Bitumen Stabilised Materials: Will theory and practice ever meet?

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AAPA Brisbane, Australia
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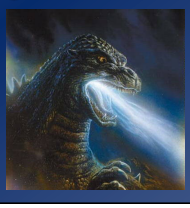
Stellenbosch Univ.

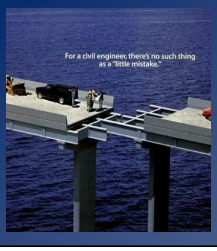
Acknowledgements

- Alan Lynch (main author) Royal Haskoning DHV
- SANRAL through SAPDM aka "Godzilla"



Theory versus Practice

Theory ? Practice



Skills Gap

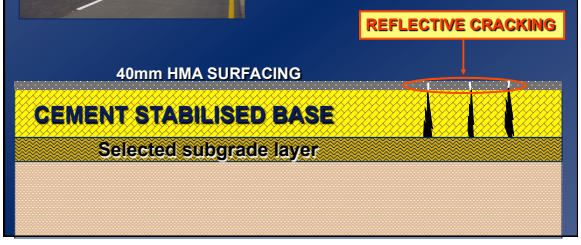
Human Resources Theory vs Practice

Researcher

Contractor

Early South African pavements

Technical Challenges



The South African "inverted" pavement

The Concept

CRACK PREVENTION LAYER

40mm HMA SURFACING

CRUSHED STONE BASE

CEMENT STABILISED SUBBASE

Selected subgrade layer

HIGHER COMPACTION | HIGHER Mr | WATER!!!!

The South African "upside-down" pavement

Distress Mode?

Unbound base

Permanent deformation (shear/ruts)

Fatigue (cracking)

The Upgrade

Durability??

40mm HMA SURFACING

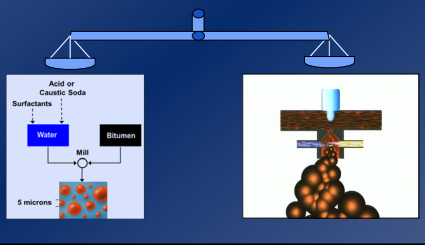
BITUMEN STABILISED BASE

CEMENT STABILISED SUBBASE

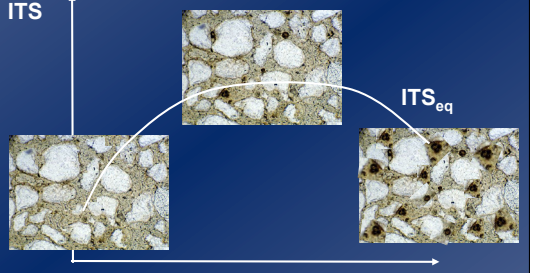
Selected subgrade layer

Key Characteristics

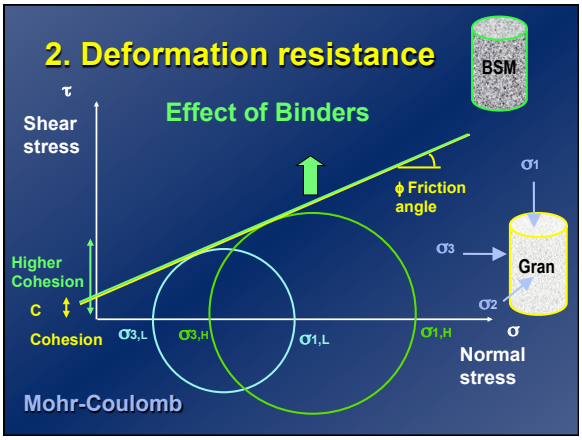
Bitumen Stabilised Materials



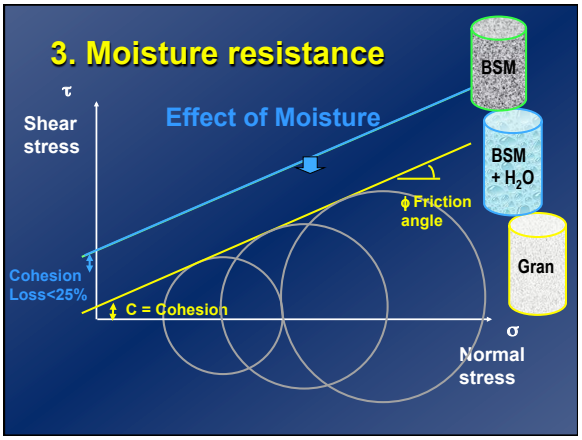
1. Non-continuously bound (bitumen saturation)



2. Deformation resistance

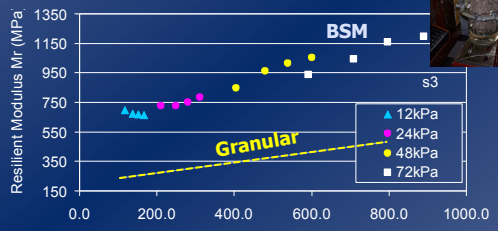


3. Moisture resistance

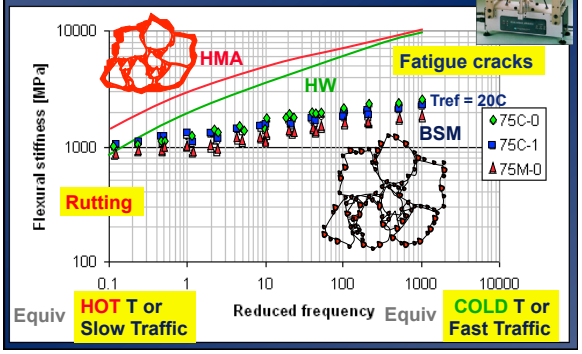


4. Stress dependency (BSM-foam)

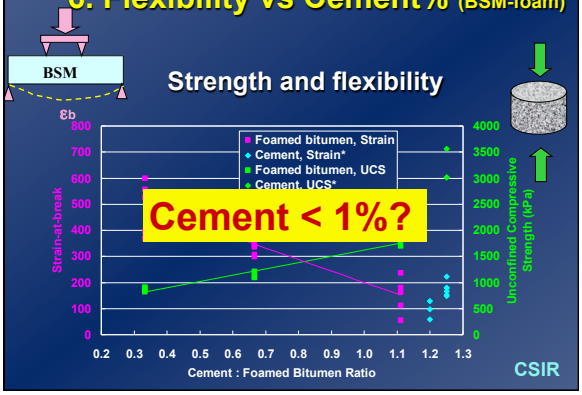
- Foamed Bitumen = 2% in CDW



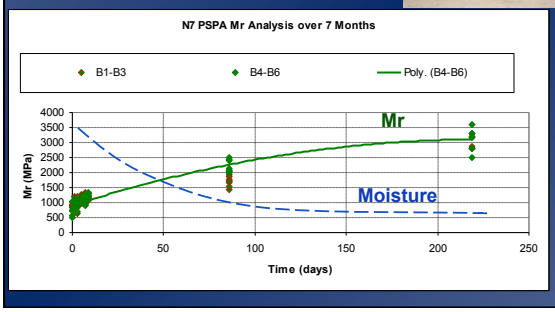
5. Visco-elasticity (BSM-foam)

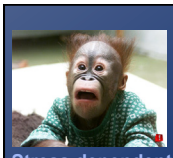


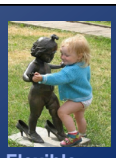
6. Flexibility vs Cement% (BSM-foam)



7. Time and moisture dependency (BSM-emulsion)







Stress dependent

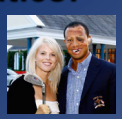
Flexible… with some rigidity

Evolutionary… time dependent

BSM is a material with multiple personalities!

Deformation Resistant

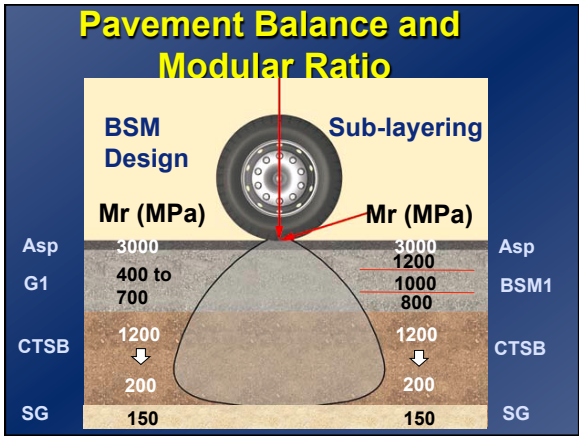
Time and moisture dependent

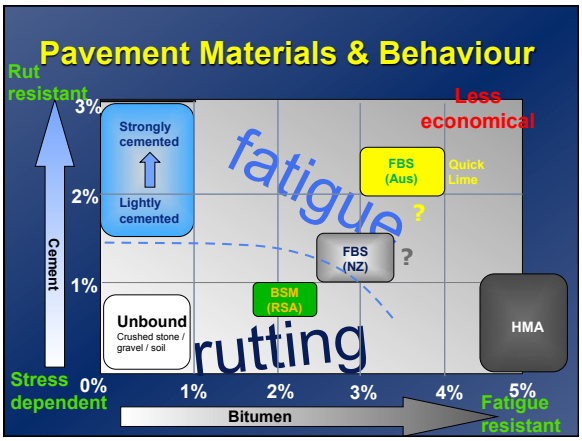


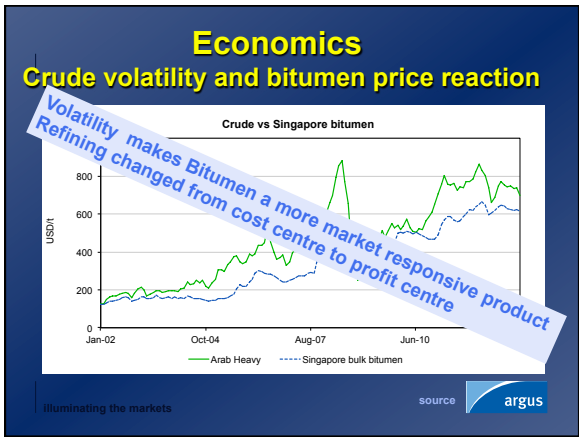
Durable?

… non-continuously bound?

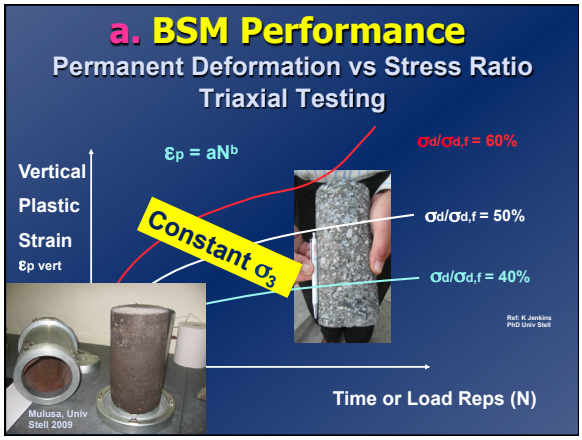

全面开通

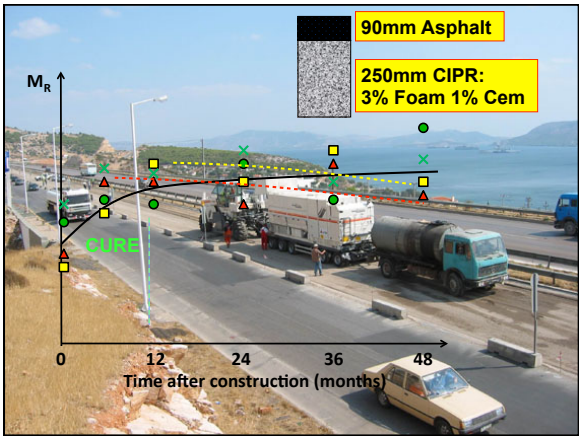

Pavement Balance and Modular Ratio
BSM Design
Sub-layering
Mr (MPa)
Mr (MPa)
Asp
G1
CTSB
SG
3000
400 to 700
1200
200
150
3000
1200
1000
800
1200
200
150
Asp
BSM1
CTSB
SG

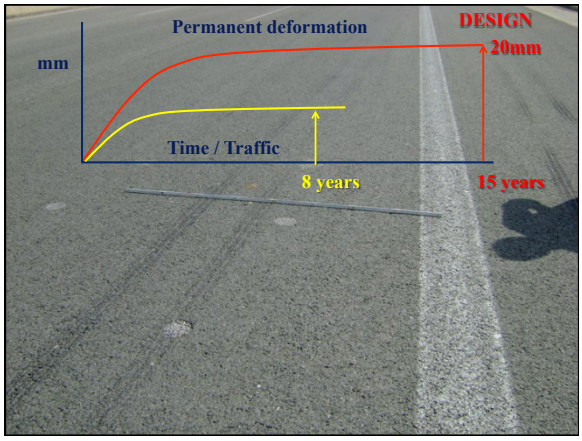

Pavement Materials & Behaviour
Rut resistant
Less economical
Strongly cemented
Lightly cemented
fatigue
FBS (Aus)
Quick Lime
FBS (NZ)
BSM (RSA)
Unbound
Crushed stone / gravel / soil
rutting
HMA
Cement
3%
2%
1%
Stress dependent
0%
1%
2%
3%
4%
5%
Bitumen
Fatigue resistant

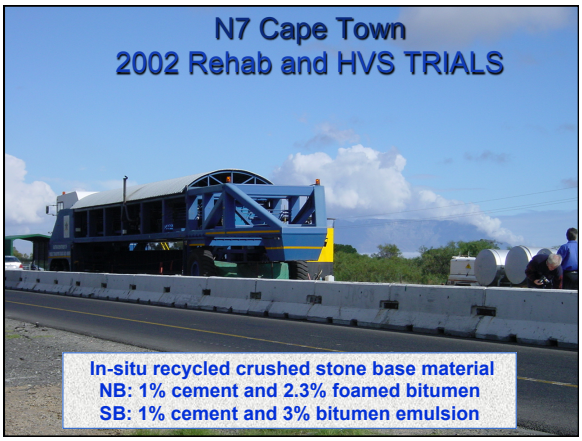

Economics
Crude volatility and bitumen price reaction
Crude vs Singapore bitumen
Volatility makes Bitumen a more market responsive product
Refining changed from cost centre to profit centre
USD/t
800
600
400
200
0
Jan-02
Oct-04
Aug-07
Jun-10
Arab Heavy
Singapore bulk bitumen
illuminating the markets
source
argus

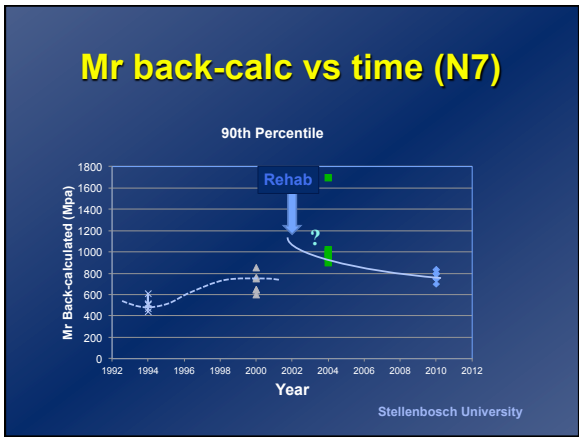

3. Material Performance
Closing the loop
Awareness
Rutting
Cracking
Reality check
Implement
Acquire knowledge
Everyone is an expert!
Develop tools
Response
Damage

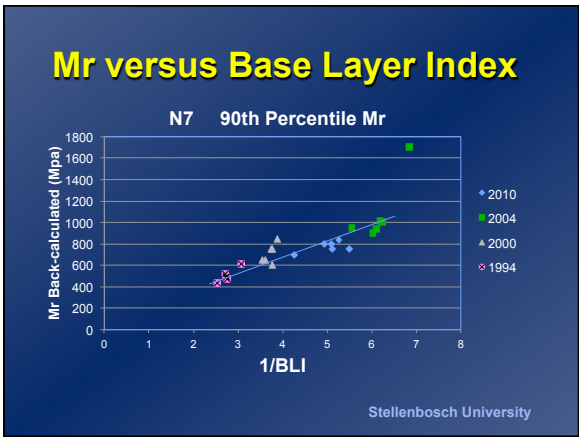

a. BSM Performance
Permanent Deformation vs Stress Ratio
Triaxial Testing
Vertical Plastic Strain εp vert
εp = aNb
σd/σd,f = 60%
σd/σd,f = 50%
σd/σd,f = 40%
Constant σ3
Ref: K Jenkins PhD Univ Stell
Mulusa, Univ Stell 2009
Time or Load Reps (N)

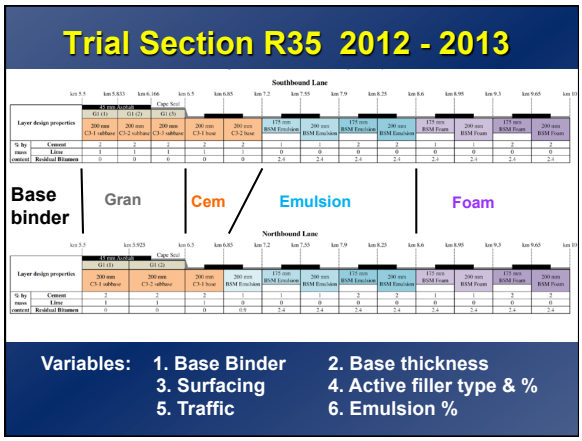

90mm Asphalt
250mm CIPR:
3% Foam 1% Cem
M_R
CURE
0
12
24
36
48
Time after construction (months)


Permanent deformation
DESIGN
20mm
mm
Time / Traffic
8 years
15 years

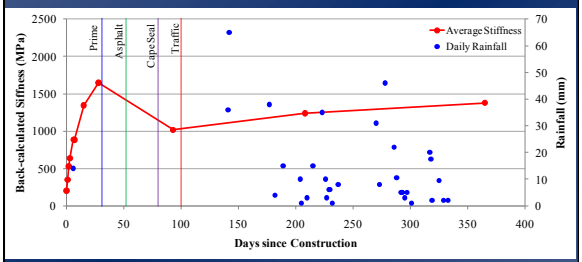

N7 Cape Town
2002 Rehab and HVS TRIALS
In-situ recycled crushed stone base material
NB: 1% cement and 2.3% foamed bitumen
SB: 1% cement and 3% bitumen emulsion


Mr back-calc vs time (N7)
90th Percentile
Rehab
?
Mr Back-calculated (Mpa)
1800
1600
1400
1200
1000
800
600
400
200
0
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
Year
Stellenbosch University

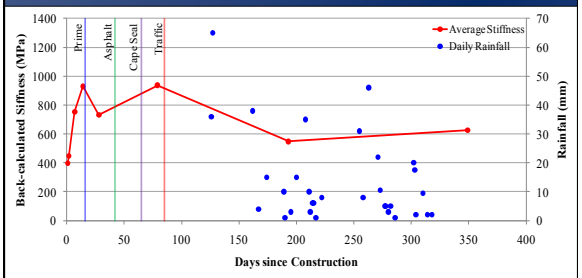

Mr versus Base Layer Index
N7 90th Percentile Mr
Mr Back-calculated (Mpa)
1800
1600
1400
1200
1000
800
600
400
200
0
0
1
2
3
4
5
6
7
8
1/BLI
2010
2004
2000
1994
Stellenbosch University


Trial Section R35 2012 - 2013
Southbound Lane
Base binder
Gran
Cem
Emulsion
Foam
Northbound Lane
Variables: 1. Base Binder
2. Base thickness
3. Surfacing
4. Active filler type & %
5. Traffic
6. Emulsion %

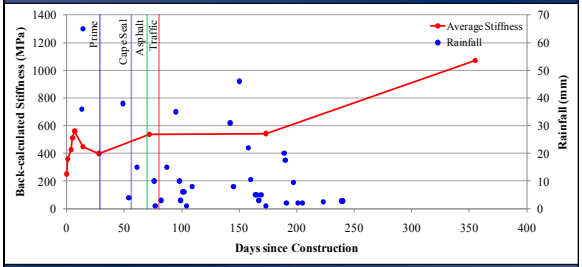
200mm Cemented Base SB



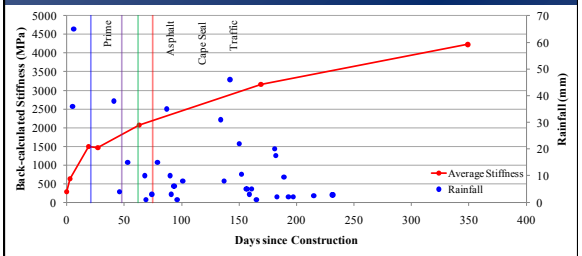
200mm BSM Foam (2.4%b, 1%c) SB



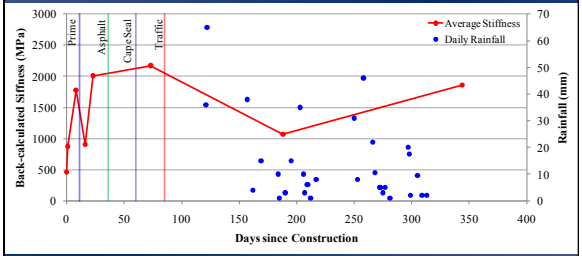
200mm BSM Foam (2.4%b, 1%c) NB



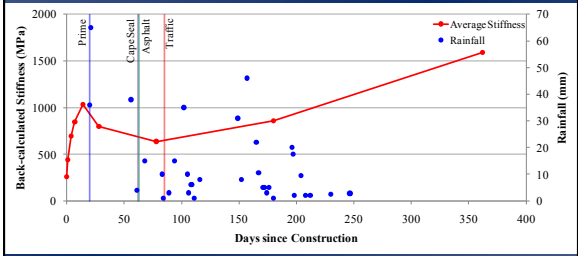
175mm BSM Foam (2.4%b, 2%c) NB



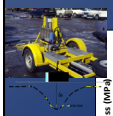
200mm BSM Emulsion (2.4%b, 2%c) SB

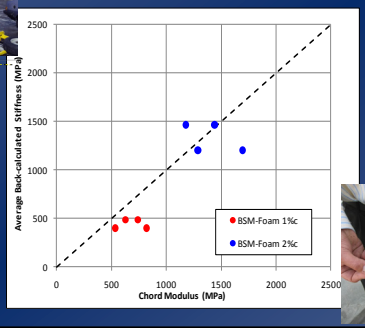


200mm BSM Emulsion (2.4%b, 1%c) NB

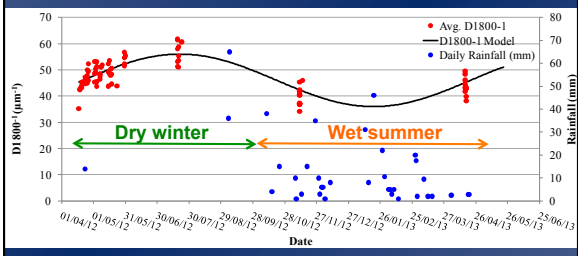


Back-calc vs Core triaxial

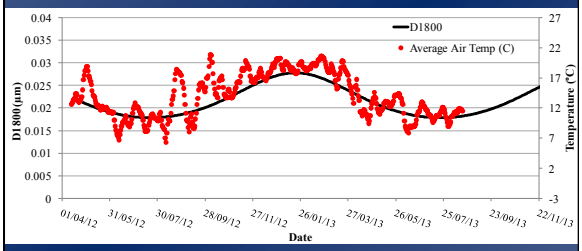




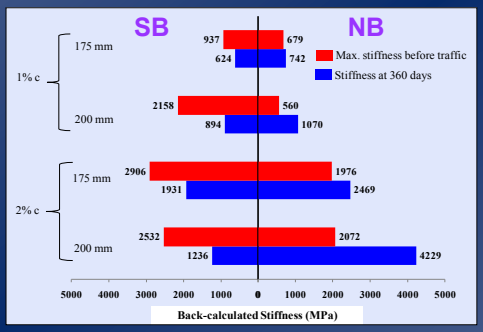
Seasonal stiffness variation



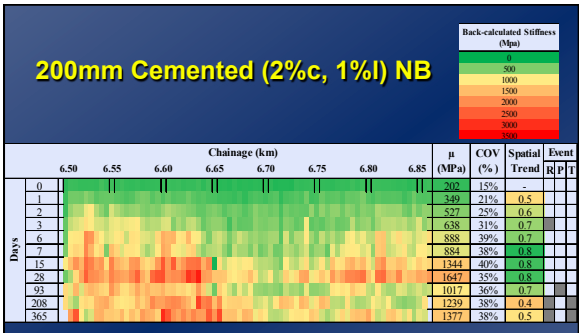
Seasonal stiffness variability



BSM-foam



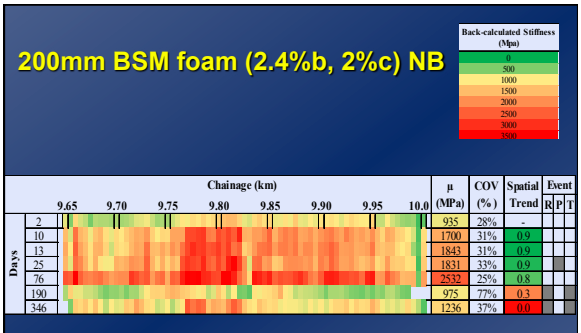
200mm Cemented (2%c, 1%l) NB



Days	μ (MPa)	COV (%)	Spatial Trend	Event R	Event P	Event T
0	202	15%	-			
1	349	21%	0.5			
2	527	25%	0.6			
3	638	31%	0.7			
6	888	39%	0.7			
7	884	38%	0.8			
15	1344	40%	0.8			
28	1647	35%	0.8			
93	1017	36%	0.7			
208	1239	38%	0.4			
365	1377	38%	0.5			

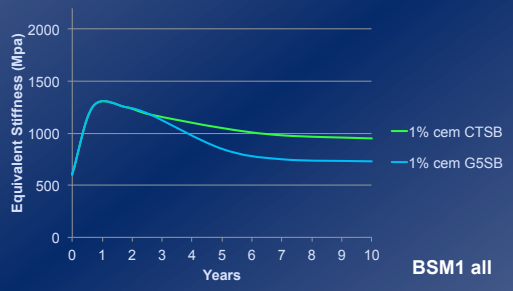
Spatial and Temporal Variation

200mm BSM foam (2.4%b, 2%c) NB



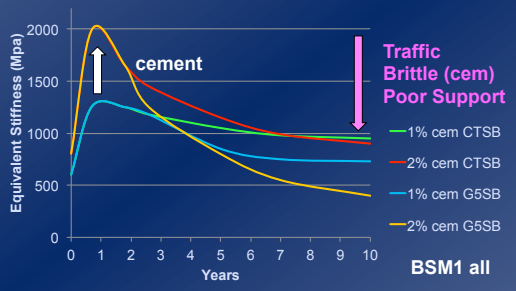
Days	μ (MPa)	COV (%)	Spatial Trend	Event R	Event P	Event T
2	935	28%	-			
10	1700	31%	0.9			
13	1843	31%	0.9			
25	1831	33%	0.9			
76	2532	25%	0.8			
190	975	77%	0.3			
346	1236	37%	0.0			

BSMs Mr change: Effective Long Term Stiffness



BSM1 all

BSMs Mr change: Effective Long Term Stiffness



BSM1 all

Closure

Economical BSMs

Research / Practice

- Lower BC
- Improve QC
- Reduce variability
- Operator training

- "Gadgets"
- Data management
- Skills requirement

- Mix Design upgrades
- Structural Design with material pro

- Prolific nº variables
- Difficult to simplify
- Closing loop is a ongitudinal study

Thank you !