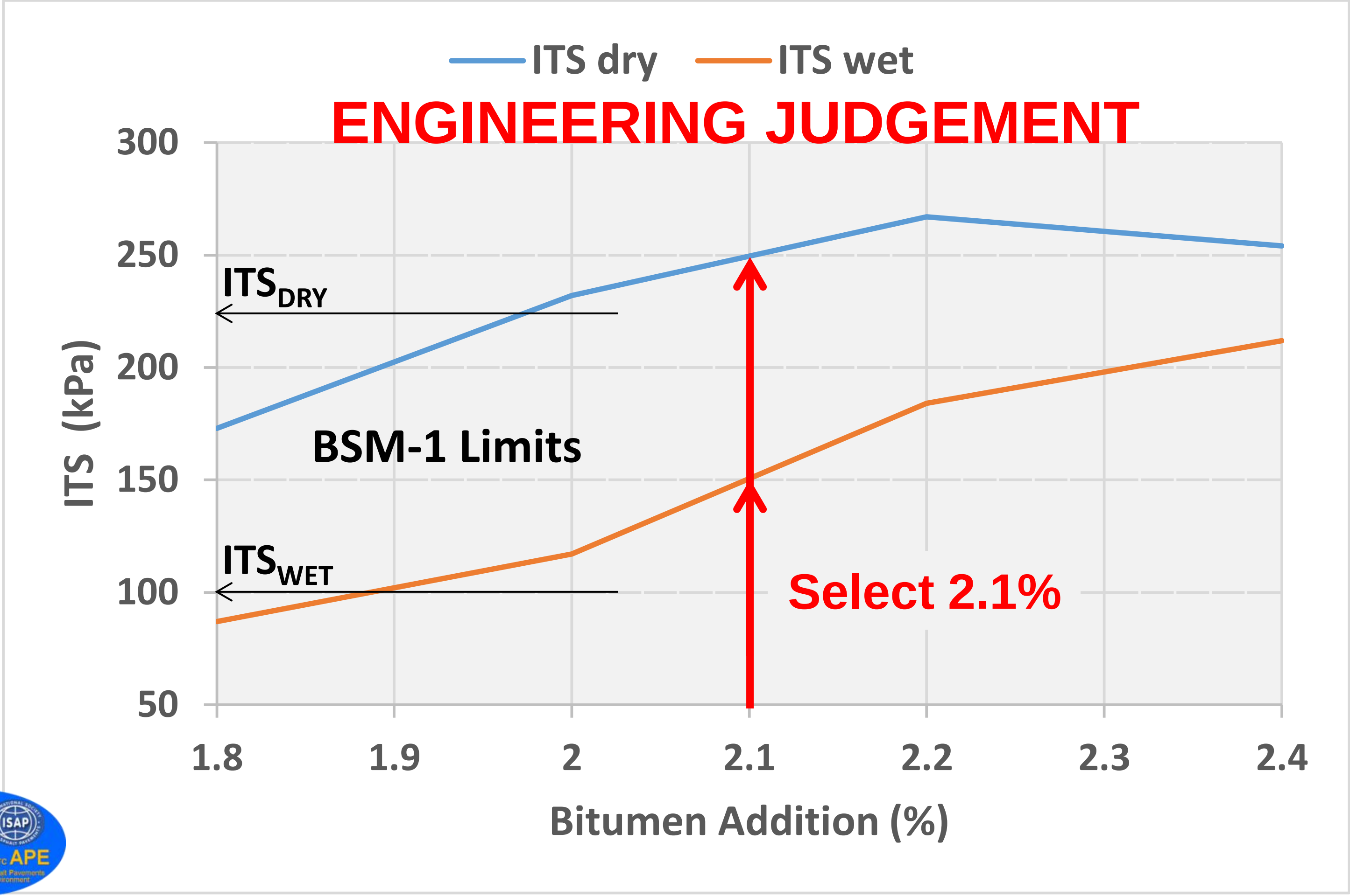


ITS_{DRY} ITS_{WET} ITS_{DRY} ITS_{WET} ITS_{DRY} ITS_{WET}

Mix Design of BSMs – South Africa

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

Mix Design of BSMs – South Africa



Mix Design # 4. Determine the Shear Properties

Specimen manufacture / curing

Triaxial testing

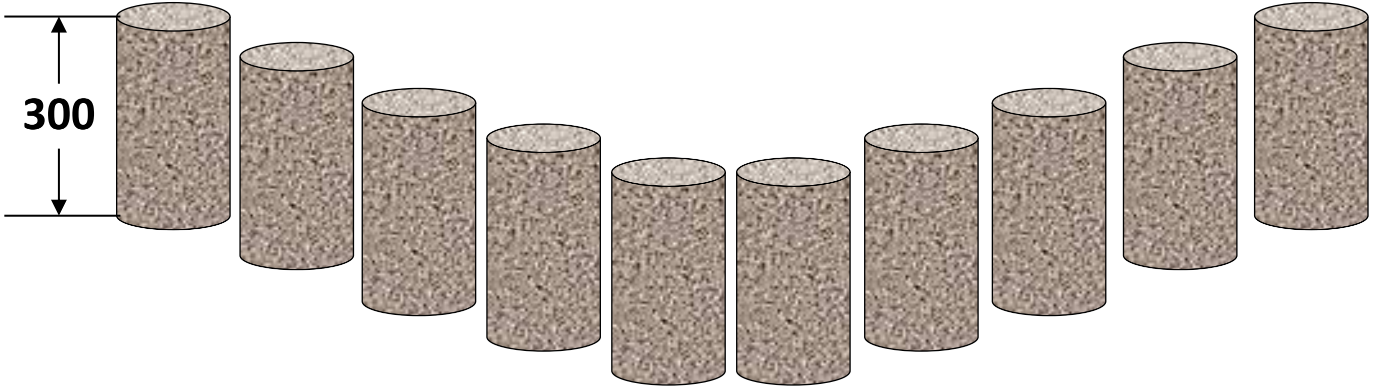
Confining pressures

Interpreting the results

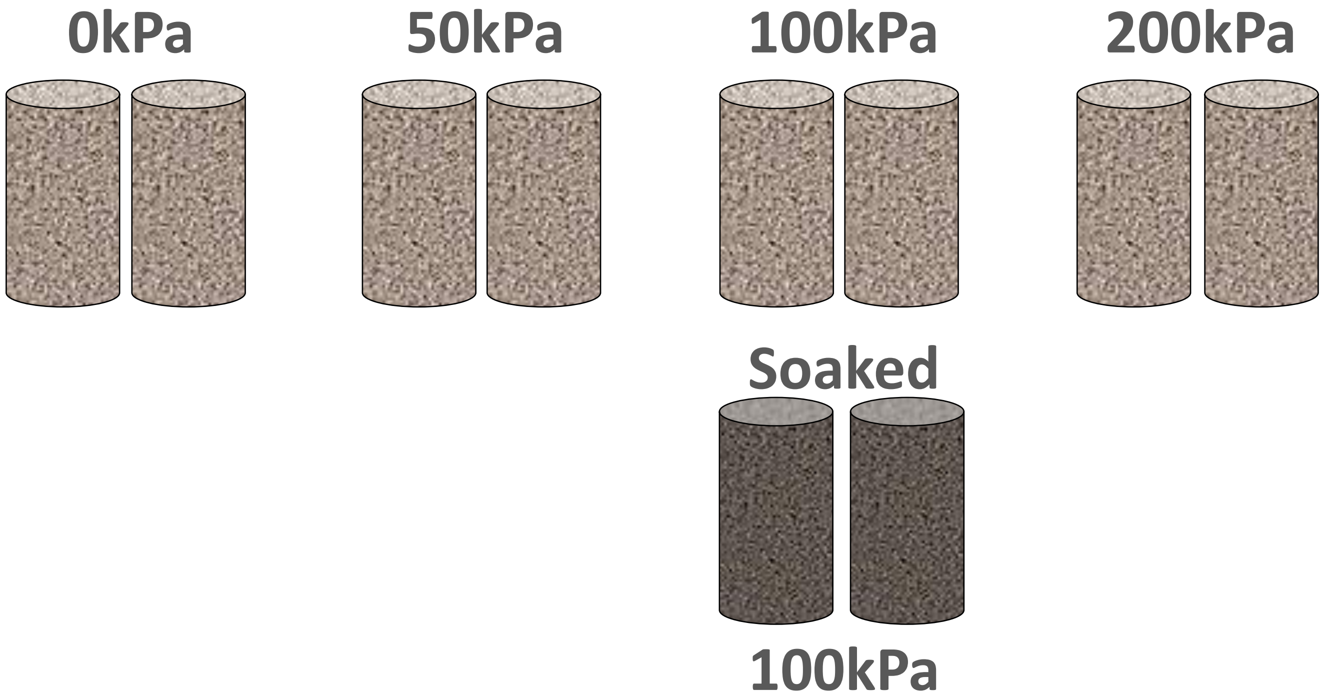
Mix Design of BSMs – South Africa

10 specimens manufactured at Optimum Bitumen Content (with active filler)

Cured at Equilibrium Moisture Content



Pairs tested at 4 different confining pressures



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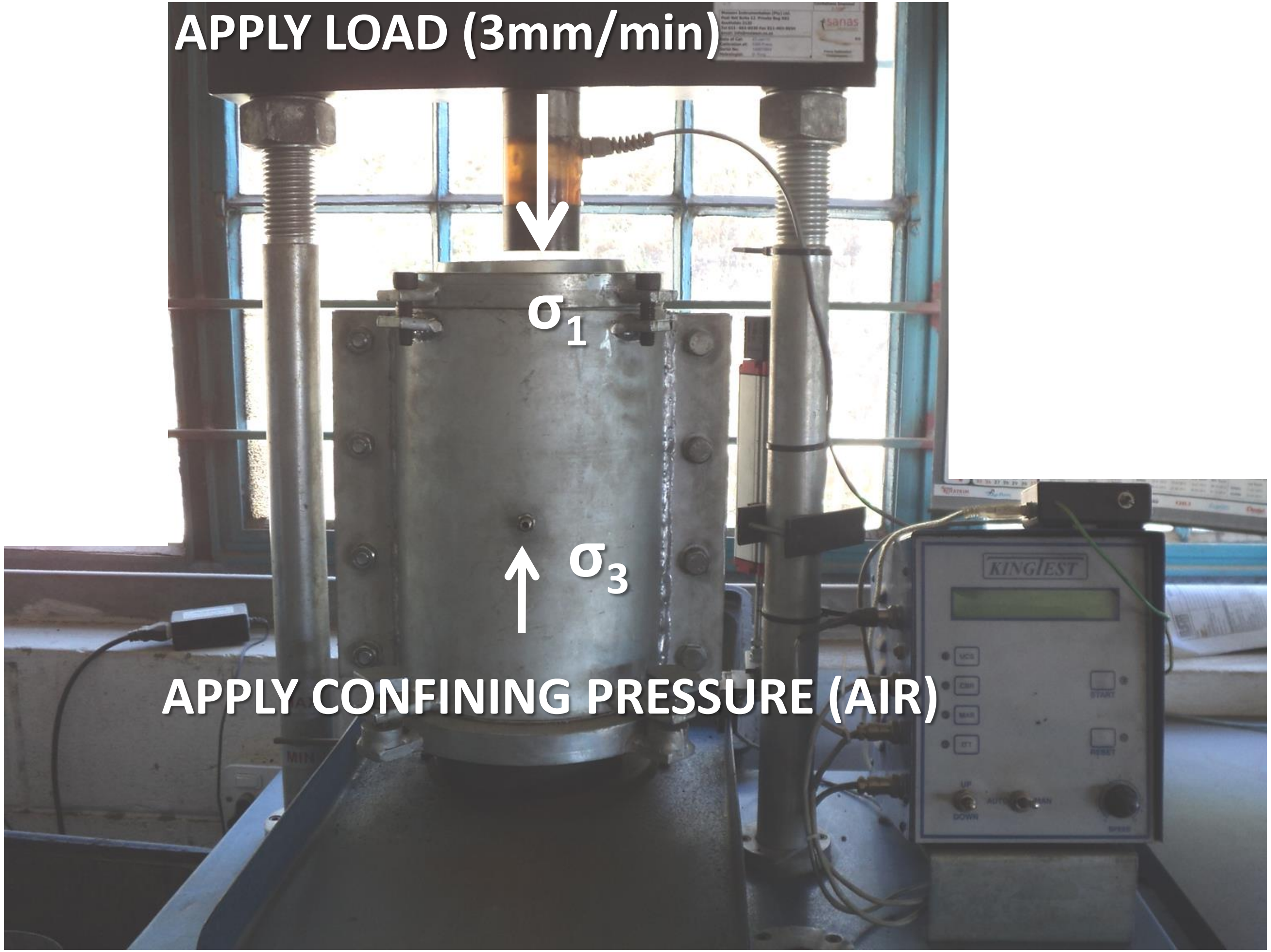
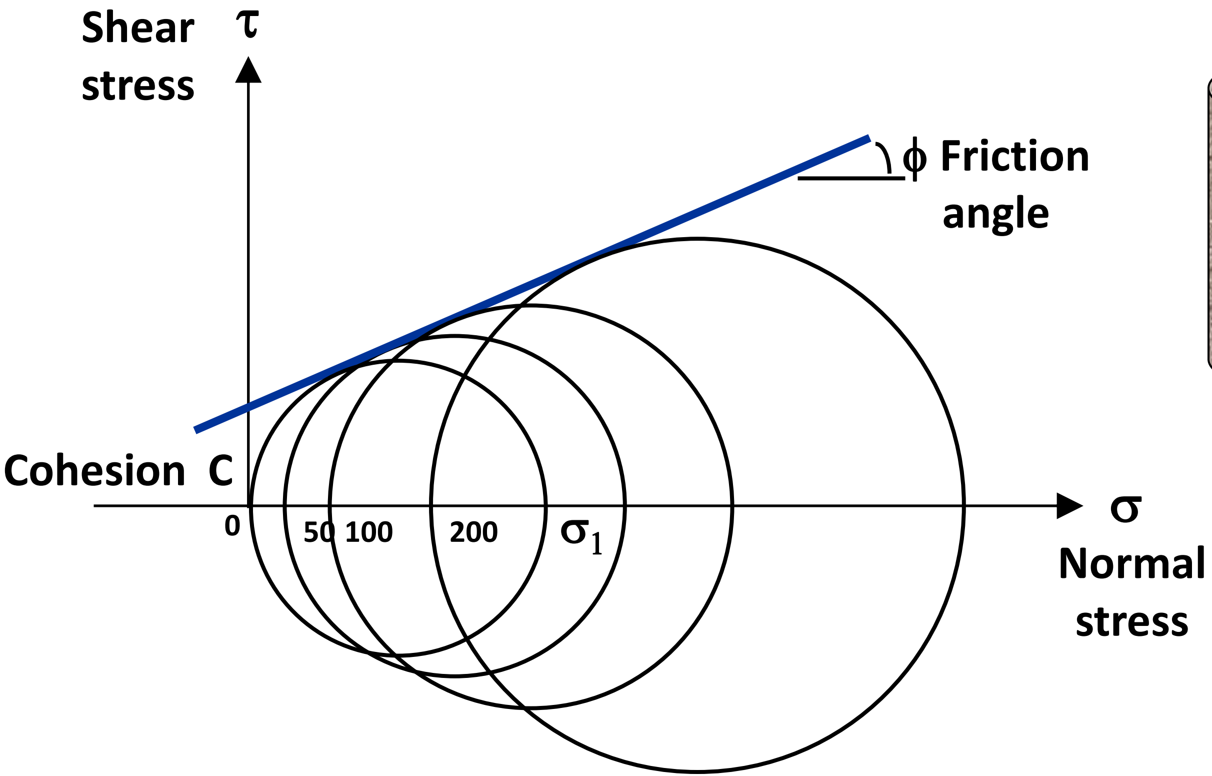
Specimen inserted into a latex bladder

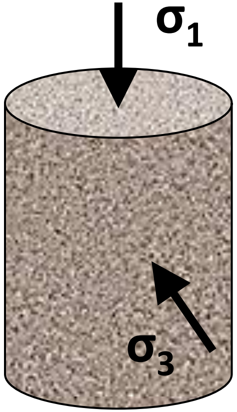
Positioned in half of split confining cylinder on base plate

Mix Design of BSMs – South Africa



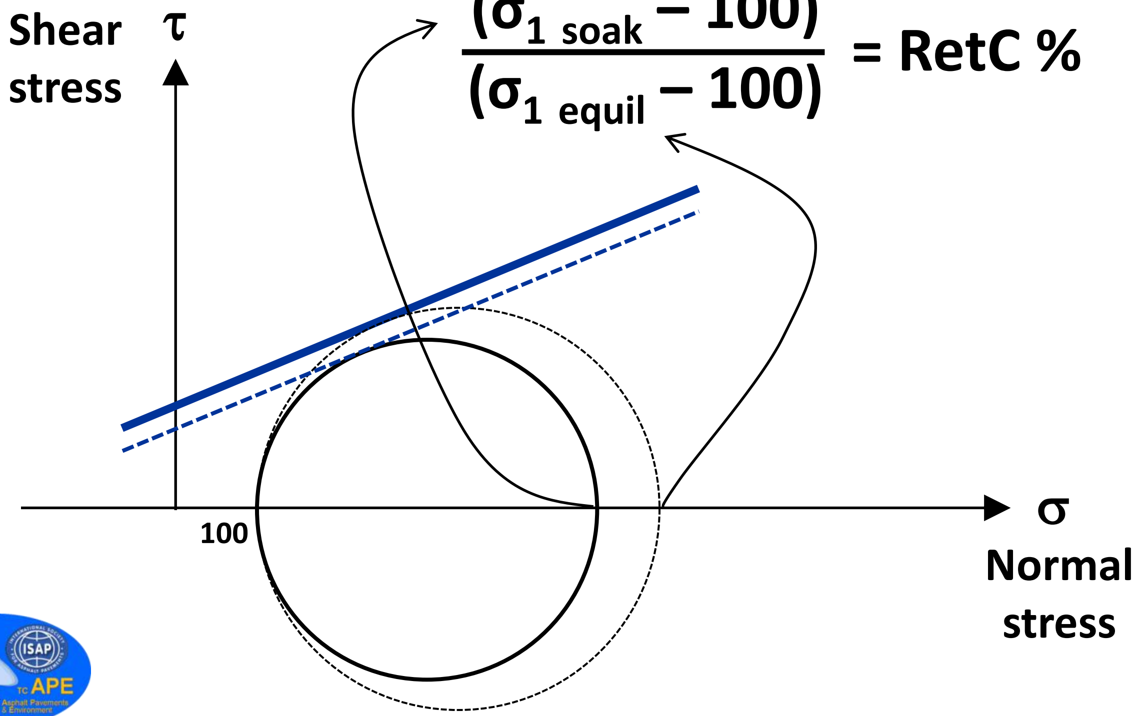
Determine the shear properties (C and ϕ)

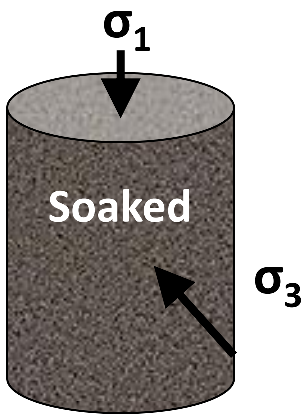




Determine the Retained Cohesion (RetC)

$$\frac{(\sigma_{1\ soak} - 100)}{(\sigma_{1\ equil} - 100)} = \text{RetC}\ \%$$





Mix Design of BSMs – South Africa

Bitumen added	(%)	2,1				
Type and percent filler added	(%)	1% Lime				
Average Diameter	(mm)	152	152	152	152	152
Average Height	(mm)	283,0	290,5	291,6	292,0	290,3
Moulding moisture content	(%)	7,5	6,8	7,6	7,0	7,7
Dry Density	kg/m3	2263	2266	2260	2261	2262
TEST RESULTS						
Applied Confining Stress (σ3)	**(kPa)**	**0**	**50**	**100**	**100 Soaked**	**200**
Applied Failure Load	(kN)	29,6	35,7	42,8	40,4	49,0
Moisture Content at break	(%)	3,6	3,7	4,0	5,8	3,9
Temperature at break	(oC)	24,9	24,8	25,0	25,3	25,0
Displacement	(mm)	4,5	5,0	5,5	5,6	6,9
CALCULATIONS						
Applied Failure Stress	(kPa)	1631	1967	2360	2226	2700
Mass of dead loads	(kg)	5,1				
Stress due to dead loads	(kPa)	2,8				
Major Principle Stress at failure (σ1,f)	**(kPa)**	1634	1970	2363	2229	2703

COHESION (C)	**(kPa)**	**368**	**INTERNAL ANGLE OF FRICTION (φ)**	**43,2**
RETAINED COHESION	**(%)**	**94**	**TG2 (2009) Material Classification** BASED ON COHESION & FRICTION ANGLE	**BSM 1**

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