BSM Stabilisation (Mix) Design

Kim Jenkins

SARF Course on BSMs

KZN DoT

13 and 14 August 2015

Stellenbosch

60th anniversary SARF Founded in 1950

THE SOUTH AFRICAN NATIONAL ROADS AGENCY SOC LTD

Reg. No.1998/009584/06

Life is full of surprises…

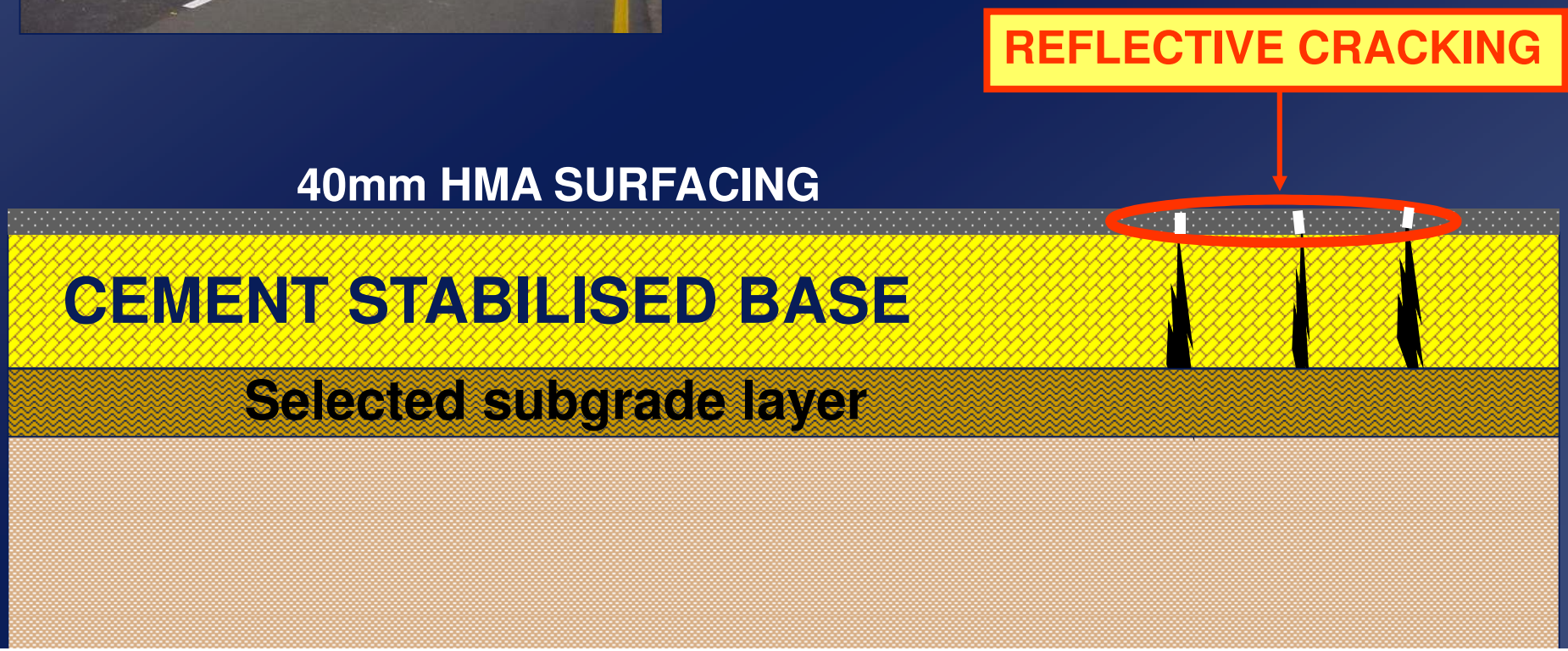
Try to keep them to a minimum

Primary Design Objectives

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

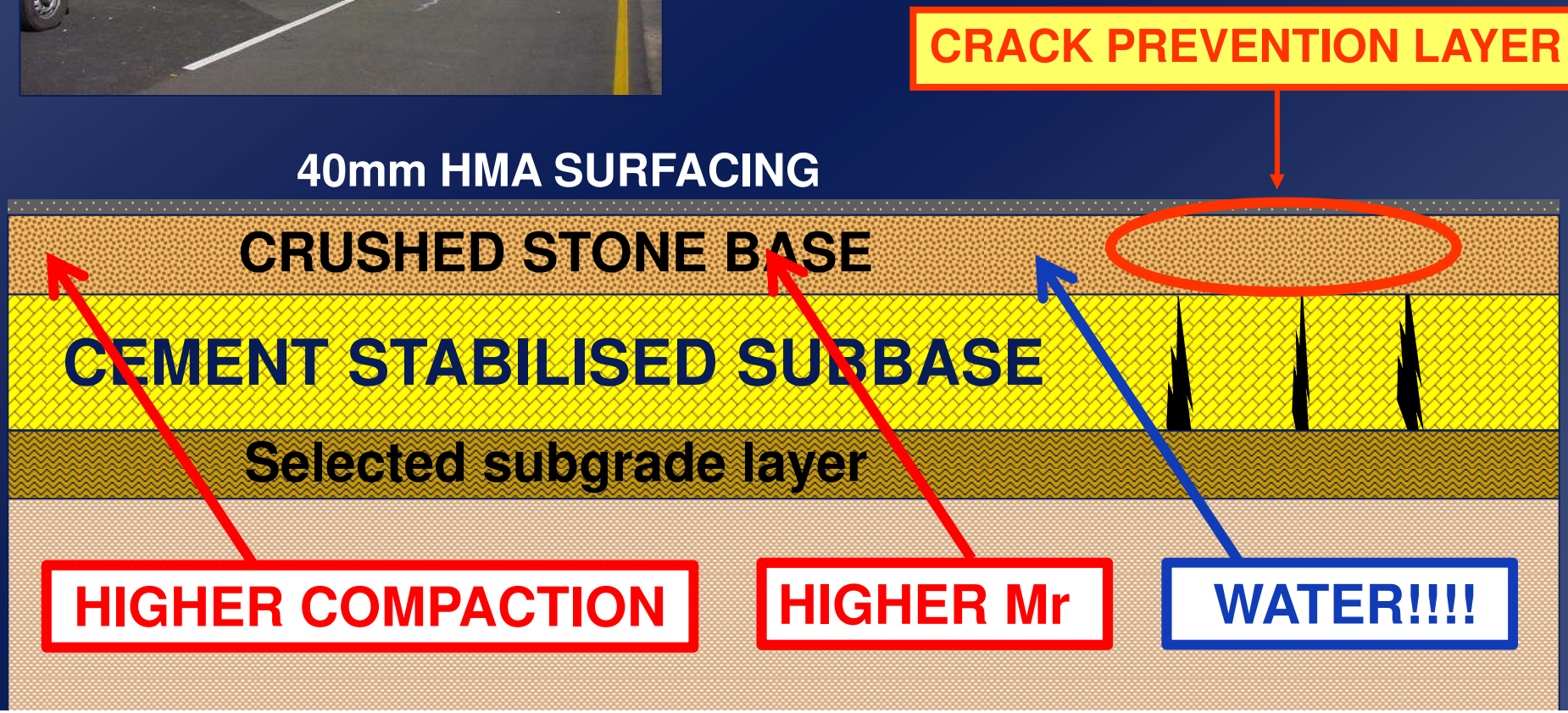
Early South African pavements

Key pavement considerations



The South African "inverted" pavement

The Concept



The South African "upside-down" pavement

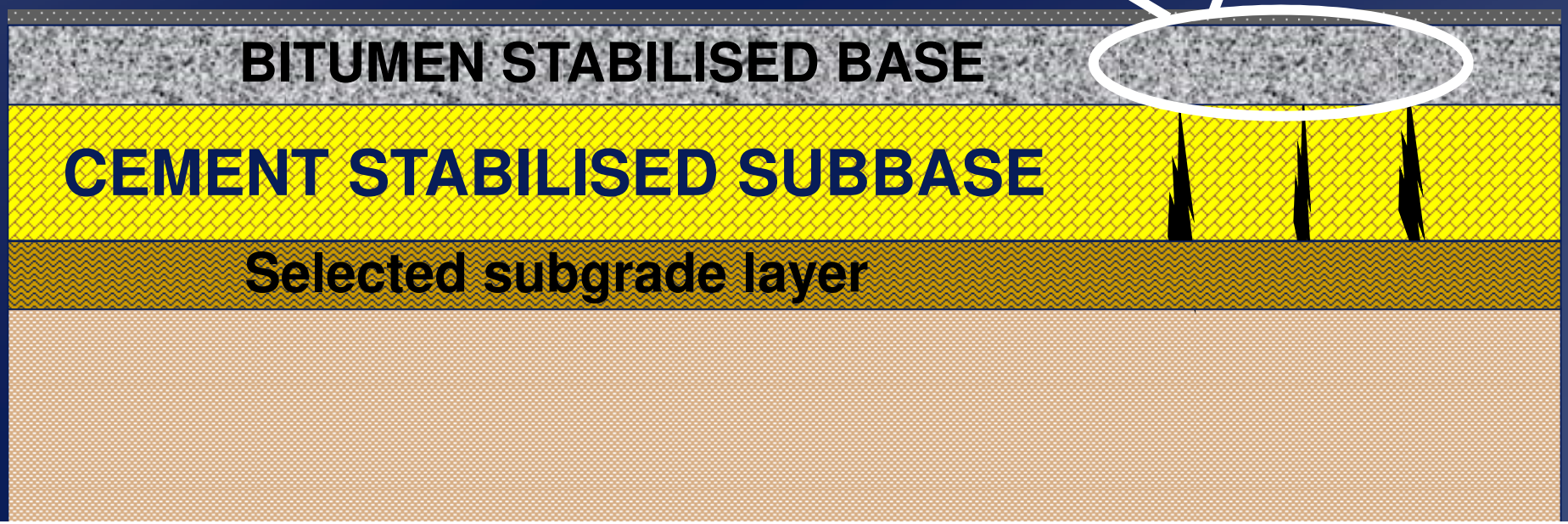
Distress Mode?

The Upgrade

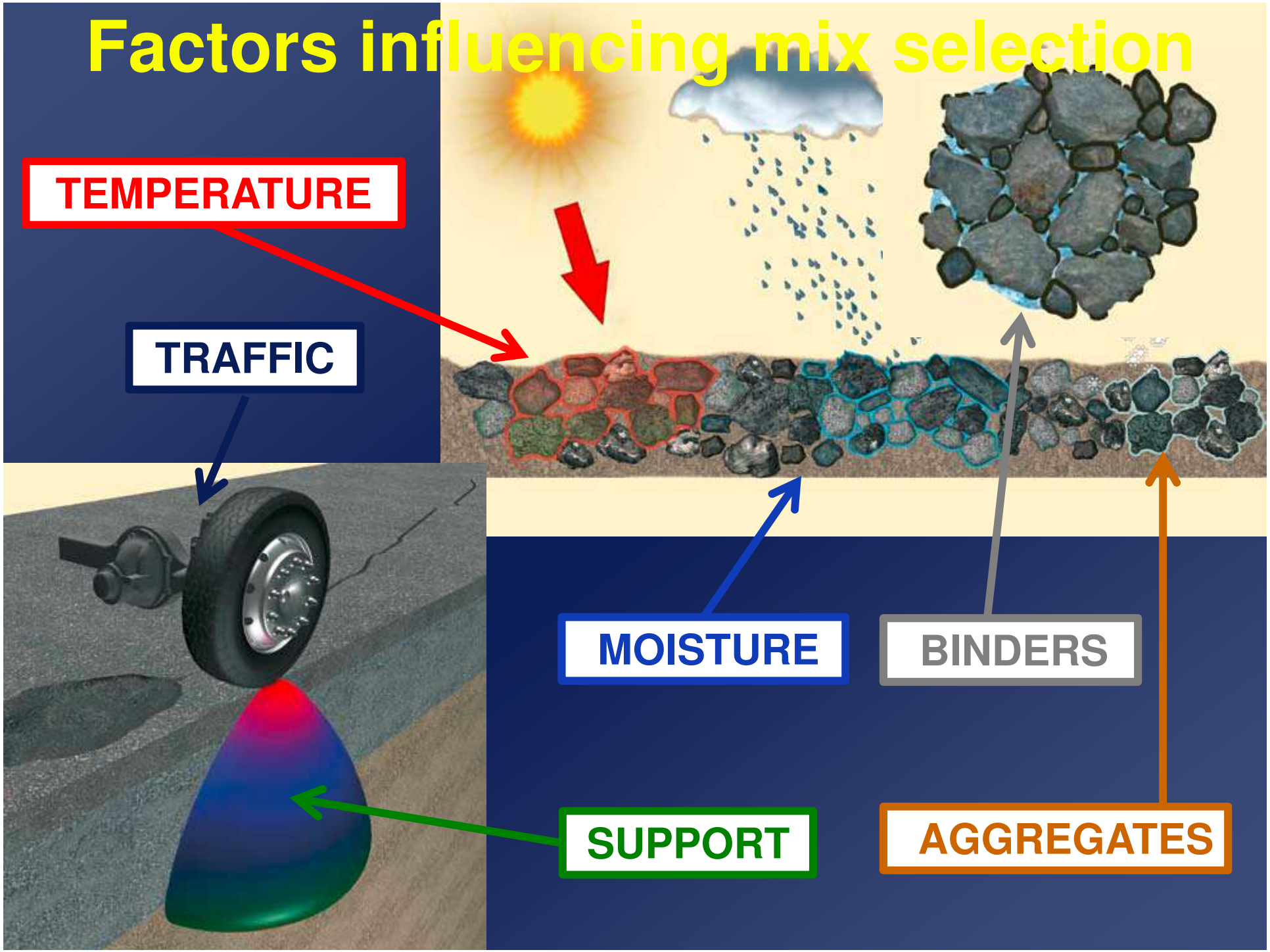
Unbound — Permanent deformation (shear/ruts)

Bound — Fatigue (cracking)

Durability??



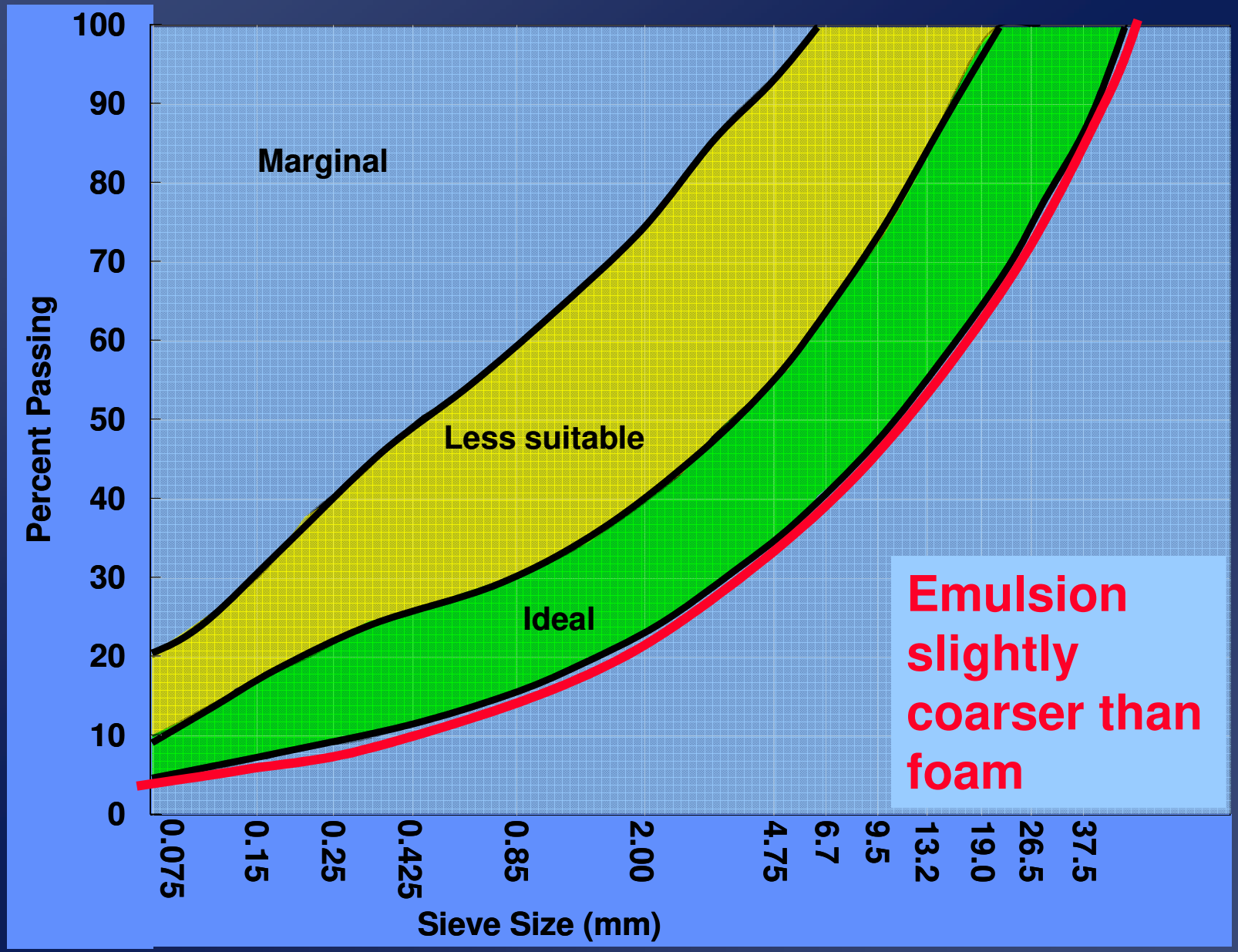
Factors influencing mix selection



Traffic vs Classes of BSM

AGGREGATES/ COMPACTION

BSM Grading requirements (1)



BSM Aggregate requirements (2)

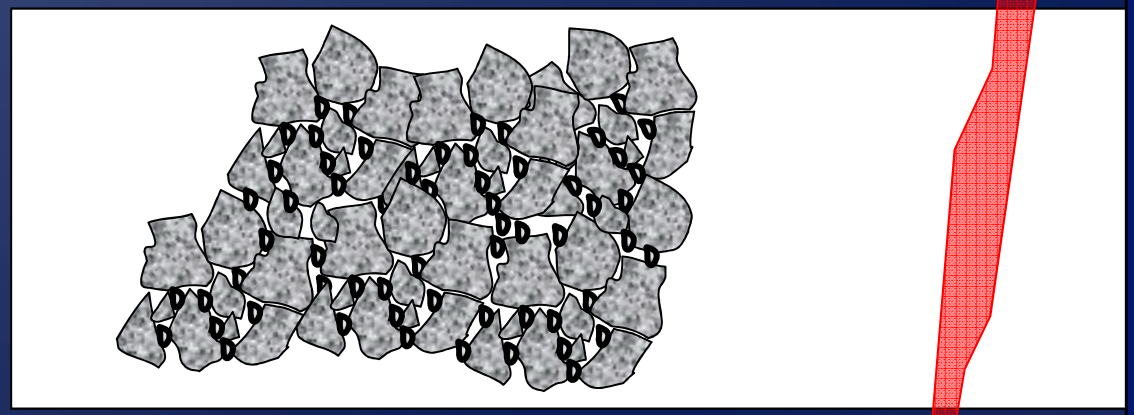
	Emulsion	Foam
•	PI < 7%	PI < 10%
•	$P_{0.075}$> 2%	$P_{0.075}$> 4%

- Reclaimed asphalt RA + (15 to 25% Crusher dust)
- Triaxial tests at representative temperature (especially hot regions)

BSM: RAP Influence

Bitumen Stabilised

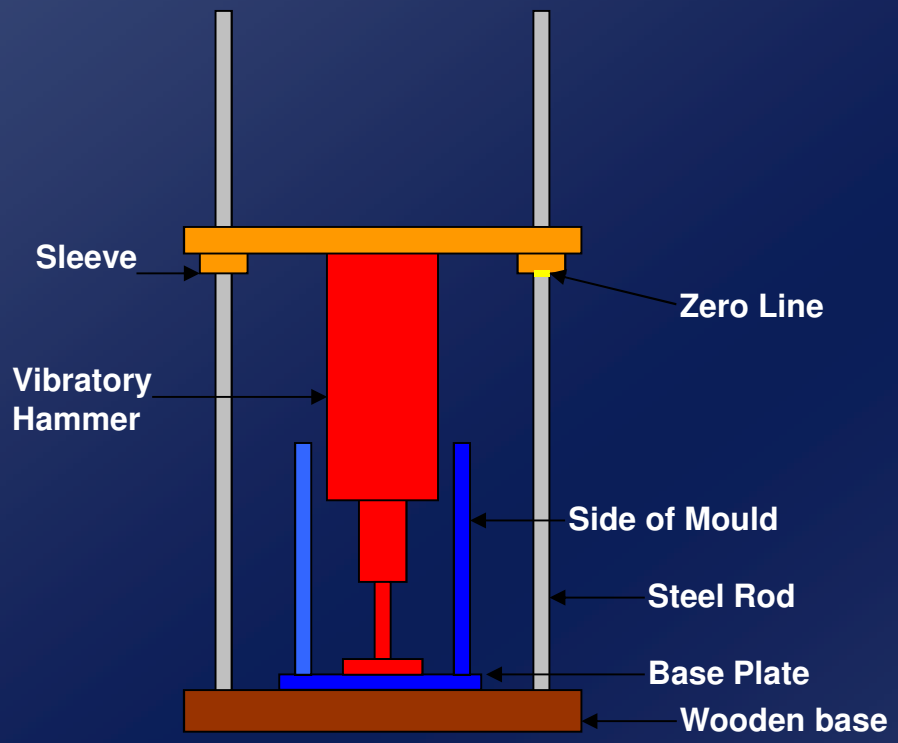
Non-continuously bound



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

Vibratory Compaction Hammer

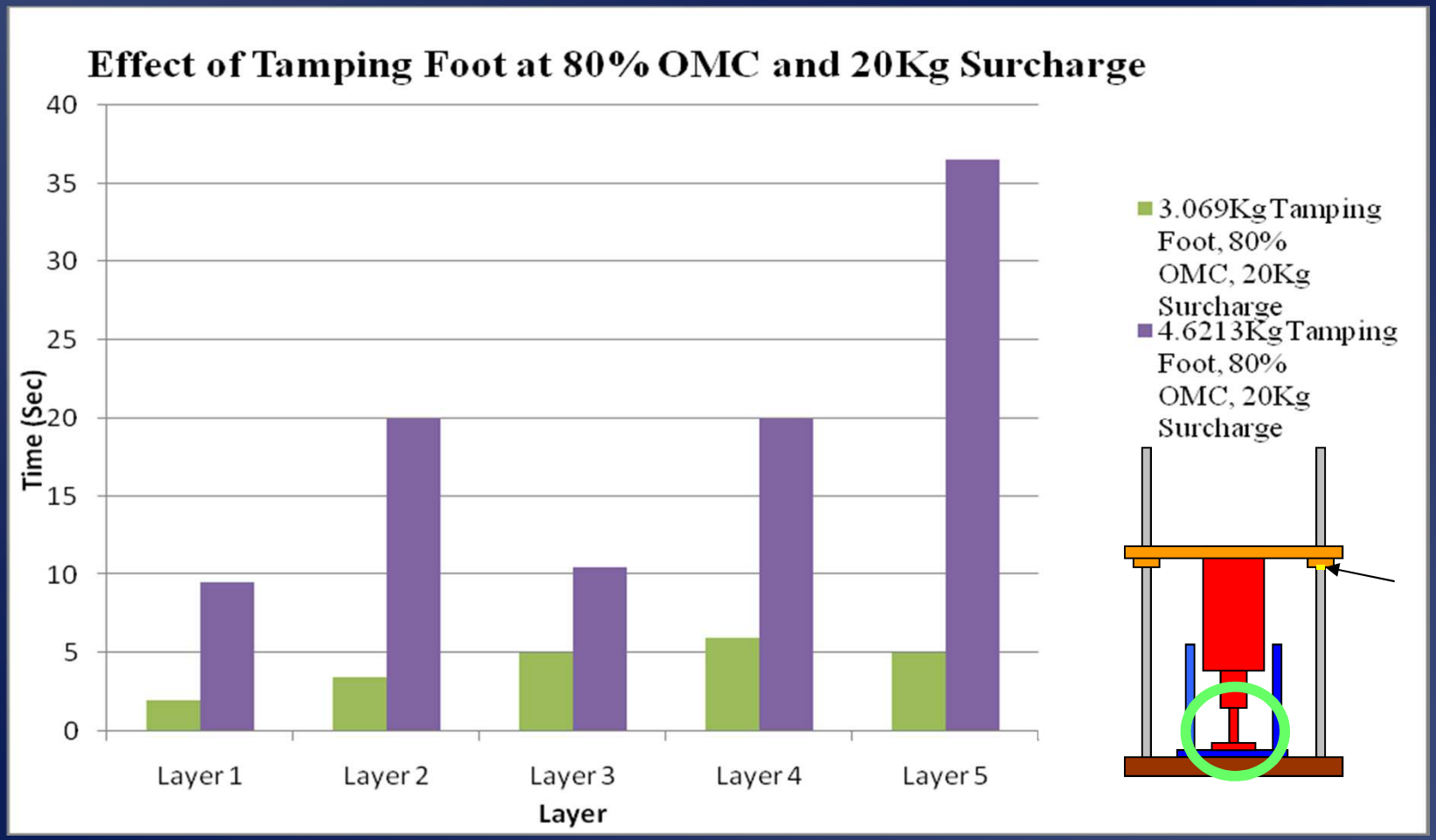
To prepare specimens



Kelfkens, U Stell

Rear View of Frame

Influence of Tamping Foot



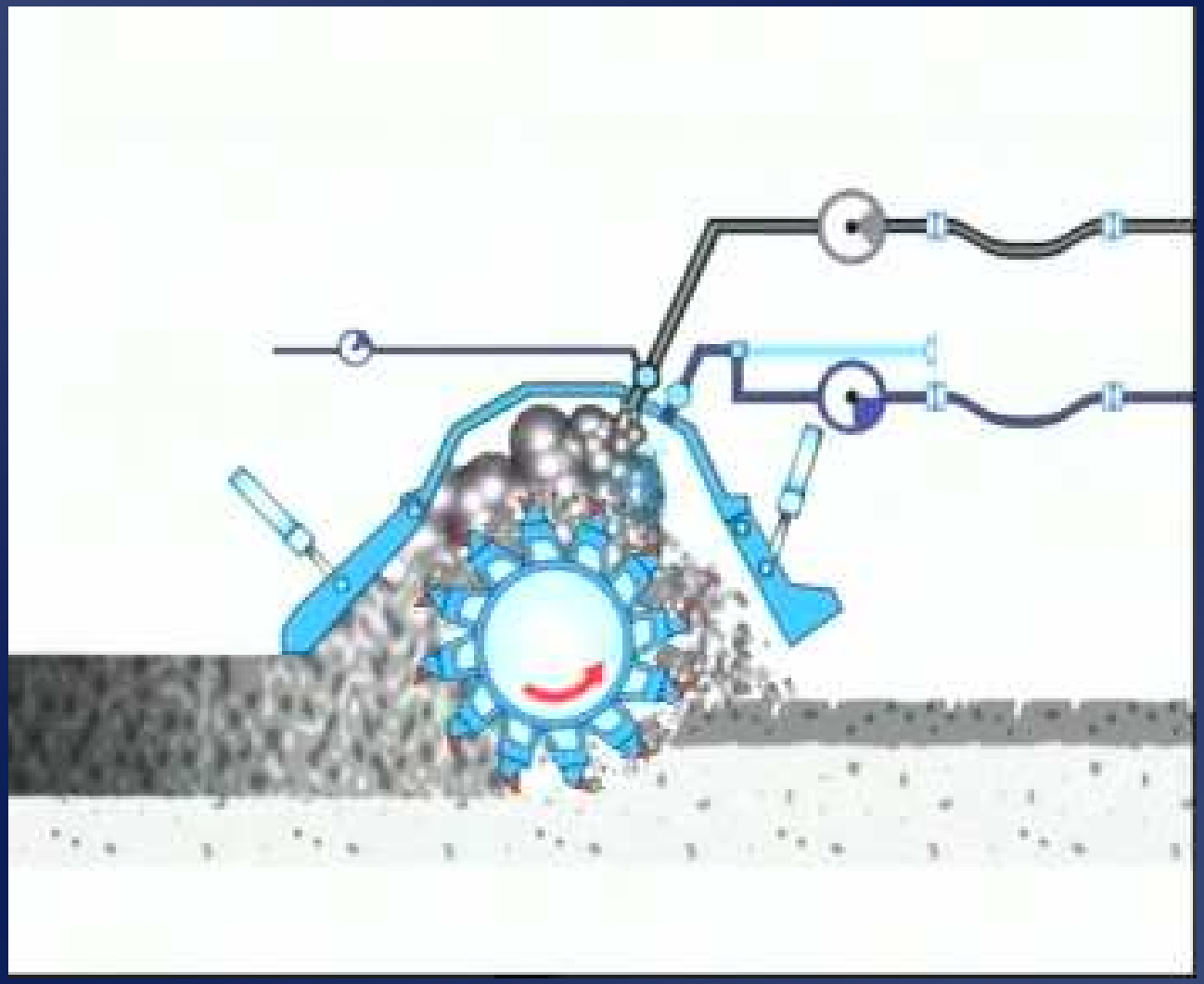
Compaction time (vibratory)

Phase	Level 1		Level 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

Comp Time

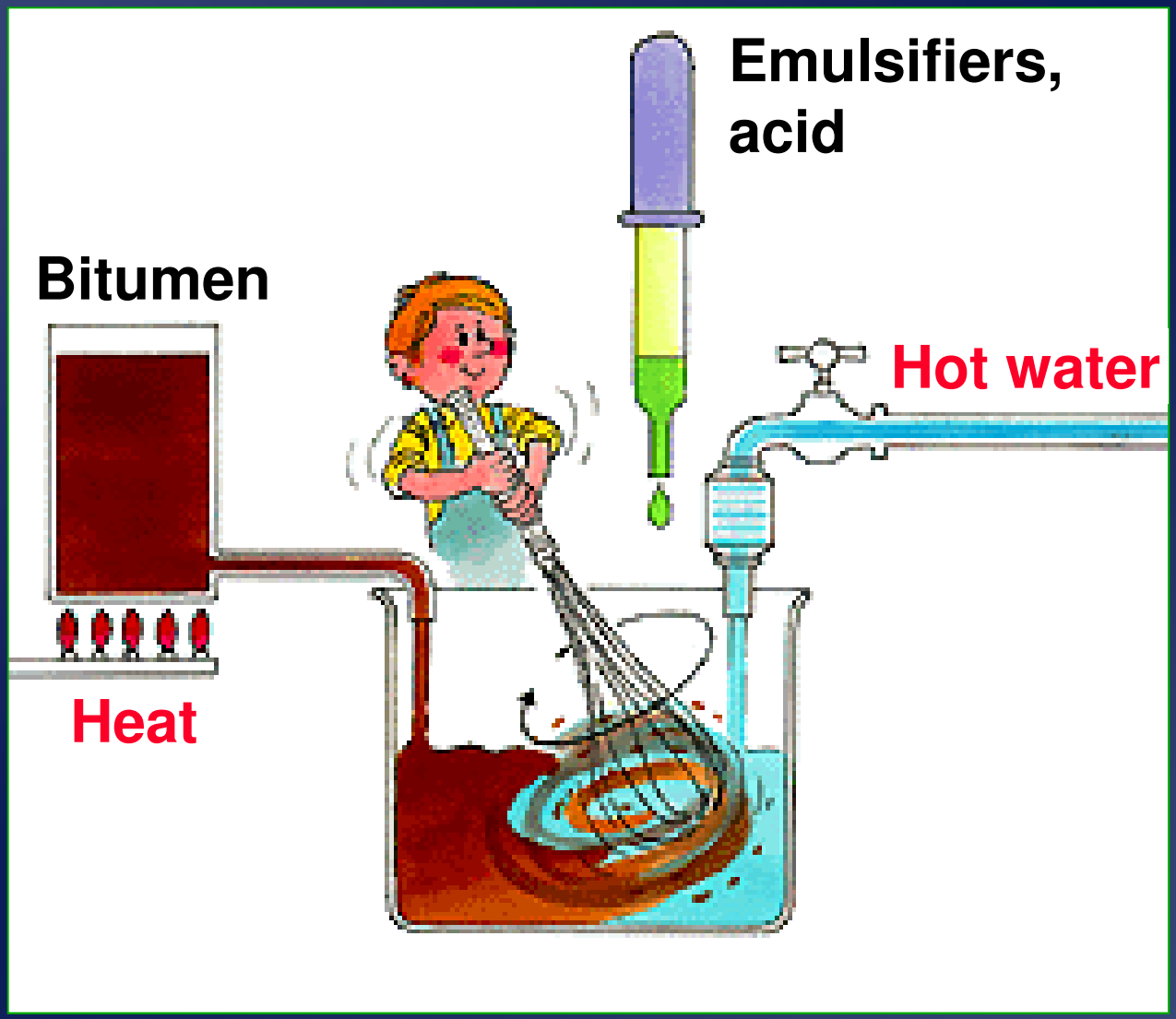
BINDERS

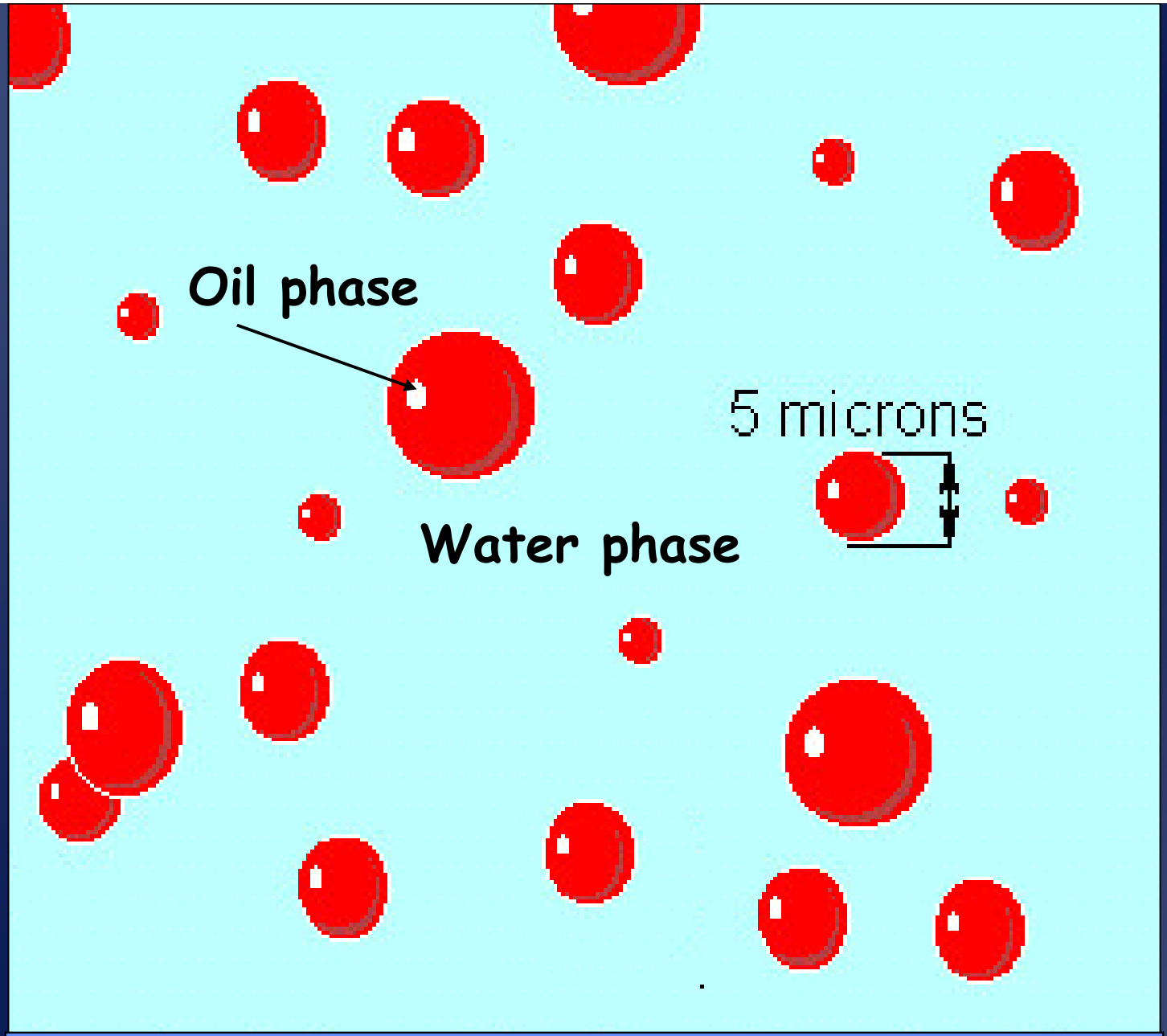
Quality Assessment:
Foamed bitumen




Emulsion
Plant

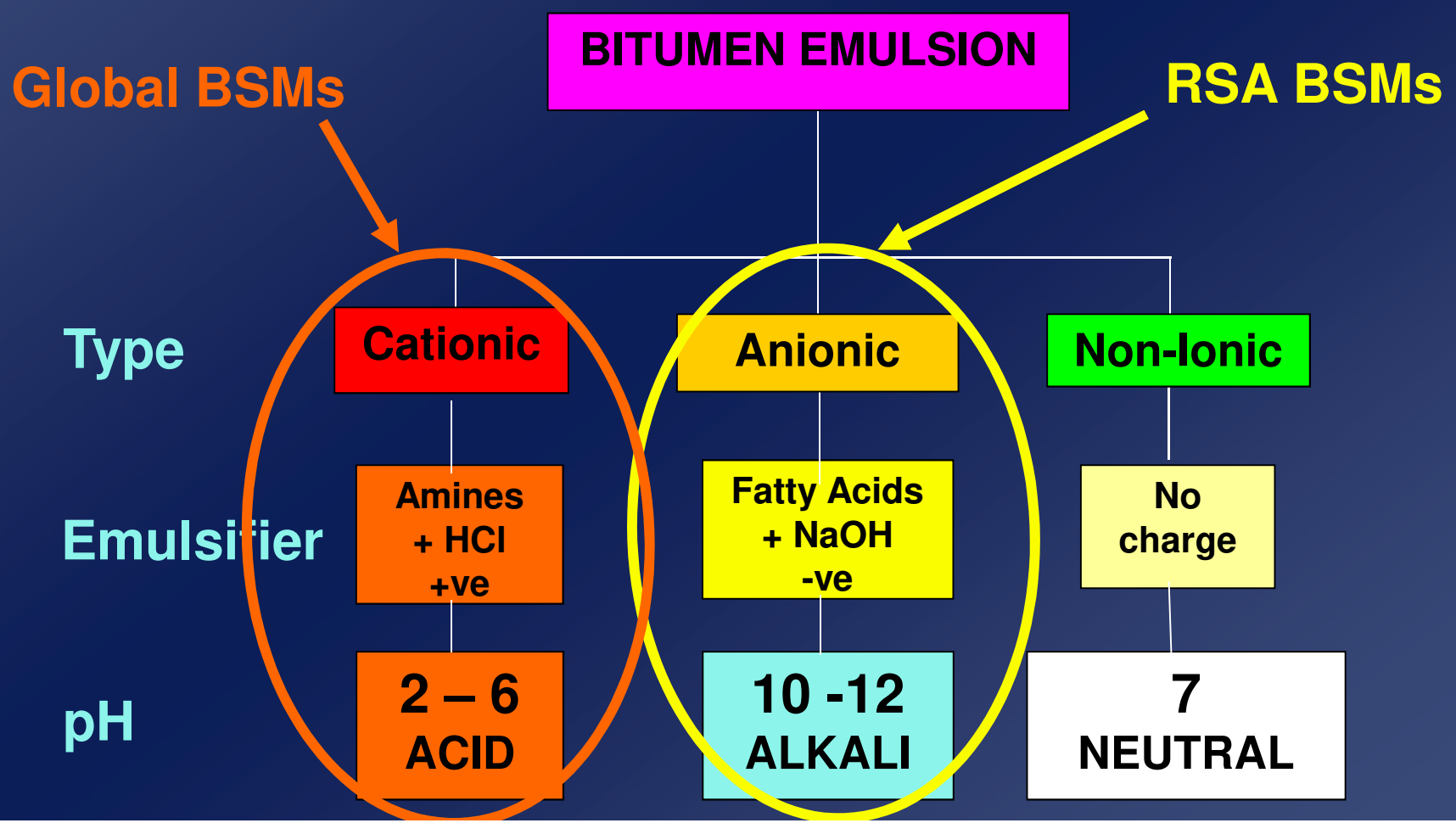
Bitumen Emulsion



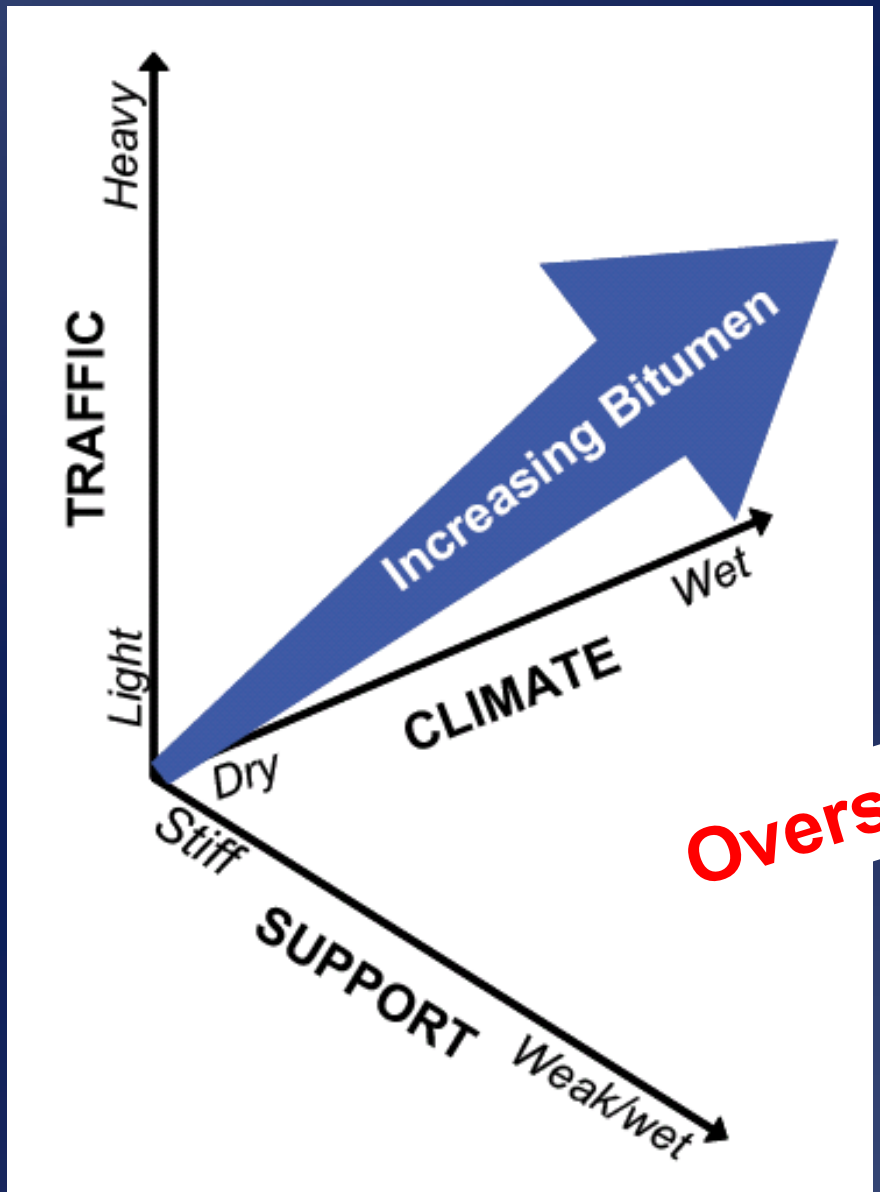


Oil in water emulsion (O/W)

Bitumen Emulsion Types



Factors influencing mix design

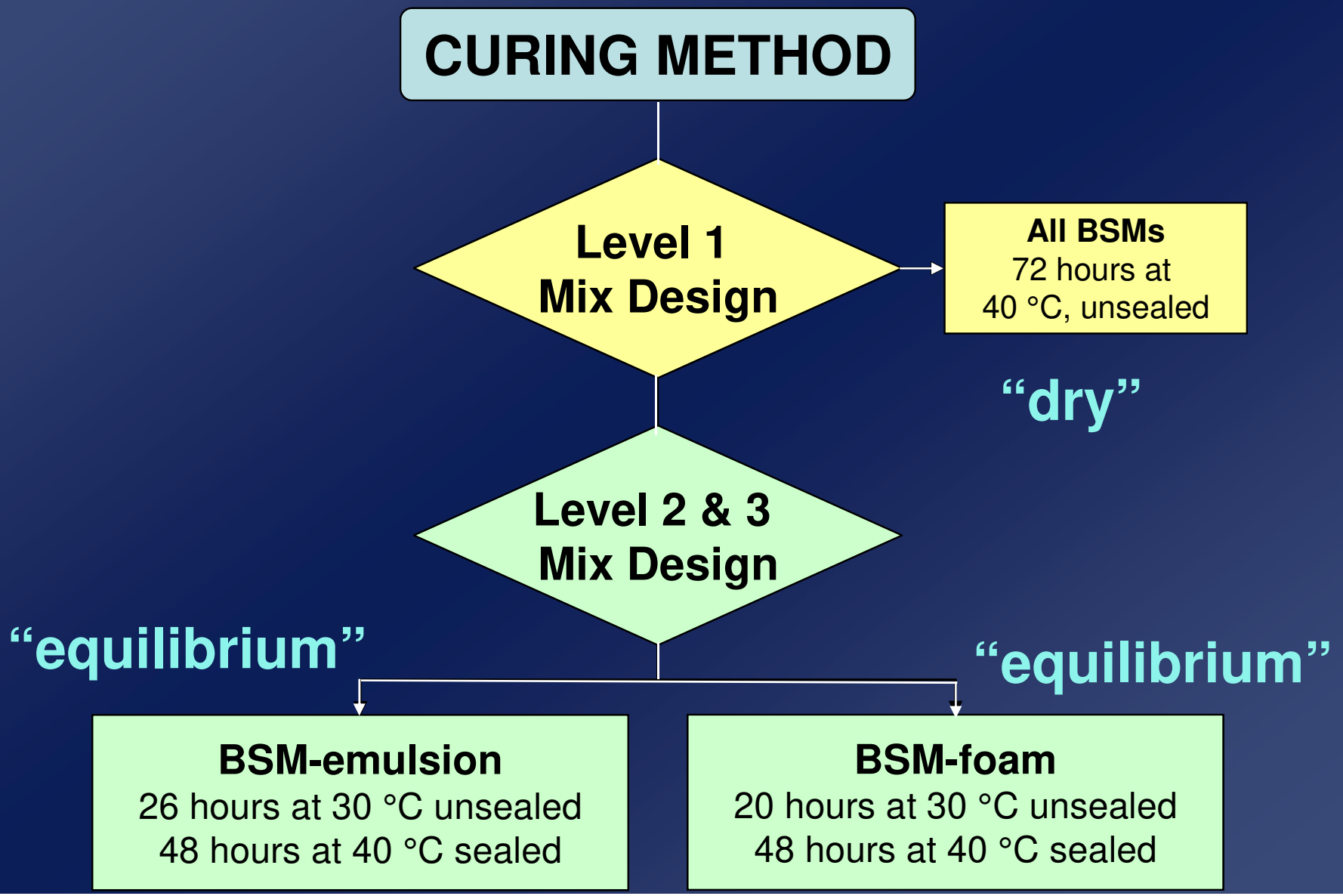


Oversimplified?

TEMPERATURE

MOISTURE

Curing Protocol $TG2_{2009}$



Curing Protocol (BSM lab)

Conditions Simulated

"dry"

Constant mass @ 40°C

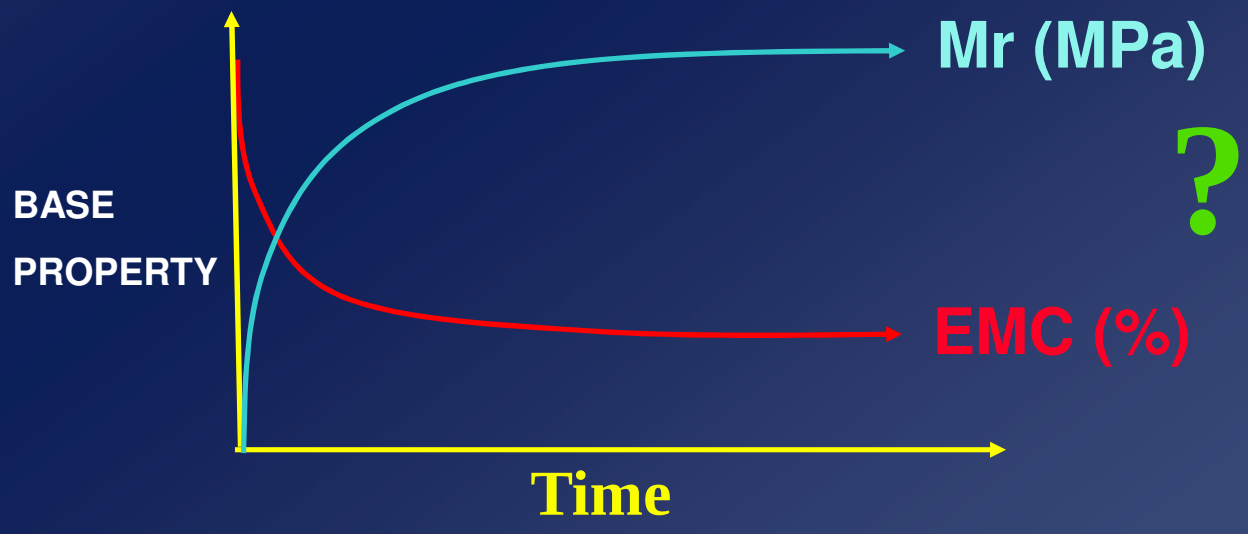
"wet"

Soak 24hrs @ 25°C

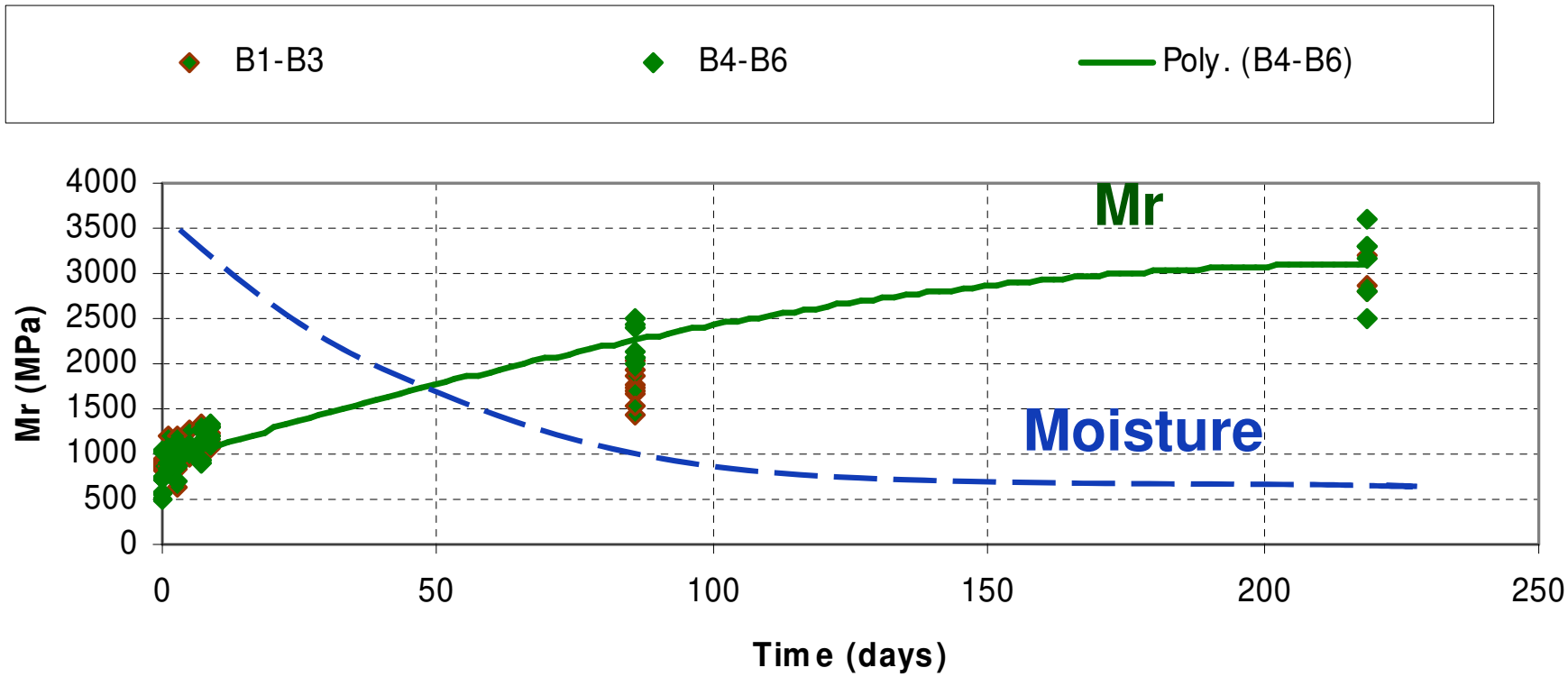
"equilibrium"

60% of OMC @ 40°C, seal

CURING: FIELD VALIDATION

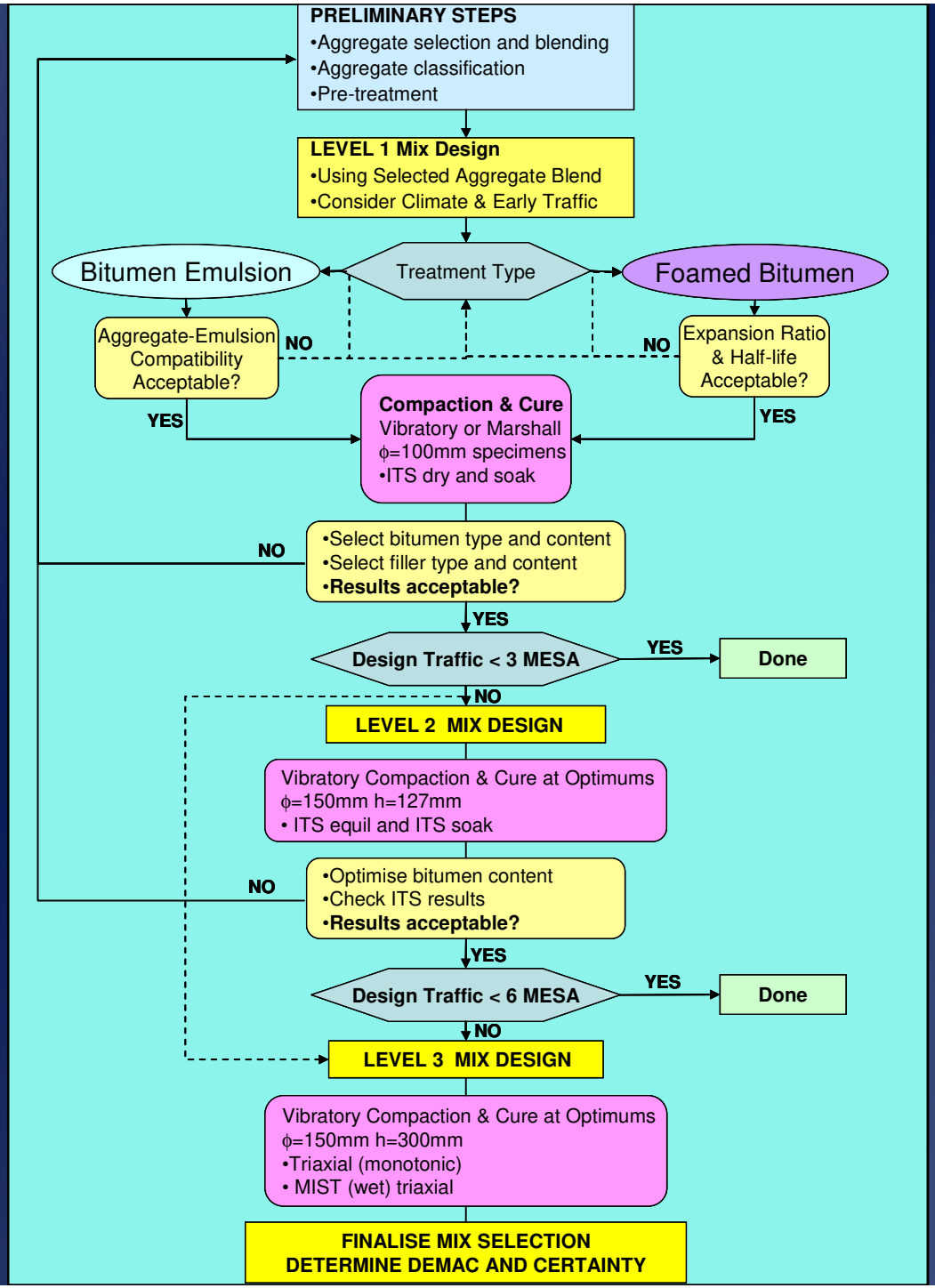


Mr (field) versus cure

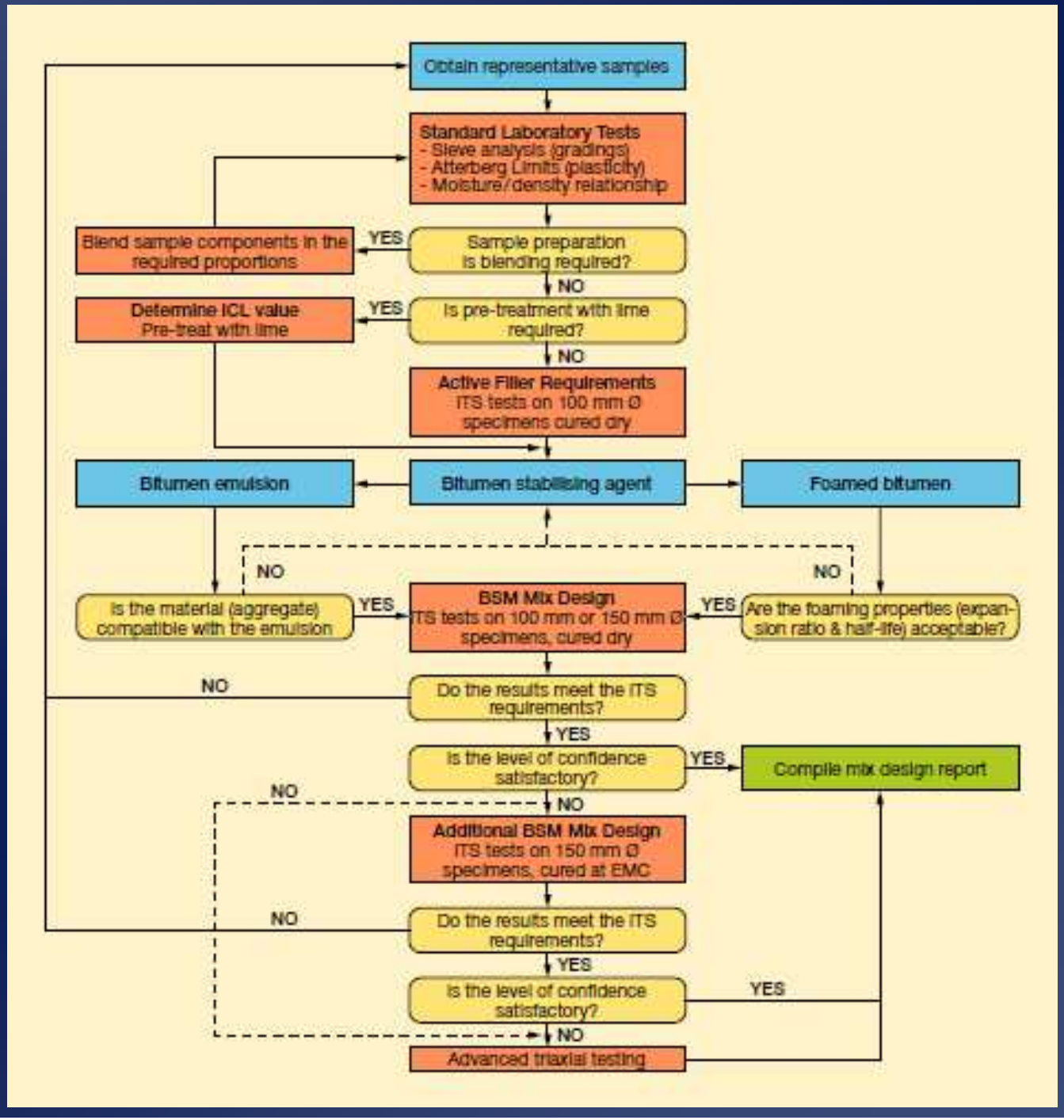


MIX DESIGN

Mix Design (TG2, 2009)



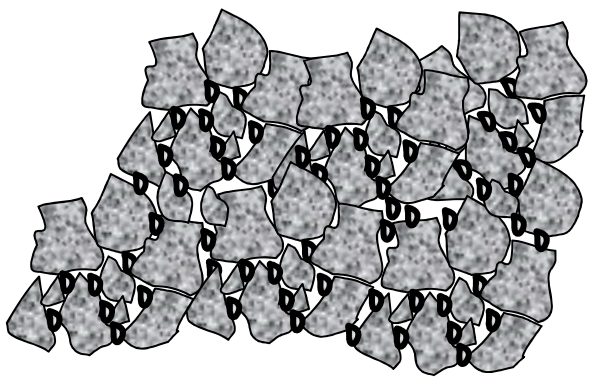
Mix Design (Wirtgen, 2012)



Testing the Material

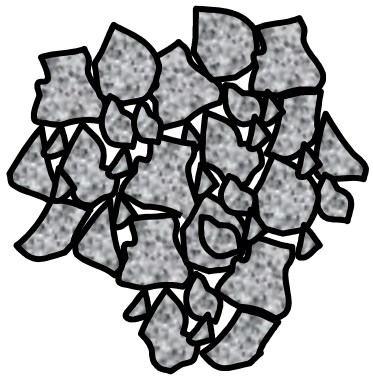
Bitumen Stabilised Material

Non-continuously bound



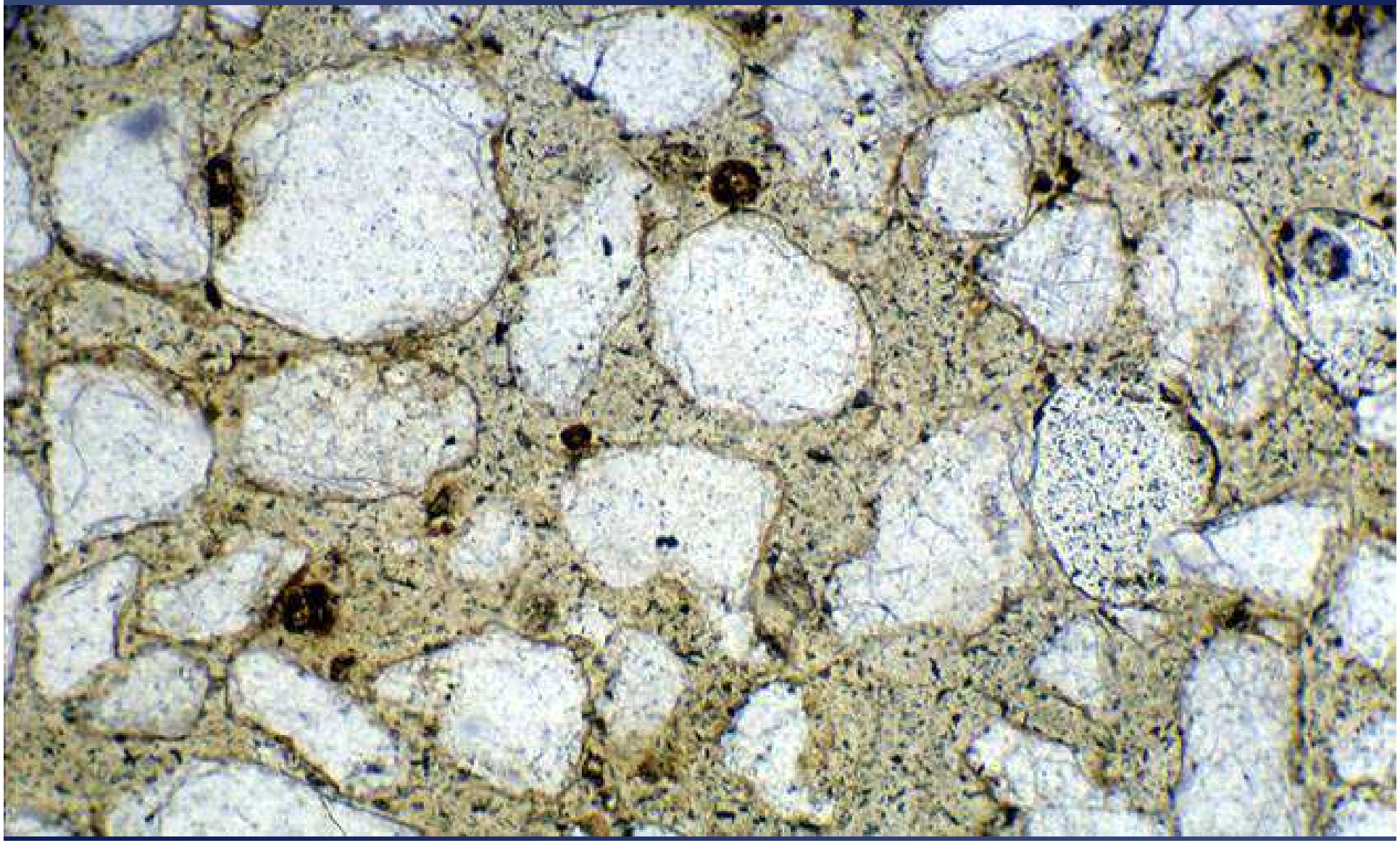
Asphalt

Continuously bound

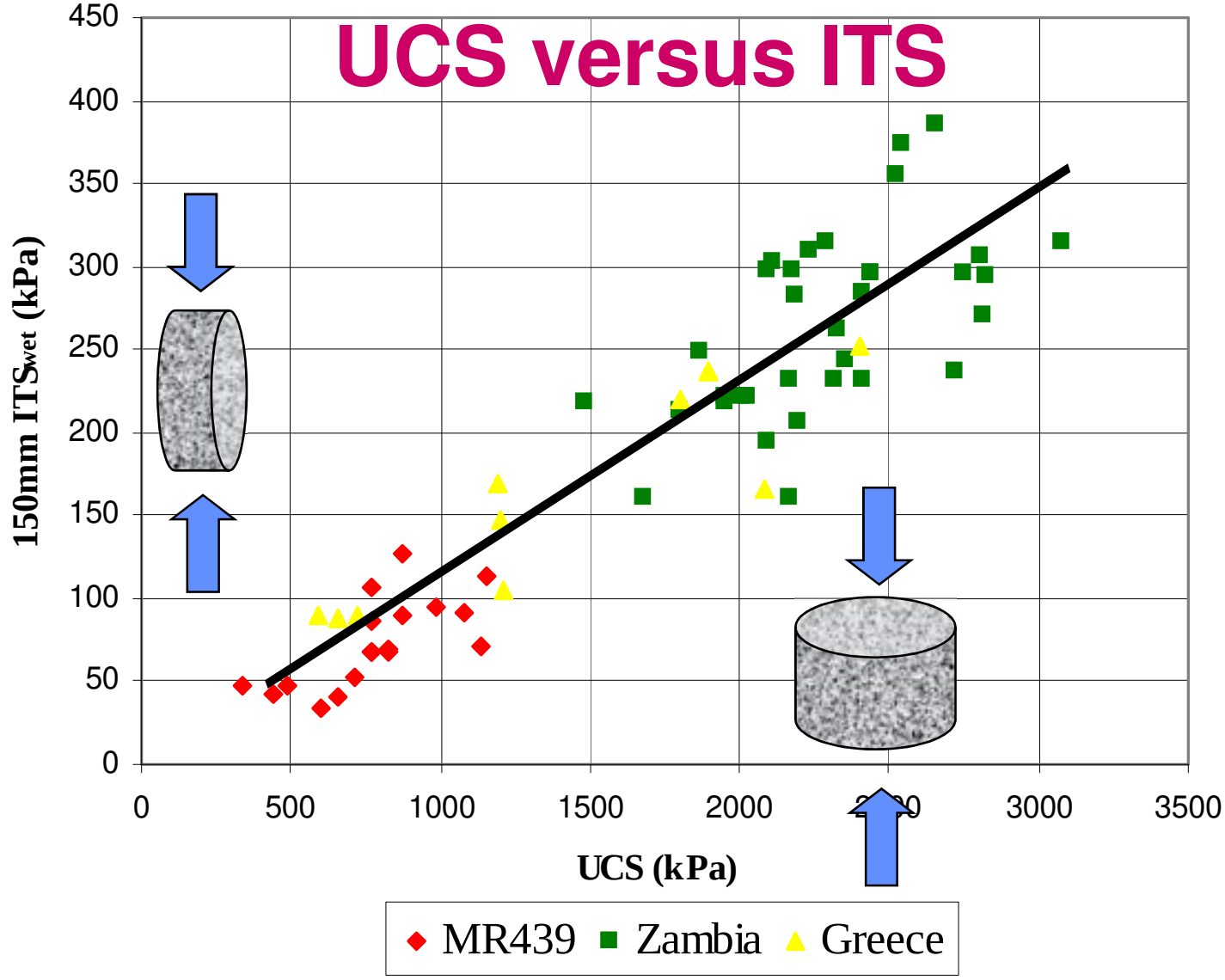


DIFFERENT BEHAVIOUR PATTERNS

BSM = non-continuously bound



Developing the Right Tools



Mix Design Approach (TG2, 2009)

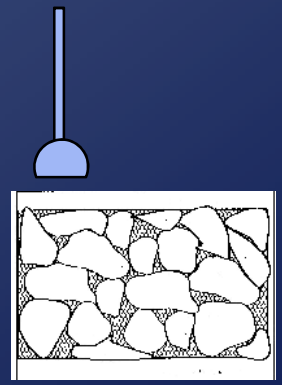
- Preliminary tests
  - Grading, MDD, OMC, Atterberg Limits (PI)
- Level 1
  - 100mmϕ Marshall ITS
  - Binder, Active filler
- Level 2
  - 150mmϕ ITS for OBC
  - > 3 MESA refine OBC
- Level 3
  - 150mmϕ 300H Triaxial
  - >6 MESA reliability

2013 BSM Stabilisation Design$_1$

Natural Material Charactr

Step 1

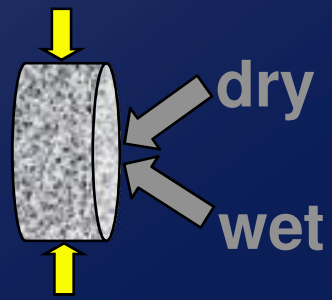
150mmϕ



Grading

Moisture density (Mod)

Atterberg Limits (PI)



3 reps

Typical Bitumen %

ITS – select active filler

0% 1%Lime 1%Cem

Typical Bitumen % for BSM-foam

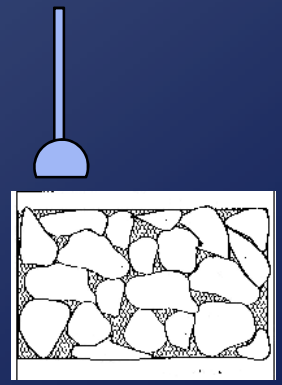
Guidelines for estimating optimum foamed bitumen addition			
Fraction passing 0.075 mm sieve (%)	Foamed bitumen addition (% by mass of dry aggregate)		Typical type of material
	Fraction passing 4.75 mm sieve		
	< 50%	> 50%	
< 4	2.0	2.0	Recycled asphalt (RA/RAP)
4 – 7	2.2	2.4	RA/Graded crushed stone/ Natural gravel/blends
7 – 10	2.4	2.8	
> 10	2.6	3.2	Gravels/sands

Typical Bitumen % BSM-emulsion

Guidelines for estimating optimum bitumen emulsion addition (60% residual bitumen)			
Fraction passing 0.075 mm sieve (%)	Bitumen emulsion (Residual bitumen) addition (% by mass of dry aggregate)		Typical type of material
	Fraction passing 4.75 mm sieve		
	< 50%	> 50%	
< 4	3.3 (2.0)	3.3 (2.0)	Recycled asphalt (RA/RAP)
4 – 7	3.7 (2.2)	4.0 (2.4)	RA/Graded crushed stone/ Natural gravel/blends
7 – 10	4.0 (2.4)	4.7 (2.8)	
> 10	4.3 (2.6)	5.3 (3.2)	Gravels/sands

2013 BSM Stabilisation Design$_1$

Natural Material Charactr



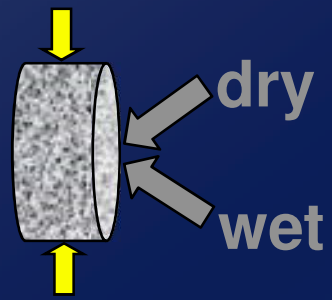
Grading

Moisture density (Mod)

Atterberg Limits (PI)

Step 1

150mmϕ



3 reps

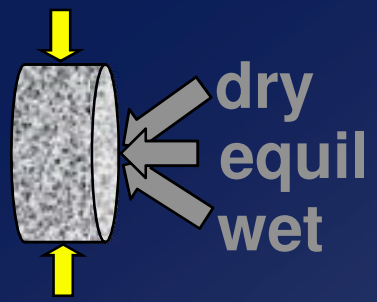
Typical Bitumen %

ITS – select active filler

0% 1%Lime 1%Cem

Step 2

150mmϕ



3 reps

Selected active filler

Bit %

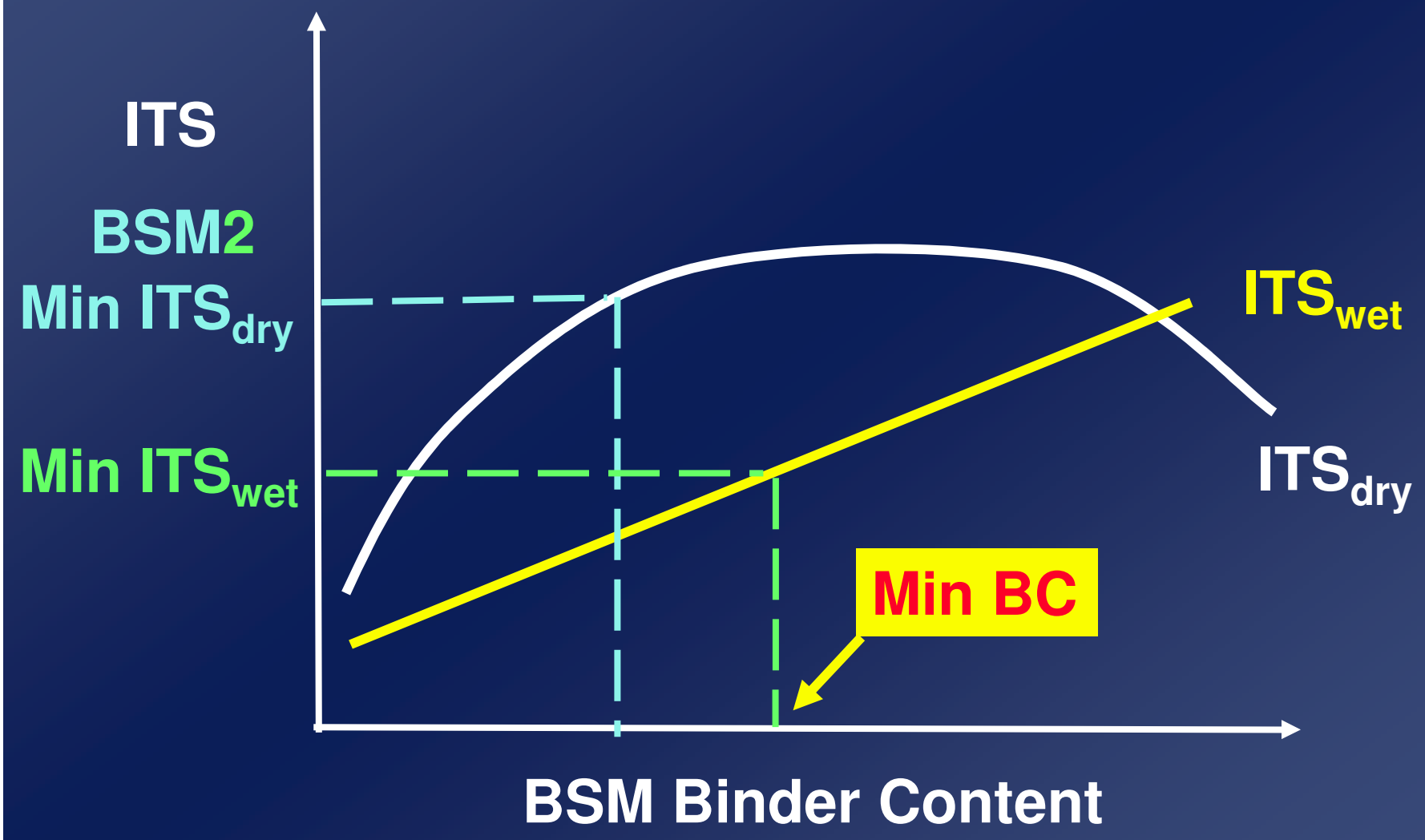
ITS – select bitumen %

-0.4% -0.2% 0% +0.2%

Recommended BSM classes based on ITS test results			
	Class 1	Class 2	Not suitable
Parent material: Test result from Mix Design	RAP and GCS RAP/GCS blend RAP/GCS/gravel	Material blends Natural gravel Marginal materials	Poor gravels Plastic materials Soils
ITS_{DRY} Both 100 mm and 150 mm Ø specimens	> 225 kPa	125 to 225 kPa	< 125 kPa
ITS_{WET} & ITS_{SOAK} Both 100 mm and 150 mm Ø specimens	> 100 kPa	50 to 100 kPa	< 50 kPa
ITS_{EQUIL} 150 mm Ø specimens only	> 175 kPa	95 to 175 kPa	< 95 kPa
Implied shear properties			
Cohesion	> 250 kPa	> 50	< 50
Angle of internal friction	> 40°	> 25°	< 25°
Implied parent material properties			
California Bearing Ratio (CBR)	> 80%	>20%	< 20%
Plasticity Index (PI)	< 10	< 15	> 15

Ref: (Wirtgen, 2012)

Binder type & content – Level 1

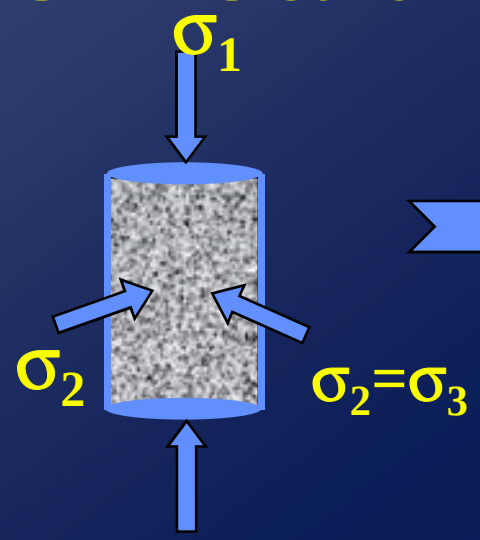


2013 BSM Stabilisation Design$_3$

Step 3

150mmϕ

300mmH



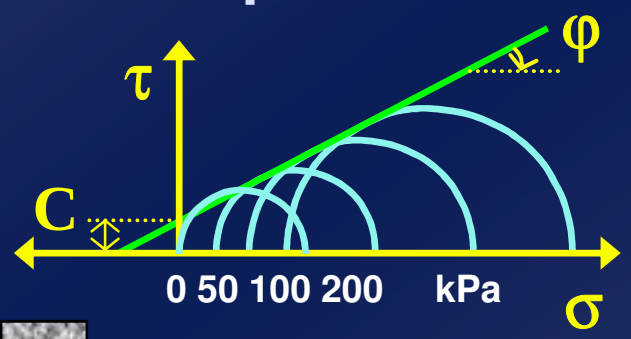
Final mix selection

Reliable performance related properties

Flexibility?

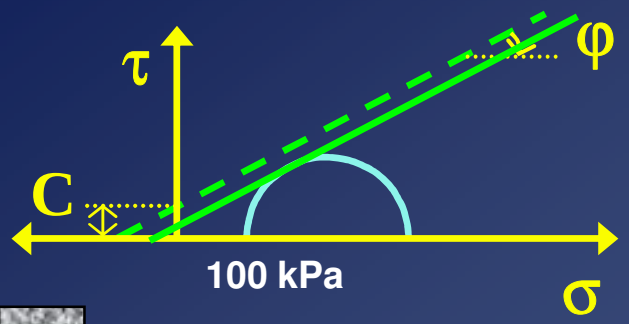
Triaxial: Shear properties

Equilibrium



4 σ_3 x 2 reps = 8 specimens

Wet



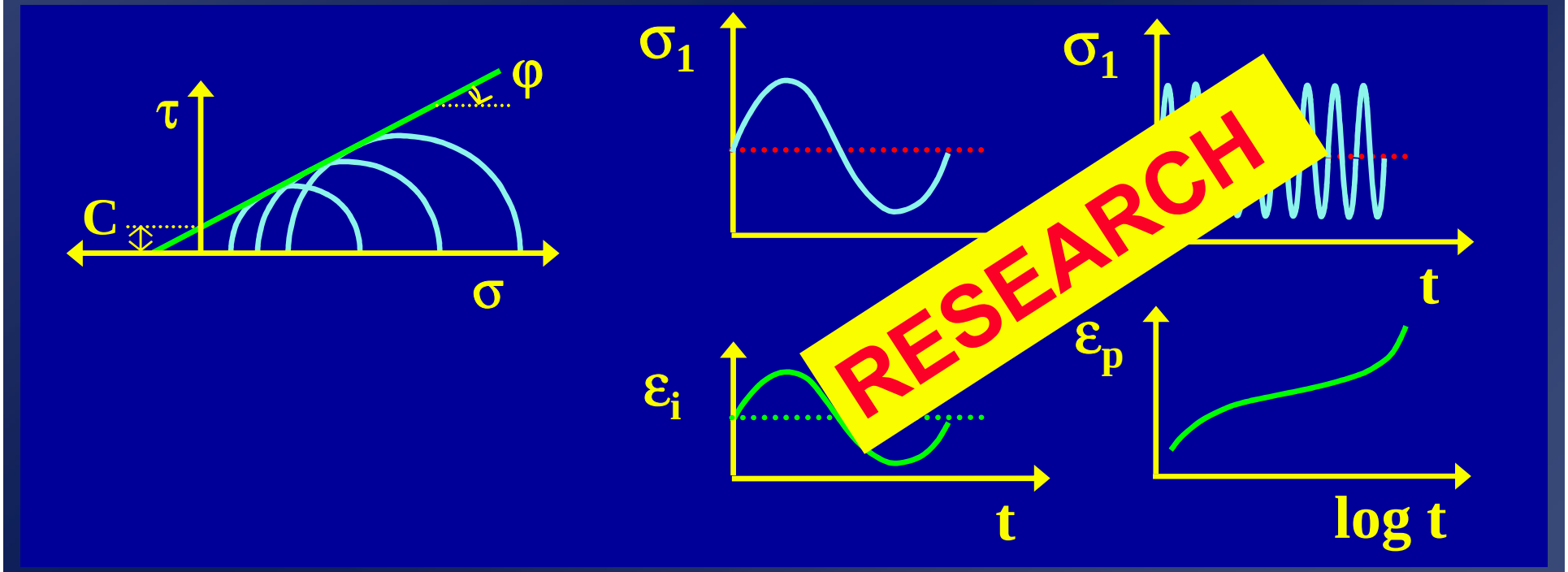
1 σ_3 x 2 reps = 2 specimens

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}

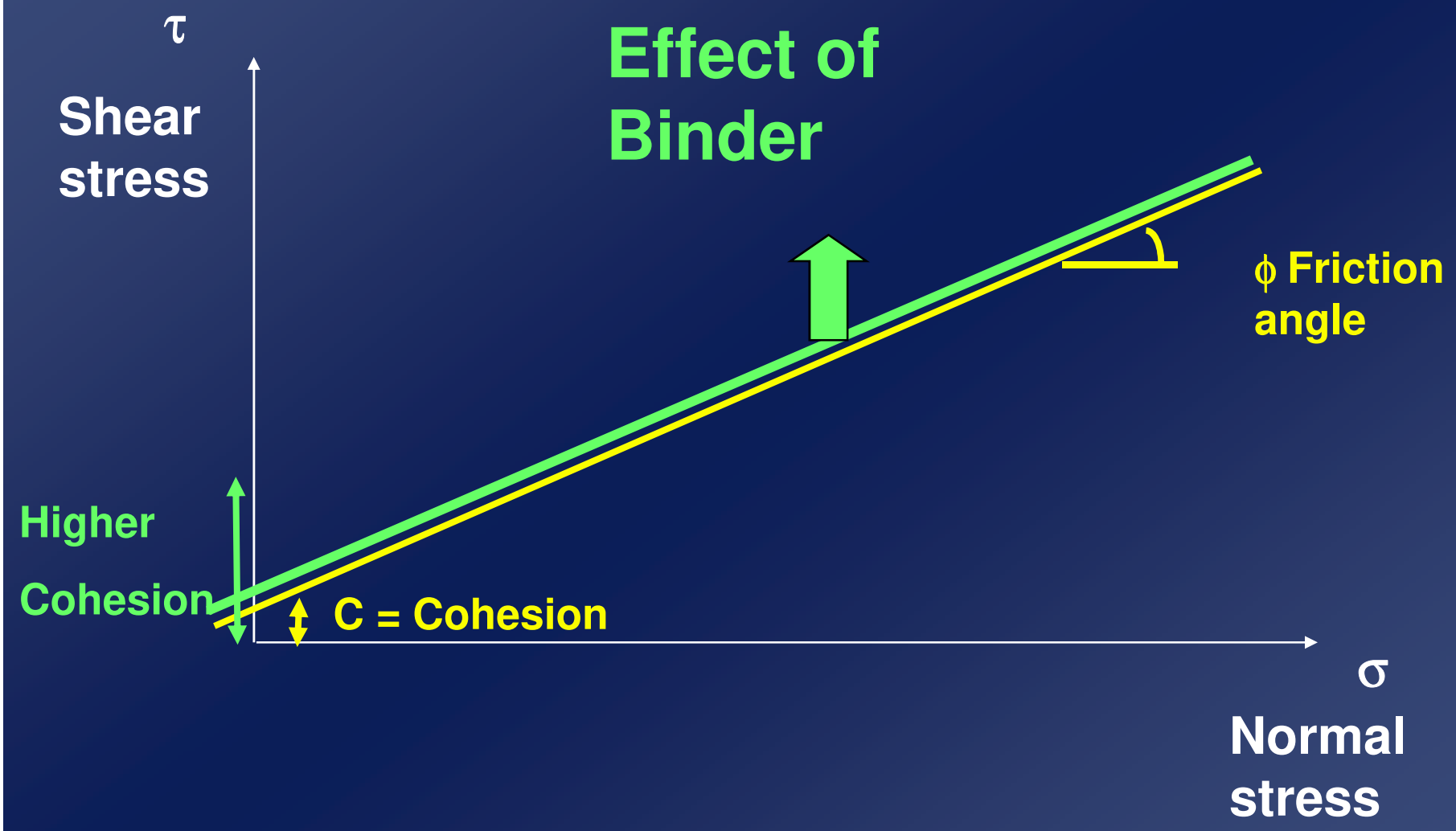
Critical Material Properties

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



Triaxial Testing

Effect of using BSM

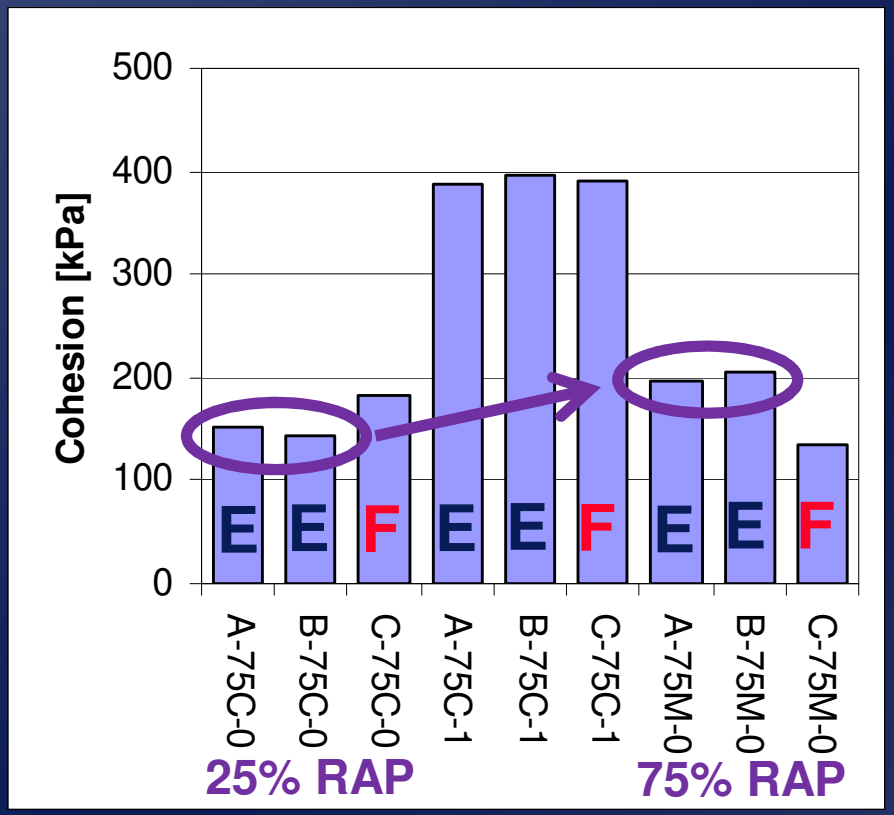


Typical target binder contents

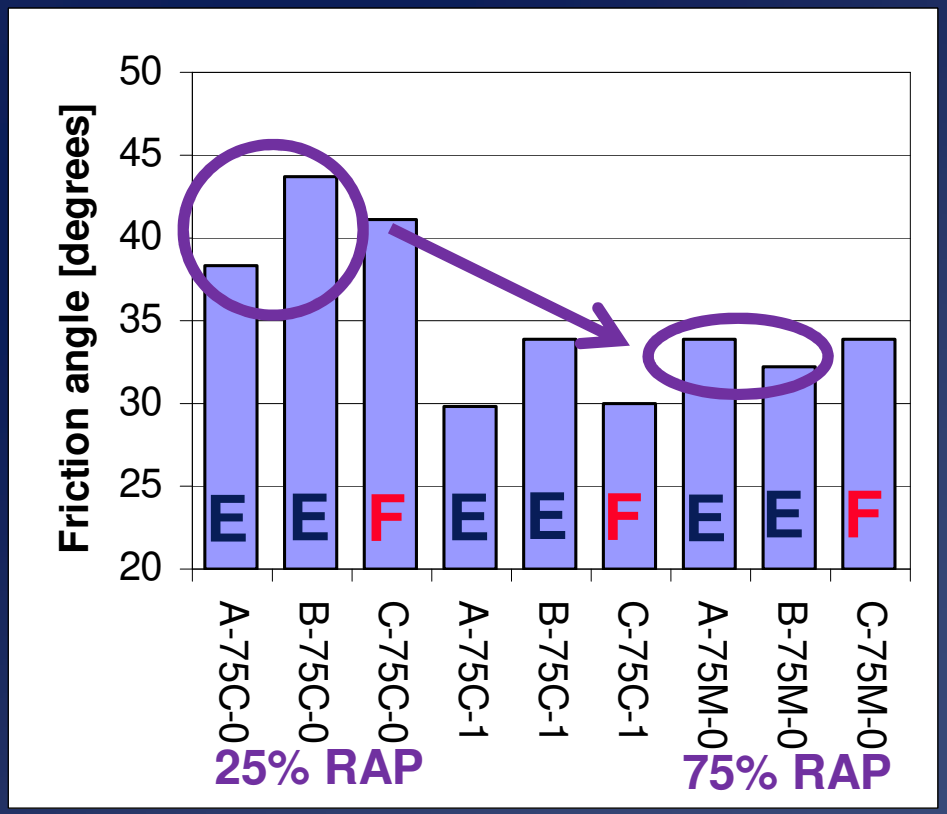
	>75% RAP + Cr Dust	Granular GM > 2	Granular GM < 2
Typical Binder Cont. (%)	2%	2.5%	3%

Shear properties (monotonic triaxial at 25°C)

Cohesion C

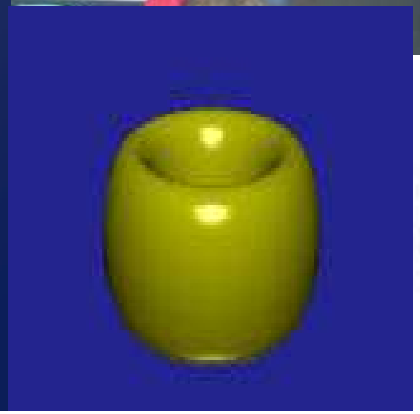


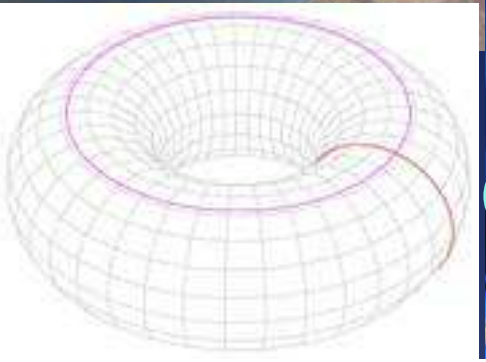
Friction Angle ϕ



Ebels

Simple triaxial trials - with latex membrane as confining tube

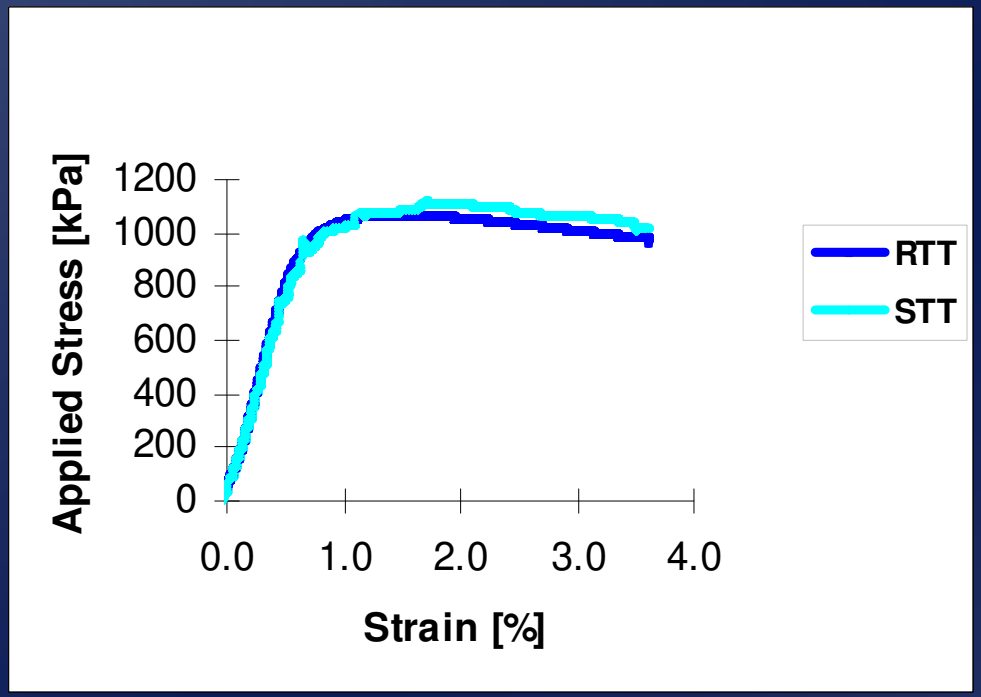


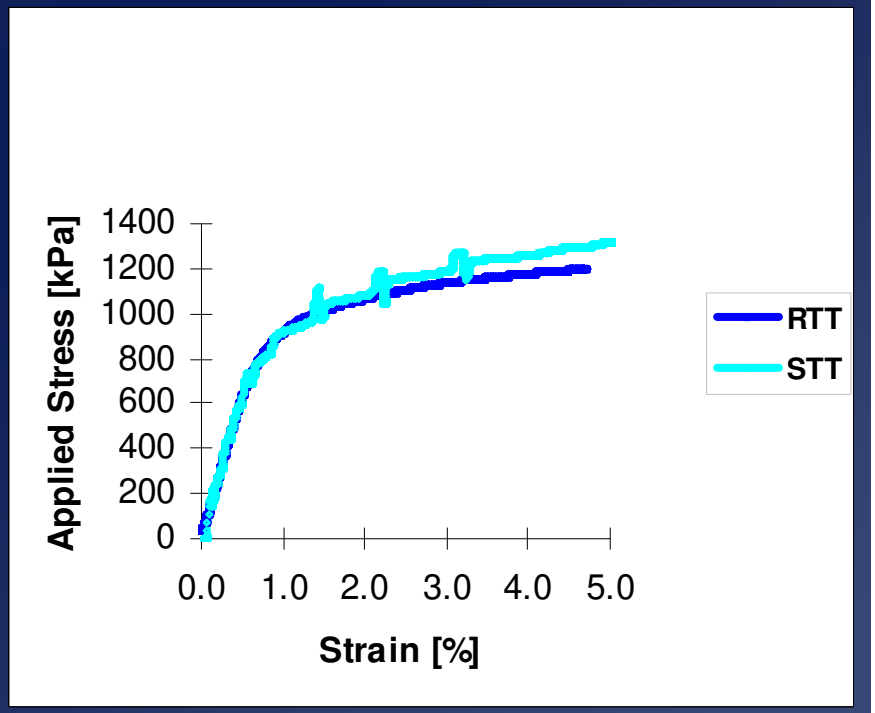


(Mulusa)

New “Simple triaxial”

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**

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

MOISTURE DAMAGE

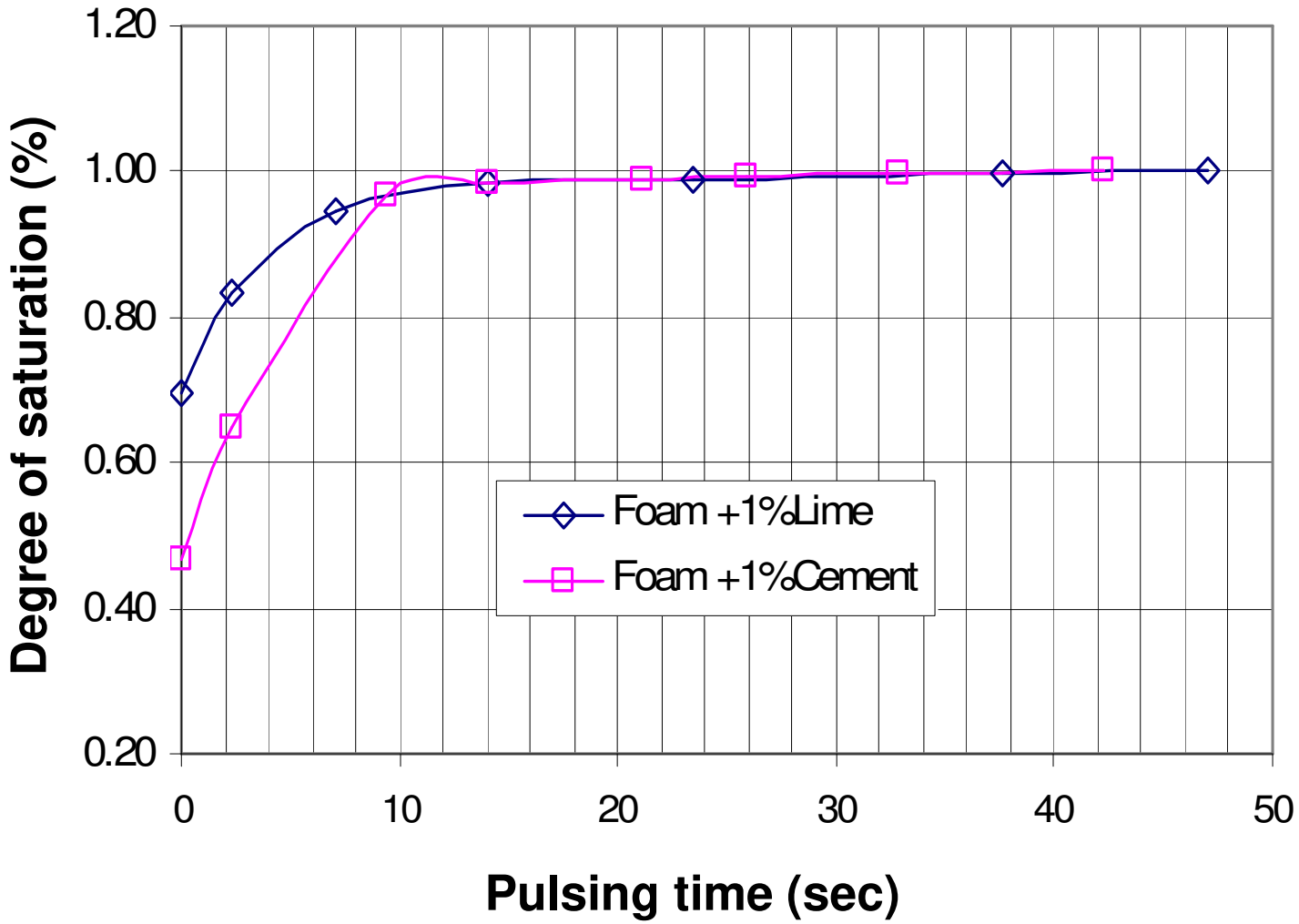
Durability of BSMs: Improved Tests

- Untreated Material Properties
- Moisture sensitivity tests

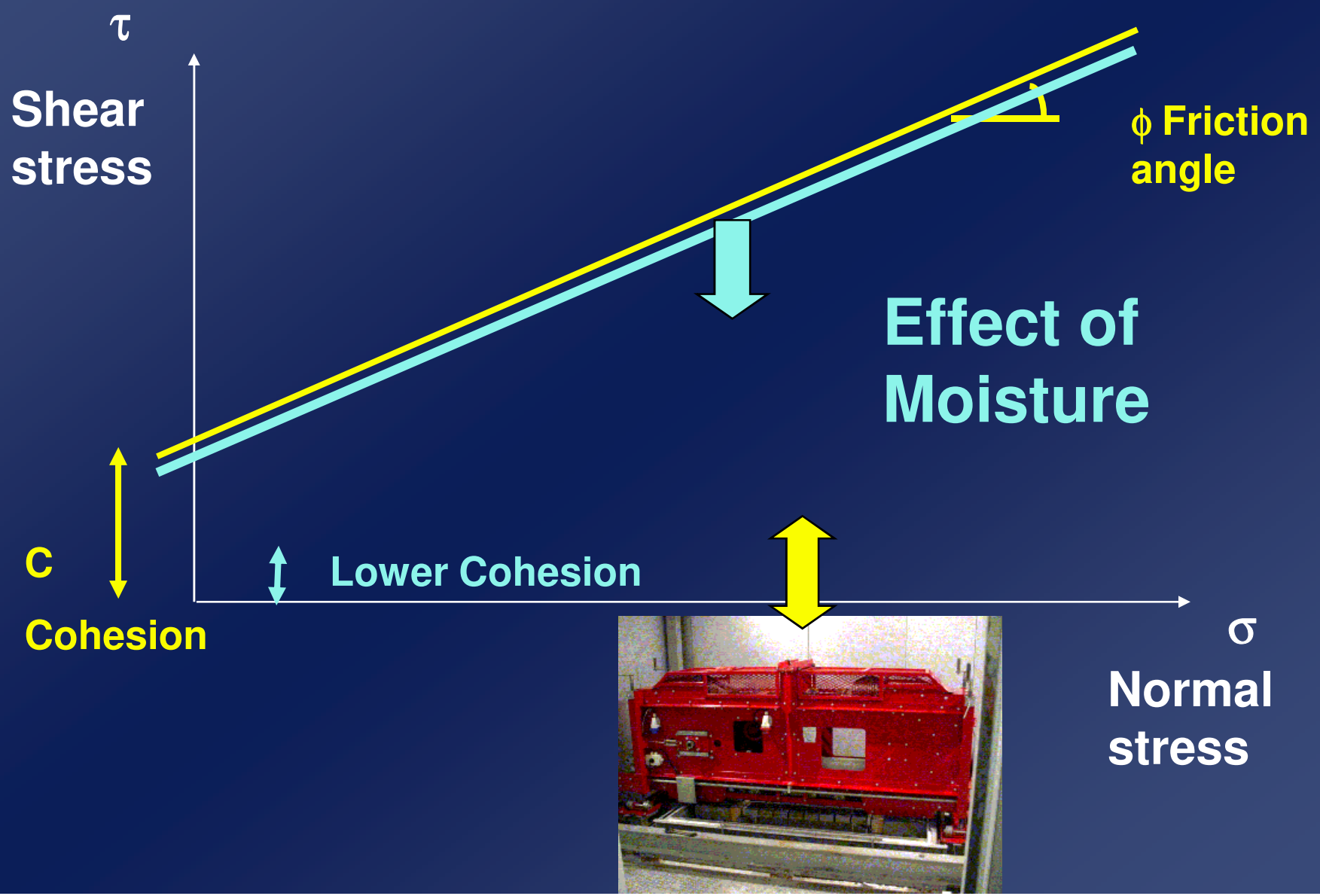
Moisture Induction Sensitivity Test MIST

(Twagira)

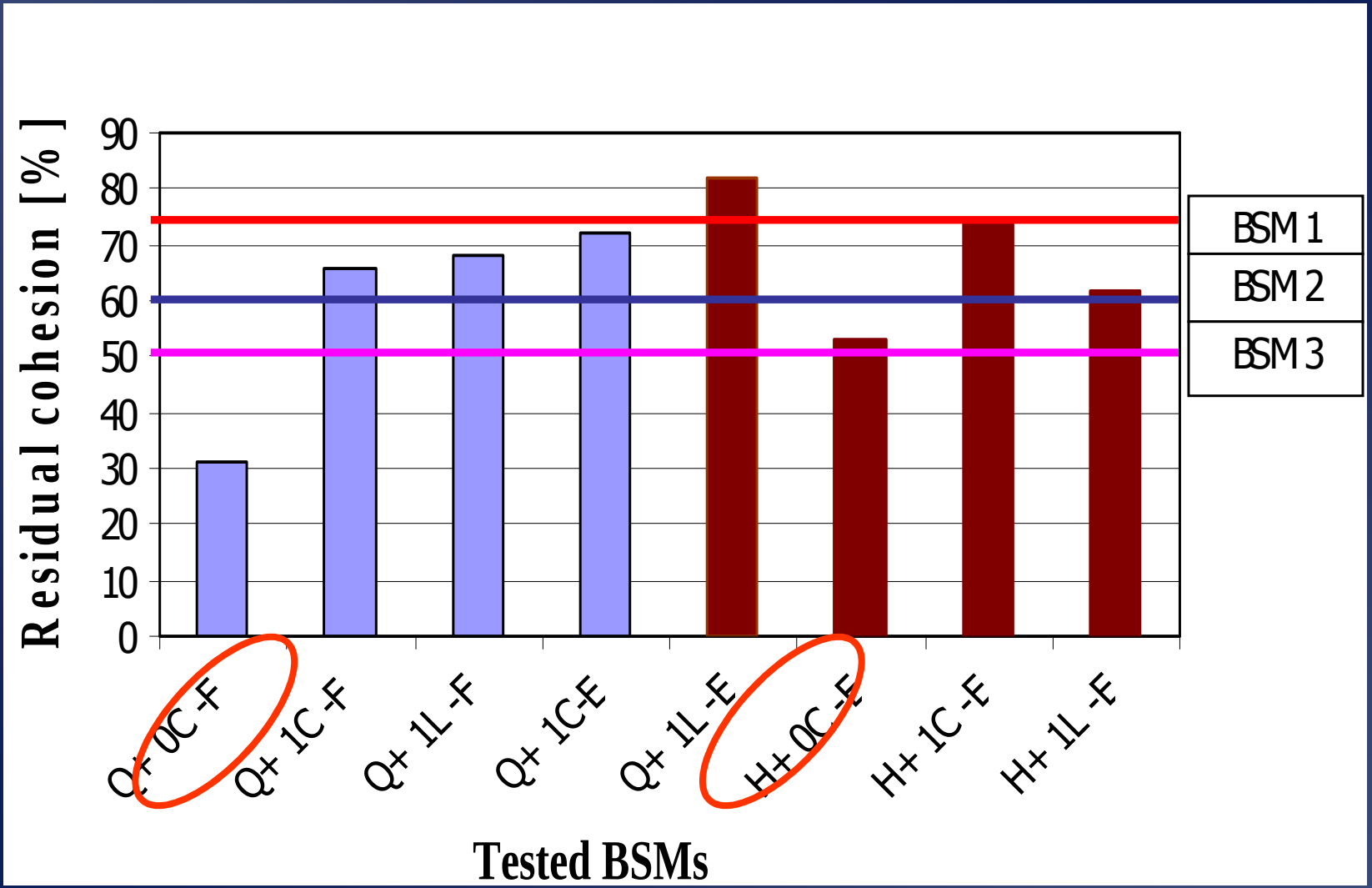
MIST saturation time



Effect of moisture



Retained Cohesion (Twagira)

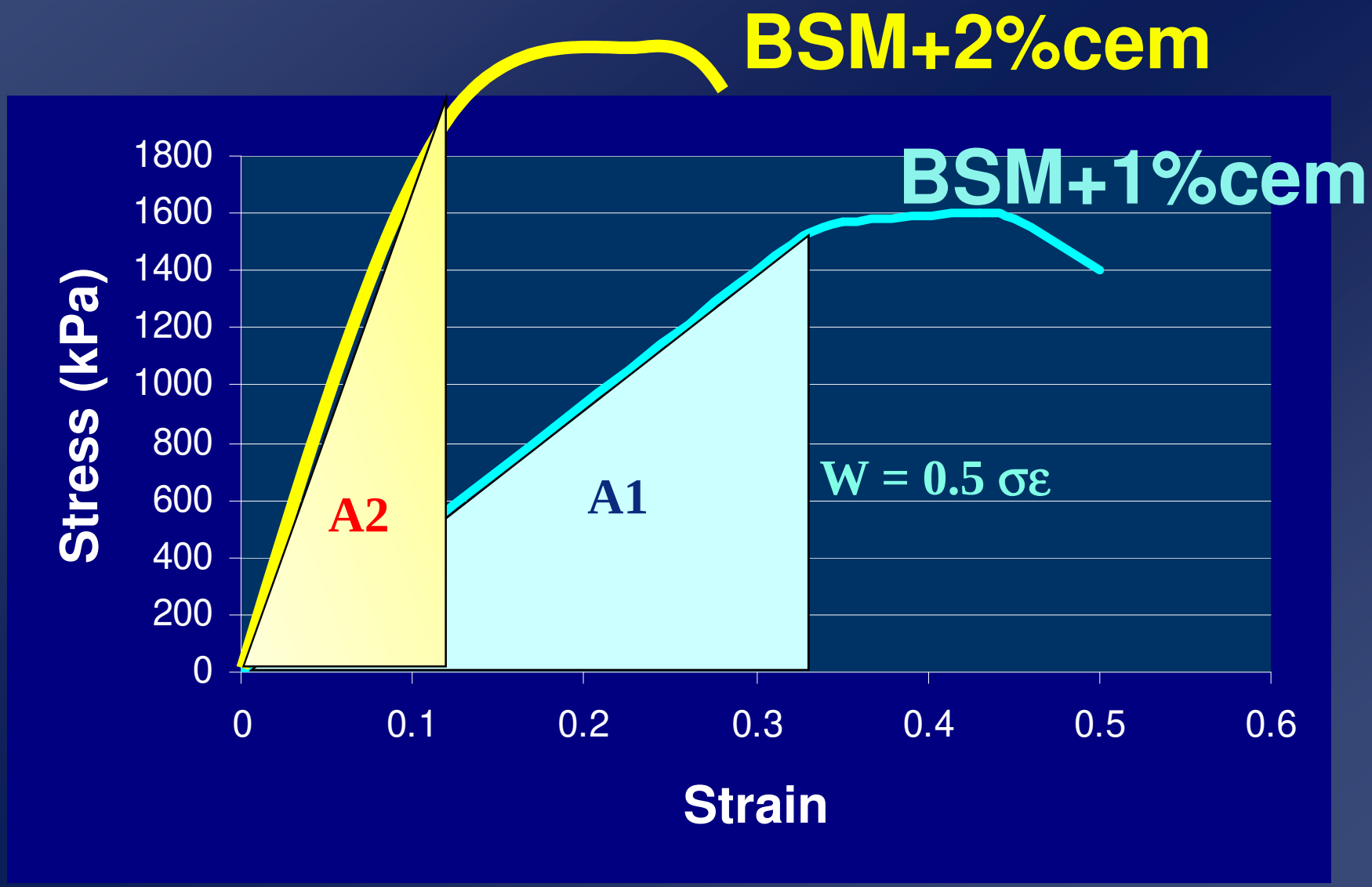


BSM Classification ito Moisture Resistance

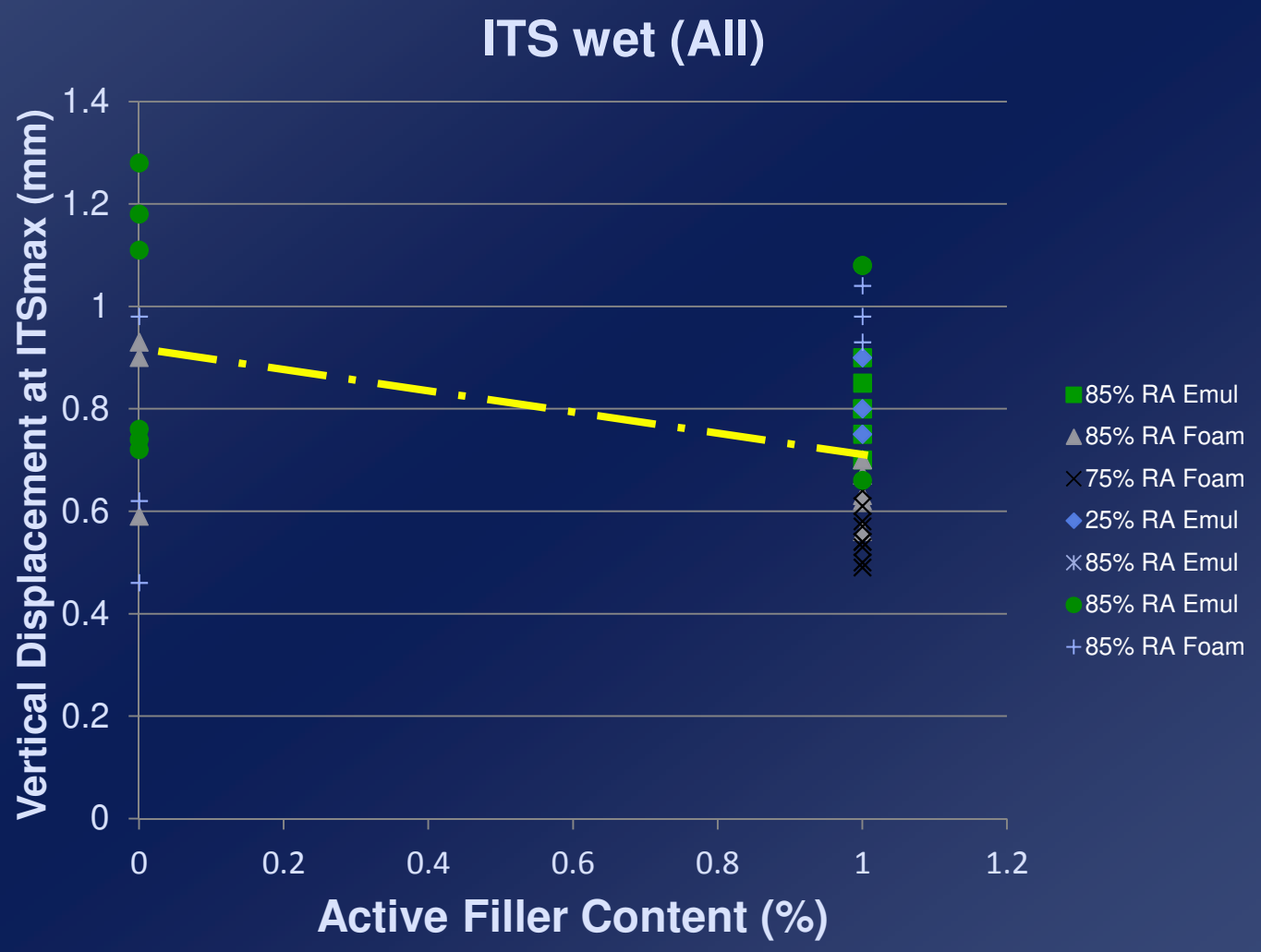
Equivalent BSM Class	Retained Cohesion (%)
BSM 1	> 75
BSM 2	60 – 75
BSM 3	50 – 60
Unsuitable	< 50

SUPPORT

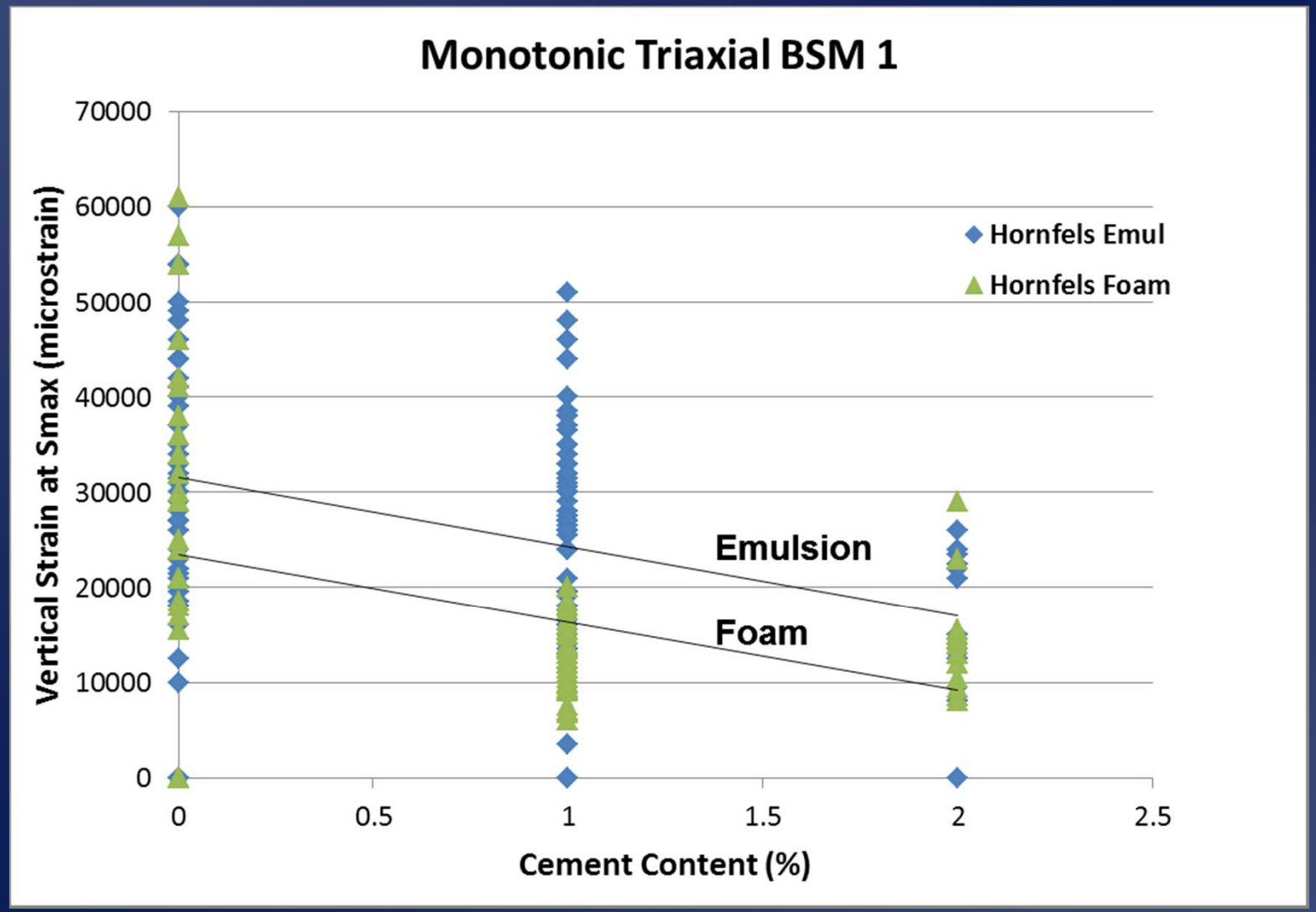
Dissipated Energy



ITS displacement measures
(from Mix Design)

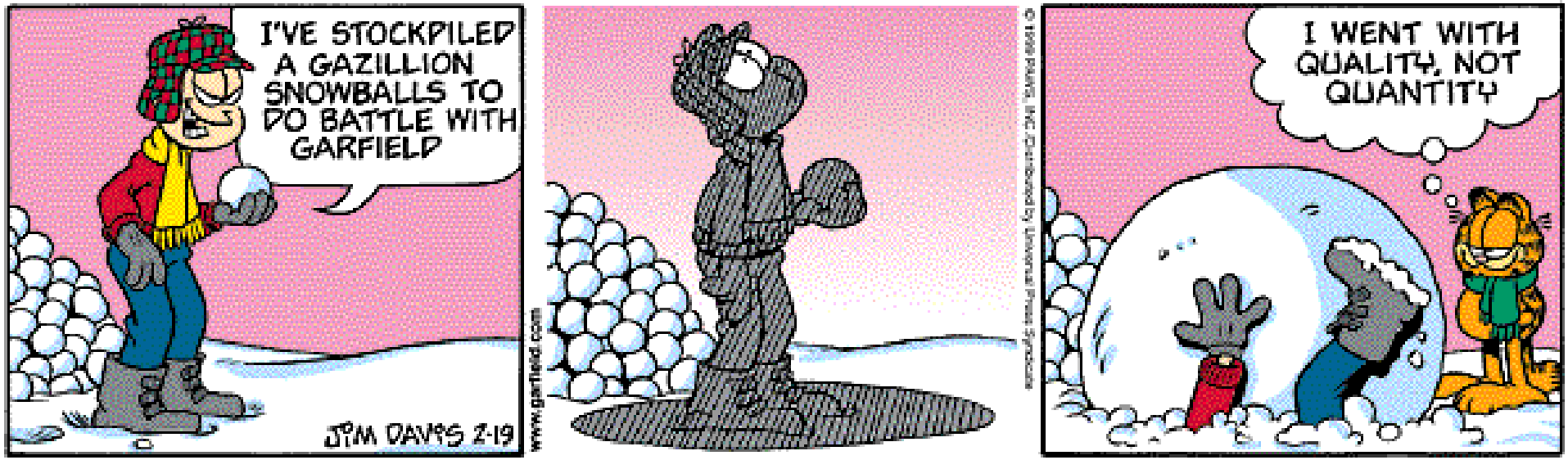


Triaxial data from Mix Design



Can refine by separating data based on σ_3

So we need quality from structural design



Conclusions

- Understanding of material behaviour of BSMs has increased significantly
- Active filler versus bitumen content is very important
- More advanced test methods (triaxial)
- Mix Design is linked to Structural Design method for BSMs

Thank you