PAVEMENT REHABILITATION using BITUMEN STABILISATION

STATE OF THE ART

23rd Road Pavement Forum

Fern Hill Hotel, Tweedie, KZN

Wednesday 9th May 2012

Dave Collings

UCD Technology

LOUDON INTERNATIONAL

THE LONG TERM BEHAVIOUR OF BITUMEN STABILISED MATERIALS (BSMs)

Understanding non-continuously bound materials

Dave Collings

Kim Jenkins

CAPSA'11

Conference on Asphalt Pavements for Southern Africa

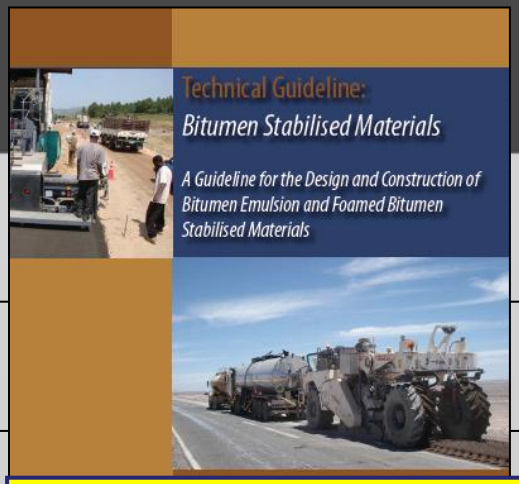
UCD Technology

LOUDON INTERNATIONAL

Stellenbosch

THE SOUTH AFRICAN NATIONAL ROADS AGENCY LTD

TG2 (2009)



Conference on Asphalt Pavements for Southern Africa

"Non-continuously bound"

Bound

Rigidity

Cement %

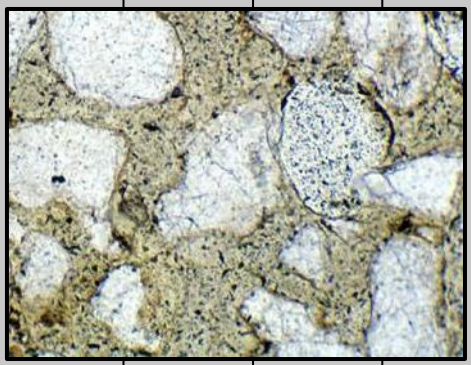
4
3
2
1
0

Cement stabilised

BSM

Granular

Asphalt



Unbound

0 1 2 3 4 5

Bitumen %

Bound

Flexibility

FATIGUE CRACK PROPAGATION

(Fracture mechanics)

CONTINUOUSLY BOUND MATERIAL

CRACK "TIP"

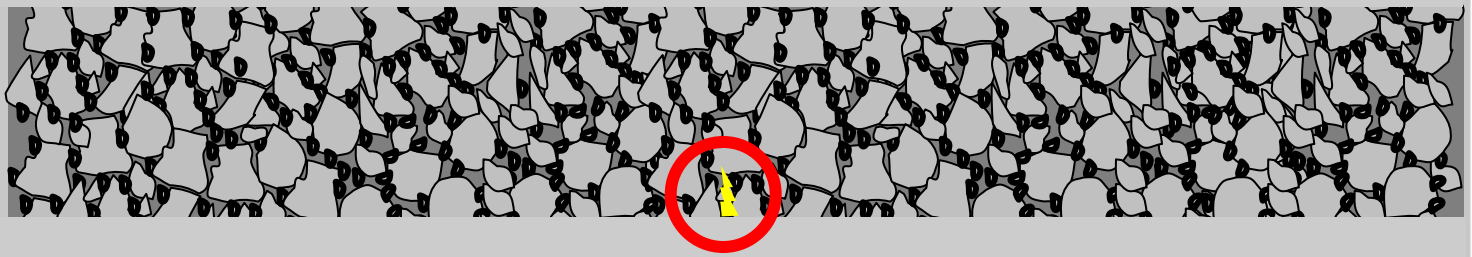
STRESS CONCENTRATION

Paris' Law: $\frac{d_c}{d_N} = A.K^n$

K: Stress intensity factor at crack tip

$\frac{d_c}{d_N}$: Increase in crack length / load cycle

NON-CONTINUOUSLY BOUND MATERIAL



Similar to unbound granular materials

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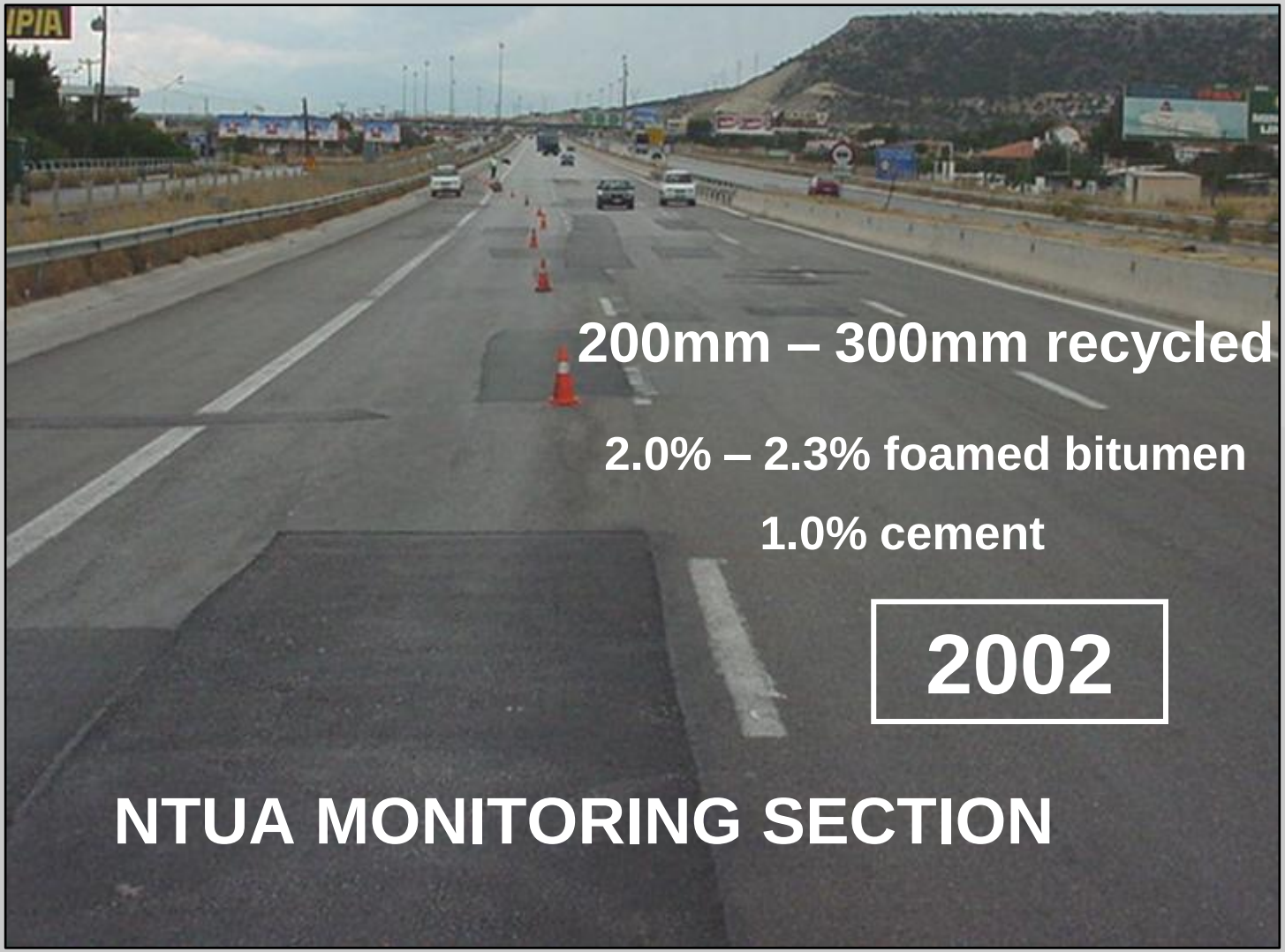
ATHENS – CORINTH HIGHWAY, GREECE



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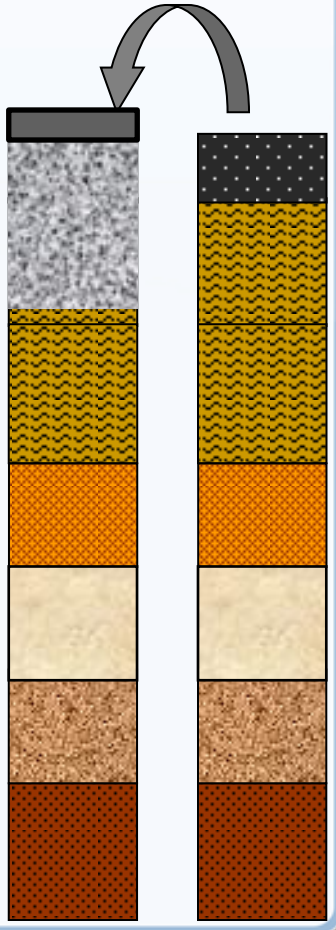
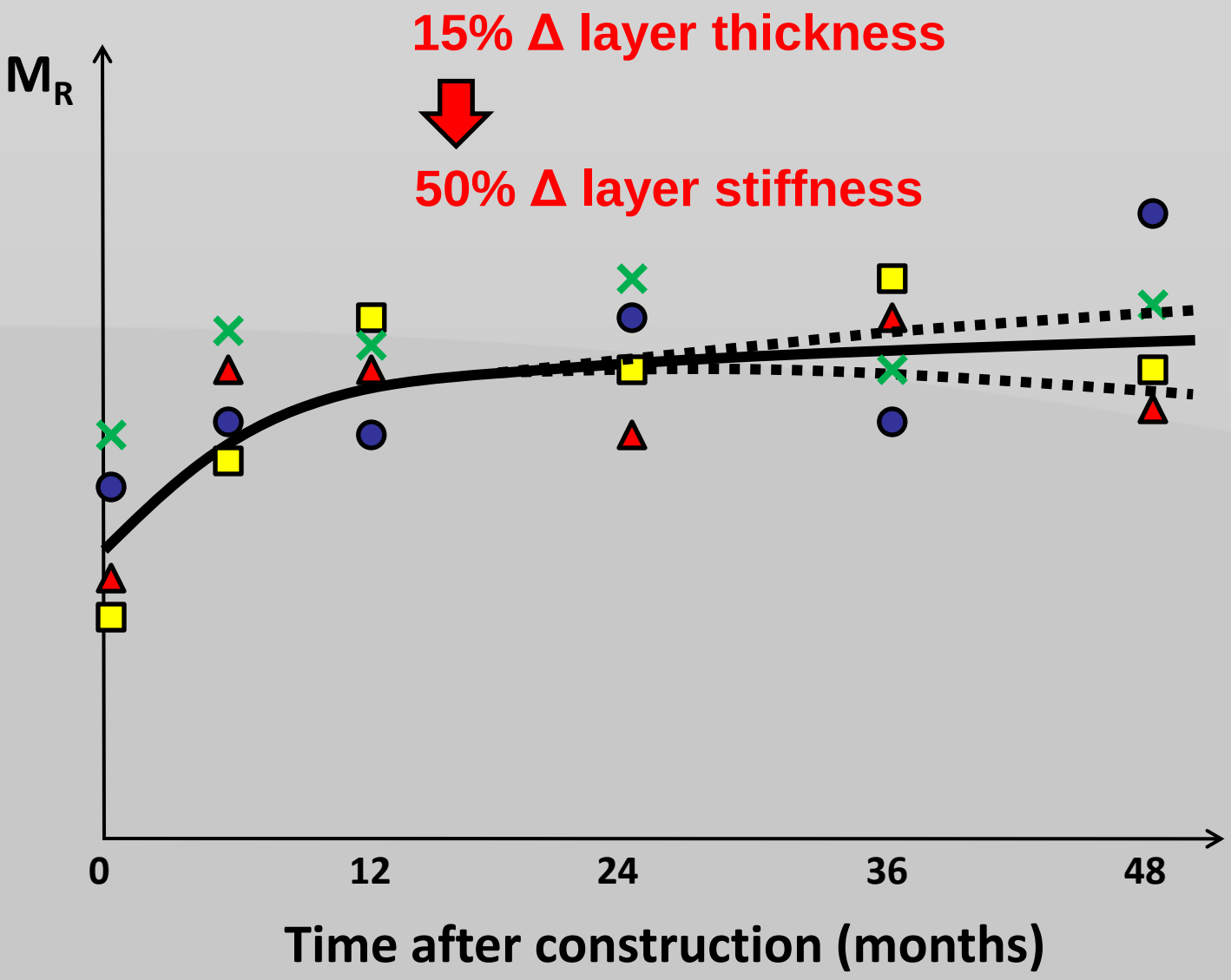


NTUA – FWD SURVEY DATA



?

Conference on Asphalt Pavements for Southern Africa

REVISITED APRIL 2010

8 years after rehabilitation

> 50 000 000 ESALs

± 100 000 vpd 15% heavy

7 500 heavies / day

(13 ton legal axle load)

$$\left(\frac{13}{8}\right)^4 = 6.9 \text{ ESAL}$$

ADE ± 30 000 / day

(4 ESALs / heavy)

9 000 000 ESALs / year

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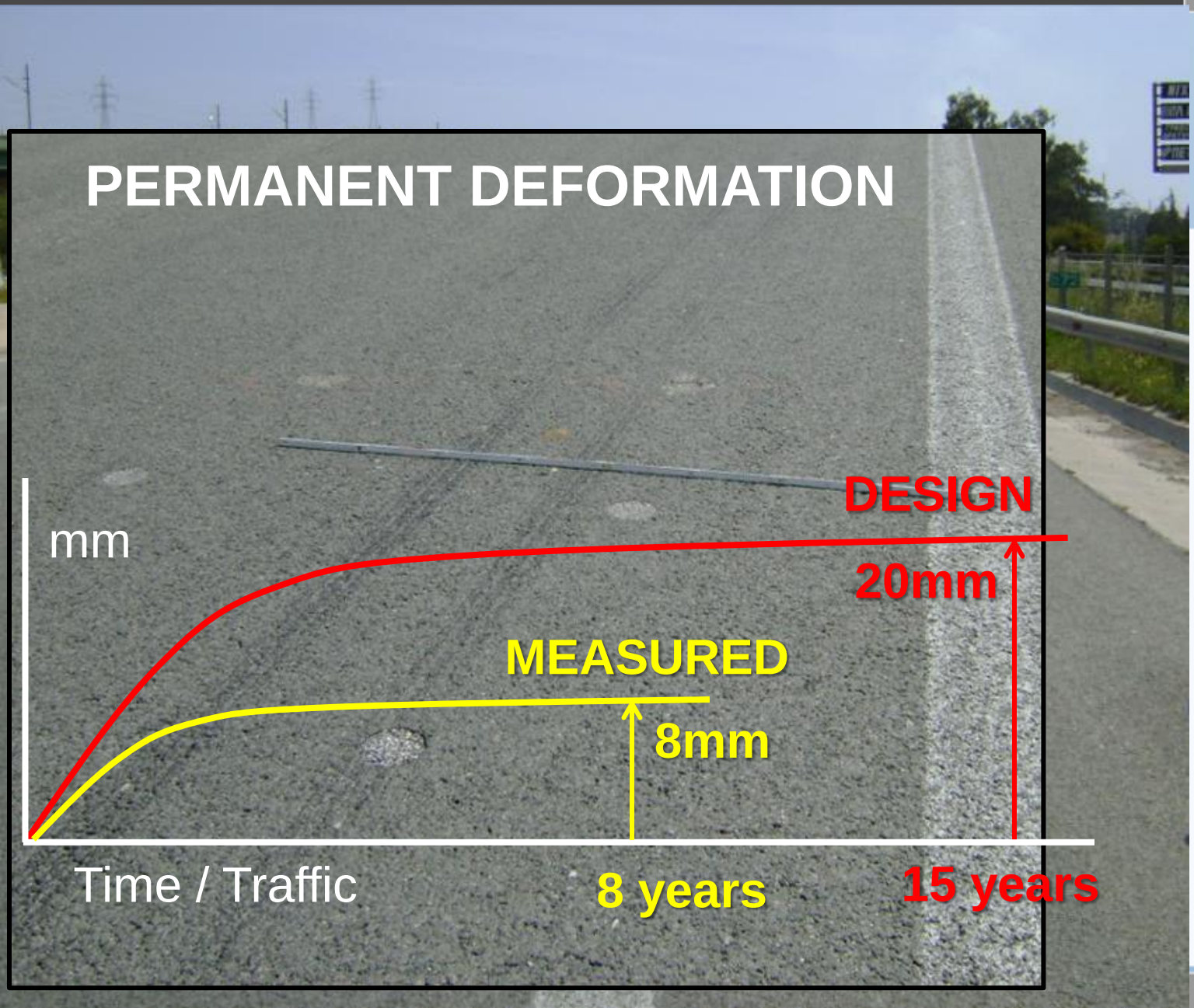
NTUA MONITORING SITE



CAPSA'11

Conference on Asphalt Pavements for Southern Africa

Rigidity

Cement %

4

3

2

1

0

Cement stabilised

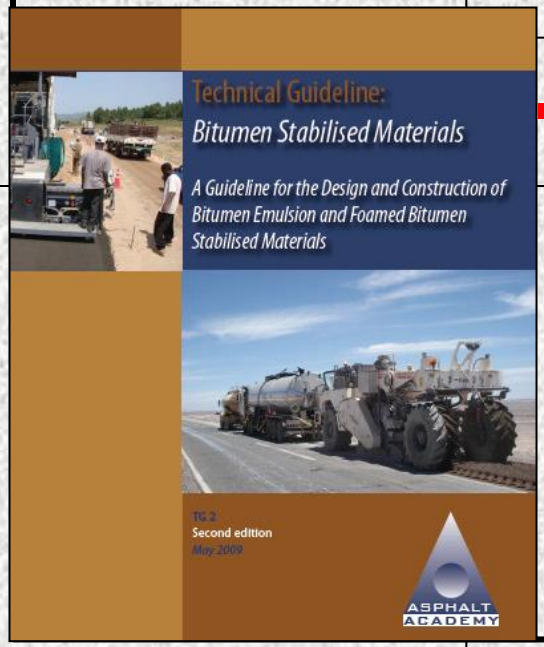
Bound

NON-CONTINUOUSLY BOUND?

SEMI-CONTINUOUSLY BOUND?

?

BOUND?



Asphalt

Bound

0 1 2 3 4 5

Bitumen %

Flexibility

Meeting of the minds

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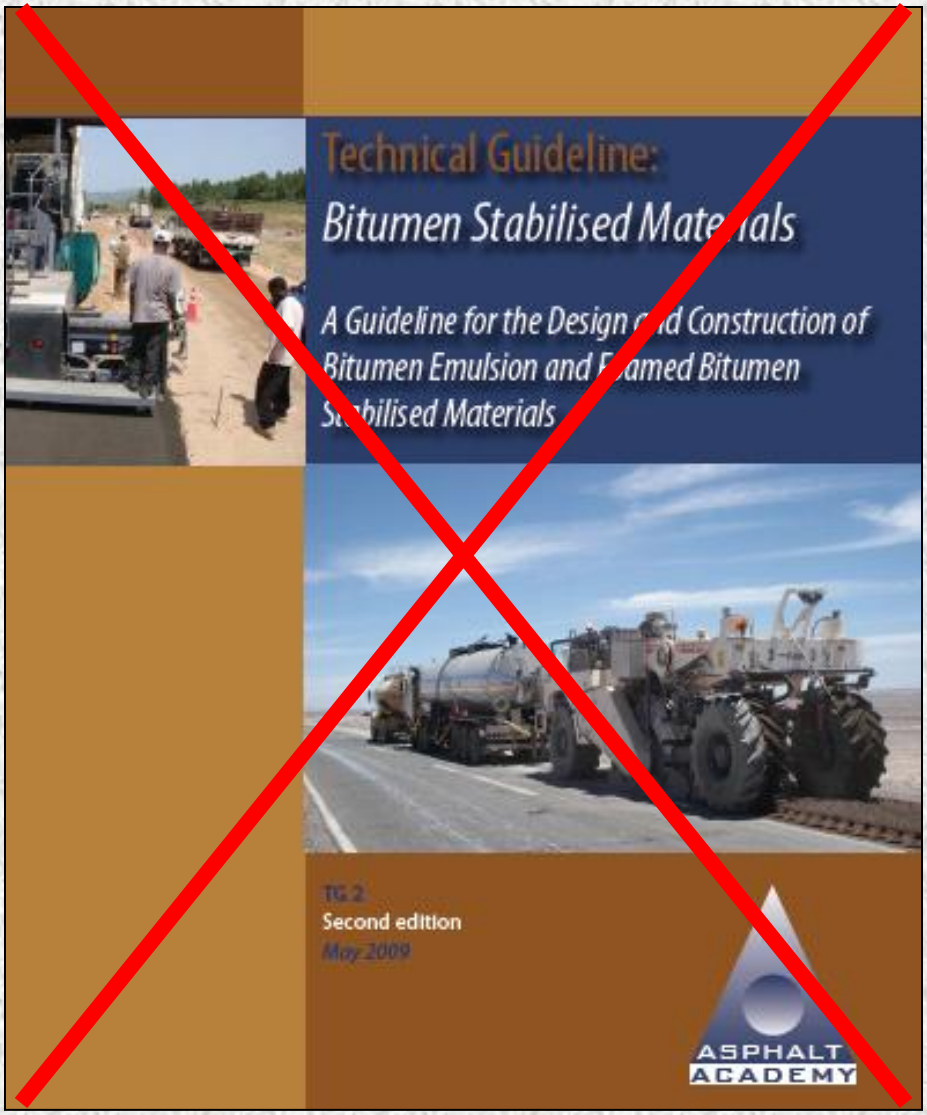
Conference on Asphalt Pavements for Southern Africa

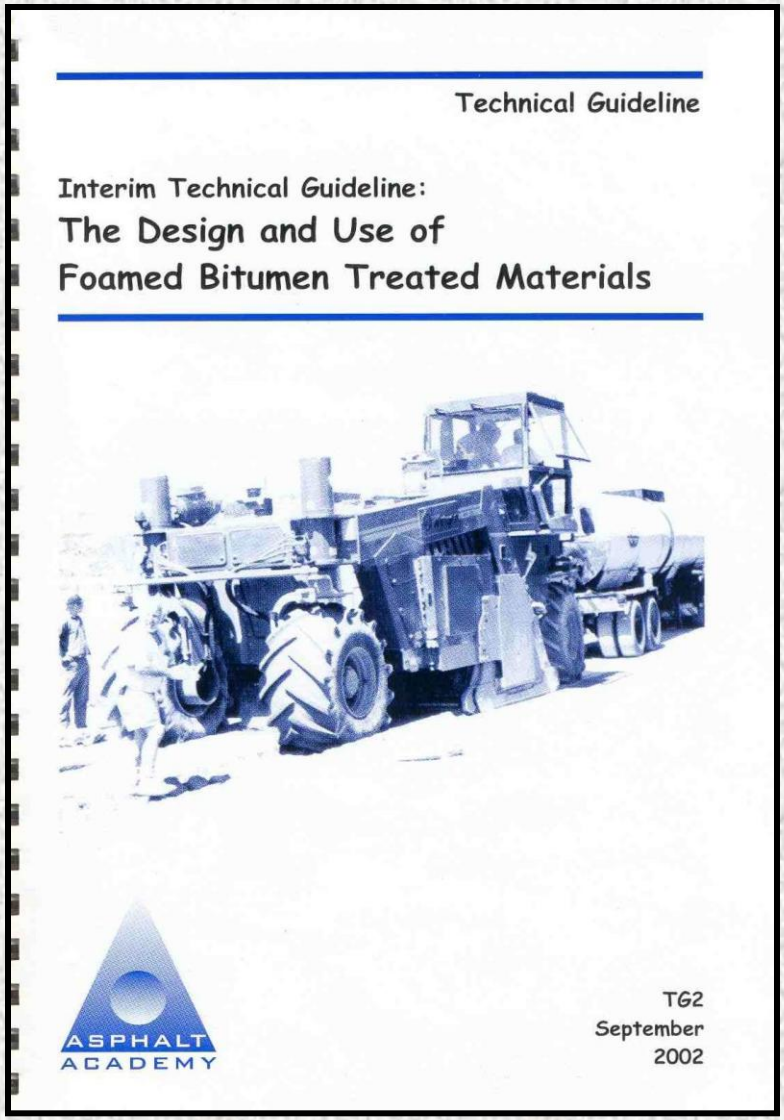
2 MONTHS LATER...

RPF November 2011: Progress Report on the SAPDM

The design and performance of stabilised material

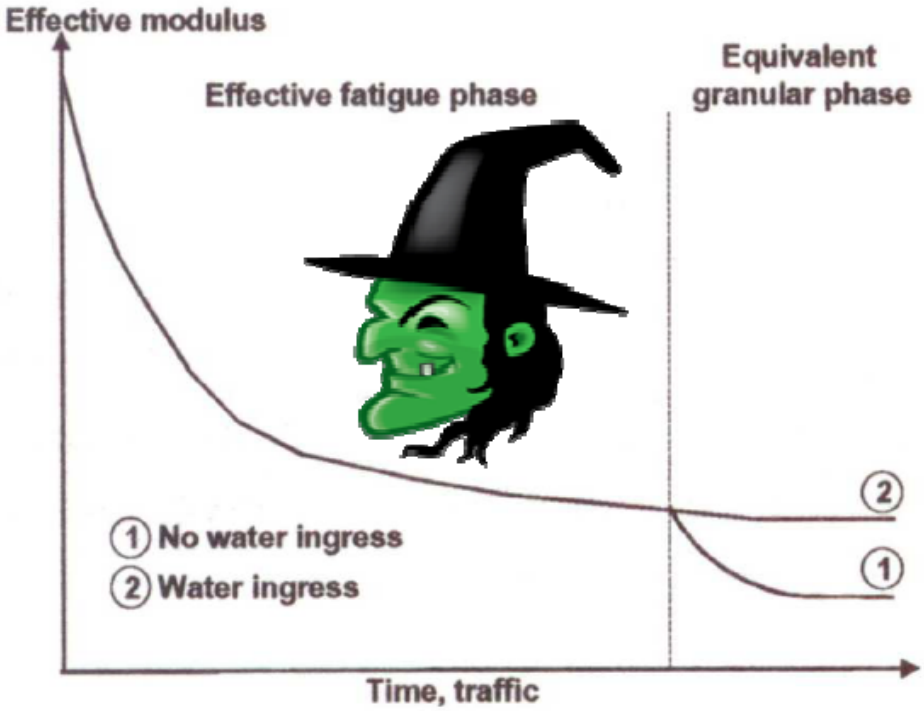
H L Theyse


Technical Guideline:
Bitumen Stabilised Materials
A Guideline for the Design and Construction of
Bitumen Emulsion and Foamed Bitumen
Stabilised Materials
TG 2
Second edition
May 2009
ASPHALT
ACADEMY


Technical Guideline
Interim Technical Guideline:
The Design and Use of
Foamed Bitumen Treated Materials
ASPHALT
ACADEMY
TG2
September
2002

TG2 2002 structural design: Let the witch-hunt begin …

- TG2 2002 p 55 - we found the root of all evil!
  - She's called "stiffness reduction"



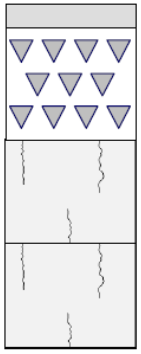
The real problem

3 “miSA” limit

(3 000 000 ESALs)

TG2 2002 structural design: Catalogue for new construction

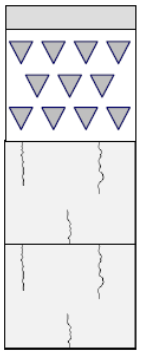
- Category A – 10 miSA



No FB design!

TG2 2002 structural design: Catalogue for new construction

- Category A – 30 miSA



No FB design!

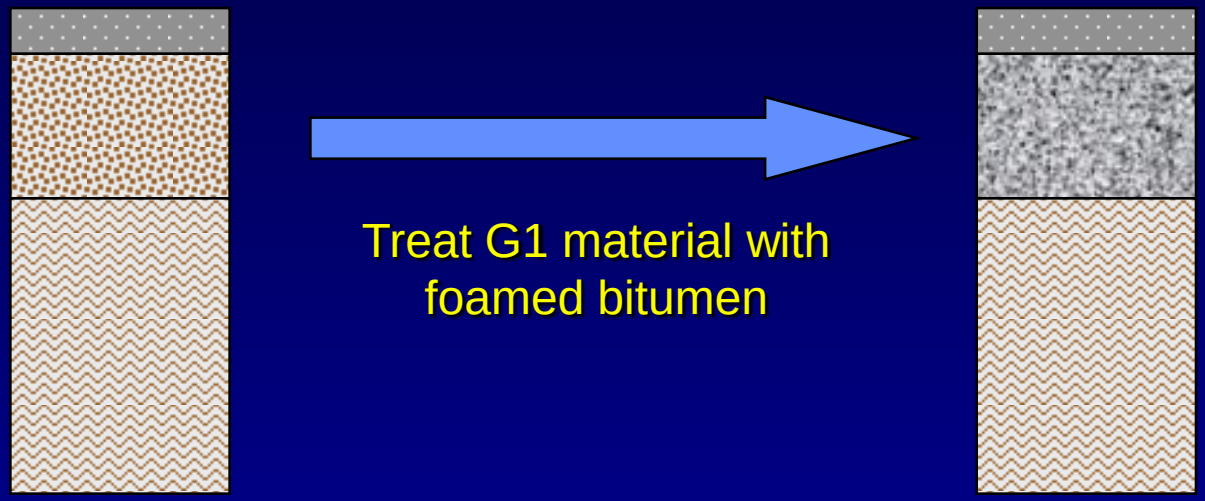
Typical SA pavement

B cat road / wet climate

40mm HMA

150mm G1

300mm C4



Treat G1 material with foamed bitumen

3 – 10 million

< 3 million

IS THIS REASONABLE ??

TRANSFER FUNCTIONS

The “Effective Fatigue” equation

$$N_{EF} = 10^{[6.499 - 0.708(\varepsilon_h/\varepsilon_b)]}$$

The Permanent Deformation equation

$$N_{PD.FB} = 1/30 \times 10^{[k+11.938RD+0.0726PS-1.628SR+0.68(cem/bit)]}$$

The Permanent Deformation equation

$$N_{PD.FB} = 1/30 \times 10^{[k+11.938RD+0.0726PS-1.628SR+0.68(cem/bit)]}$$

Cement added %
Bitumen added %

Road category	Relative density	Plastic strain	Stress ratio	
A = - 2.047	0.78 to 0.86	5 to 20	0.1 to 1.0	
B = - 1.950			MODEL	
C = - 1.816	0.8	10	0.3	0.33
D = - 1.625				

1% cement / 3% foamed bitumen

$N_{PD.FB}$ = 3 078 072 ESALs

The Permanent Deformation equation

Use cement !!

d %
Bitumen added %

Road category	Relative density	Plastic strain	Stress ratio	
A = - 2.047	0.78 to 0.86	5 to 20	0.1 to 1.0	MODEL
B = - 1.950				
C = - 1.816	0.8	10	0.3	8.0
D = - 1.625				

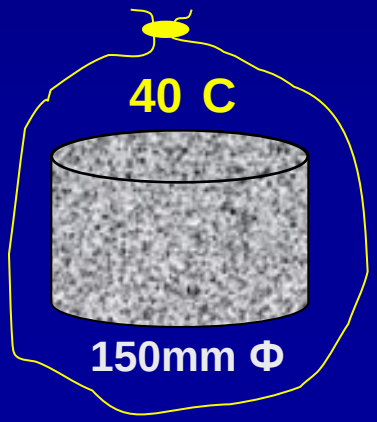
4% cement + 0.5% foamed bitumen

$N_{PD.FB}$ = 505 683 455 820 **(505 683 x 10^6) ESALs**

Add cement !!

MATERIAL CODE		ITS* at 25 C (kPa)	
		100 – 300	300 – 500
UCS at 25 C (kPa)	700 – 1400	FB4	FB3
	1400 – 2000	FB2	FB1

* unsoaked ITS



ITS SOAKED ??

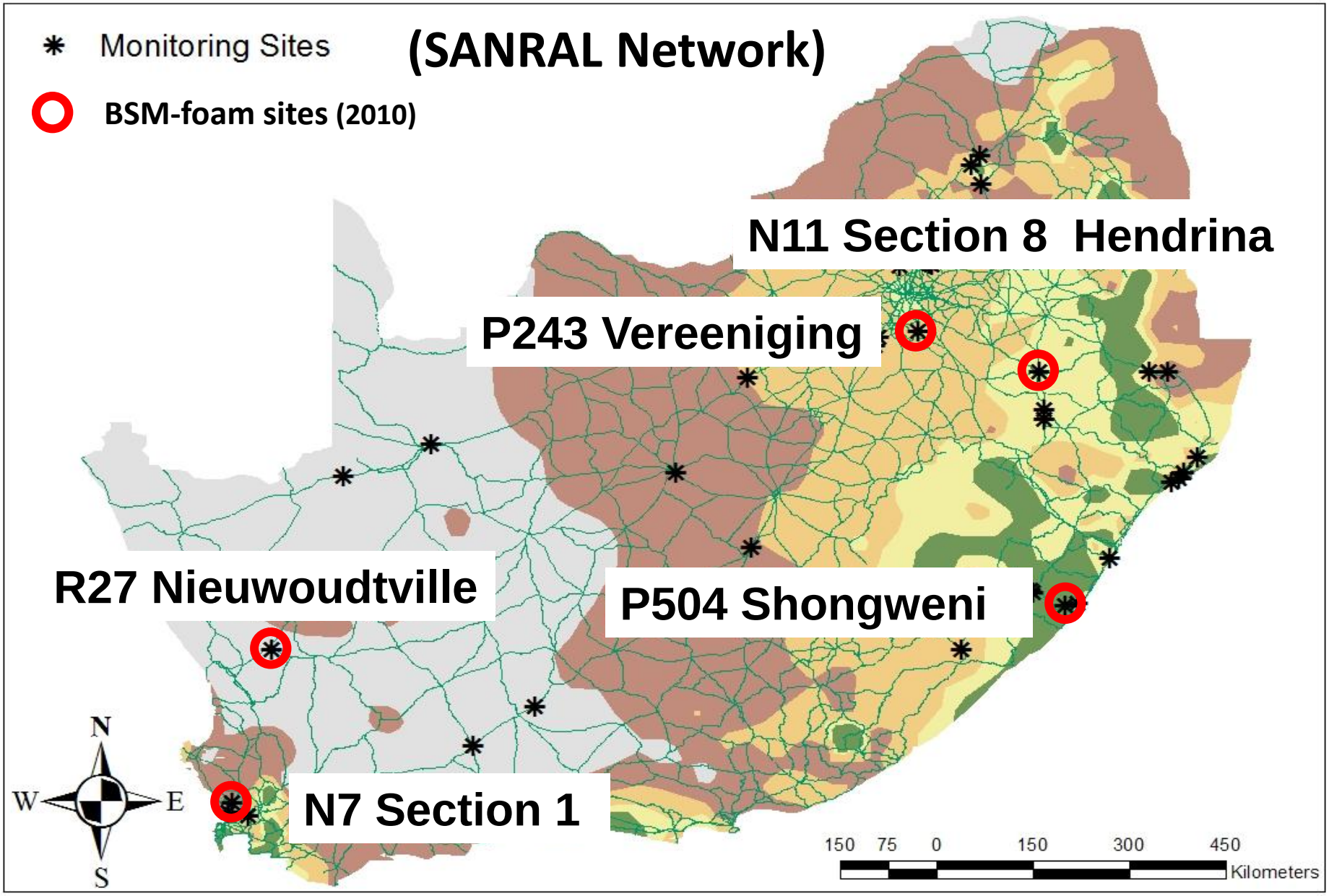
TG2 2002 structural design: Let's burn the witch

- The
  - "I
  - "E
- The
  - CAPSA'04
    - The prosecutor delivered the "knife-in-the-back" speech
    - The witch was set alight
  - 2004 – 2009
    - New group of witch-doctors appointed
    - 2009 - TG2 second edition released for bitumen stabilisation

Dr Fritz Jooste
Dr Fenella Johns
Prof Kim Jenkins

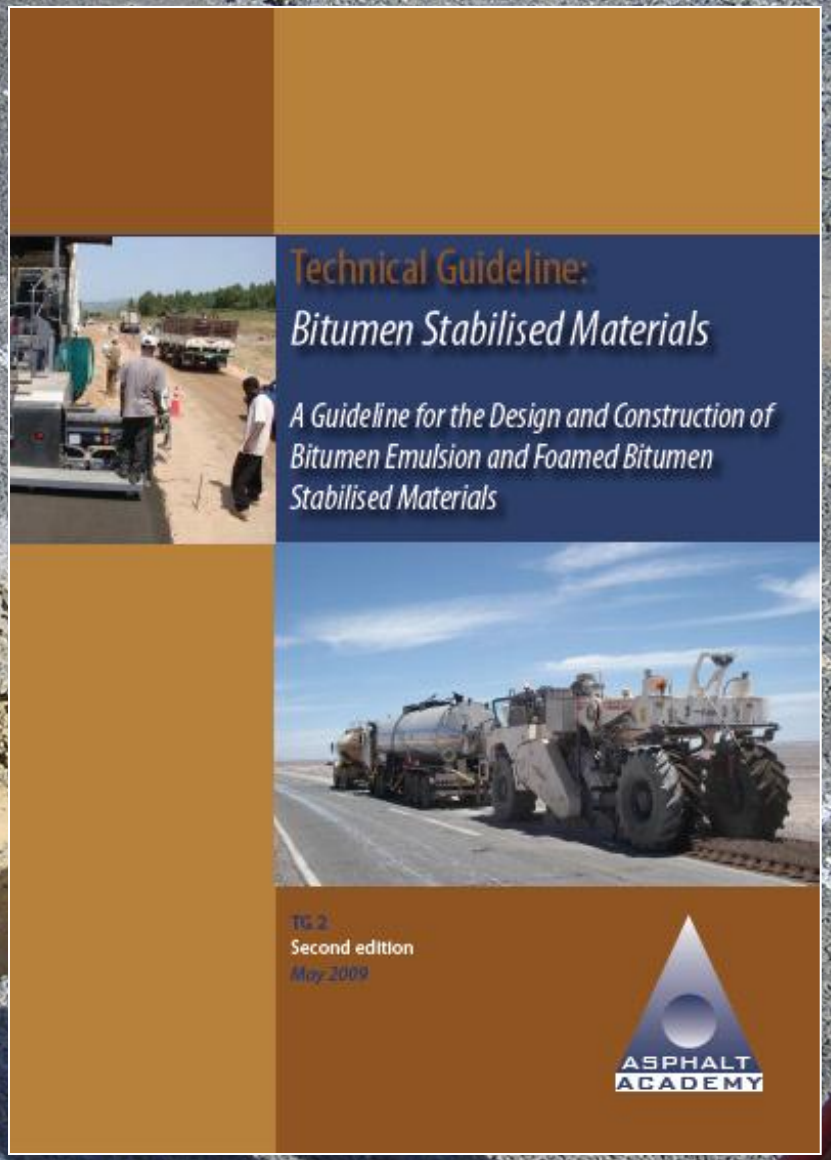
Someone is out of step…

- Objective of presentation
  - The objective is not to prove that foamed bitumen or any other type of stabilisation does not work
  - The objective is to question the current design philosophy behind foamed bitumen treatment
    - Based on laboratory data and field observations, not philosophical argument


Monitoring Sites
(SANRAL Network)
BSM-foam sites (2010)
N11 Section 8 Hendrina
P243 Vereeniging
R27 Nieuwoudtville
P504 Shongweni
N7 Section 1
N
W
E
S
150 75 0 150 300 450
Kilometers


CONSTRUCTED IN 2001
“BSM1” (crushed stone) 2.3% bitumen / 1% cement
Design (J&G / Stellenbosch University): 7 x 10^6 ESALs
Power Construction

After 10 X 10^6 E80 load repetitions



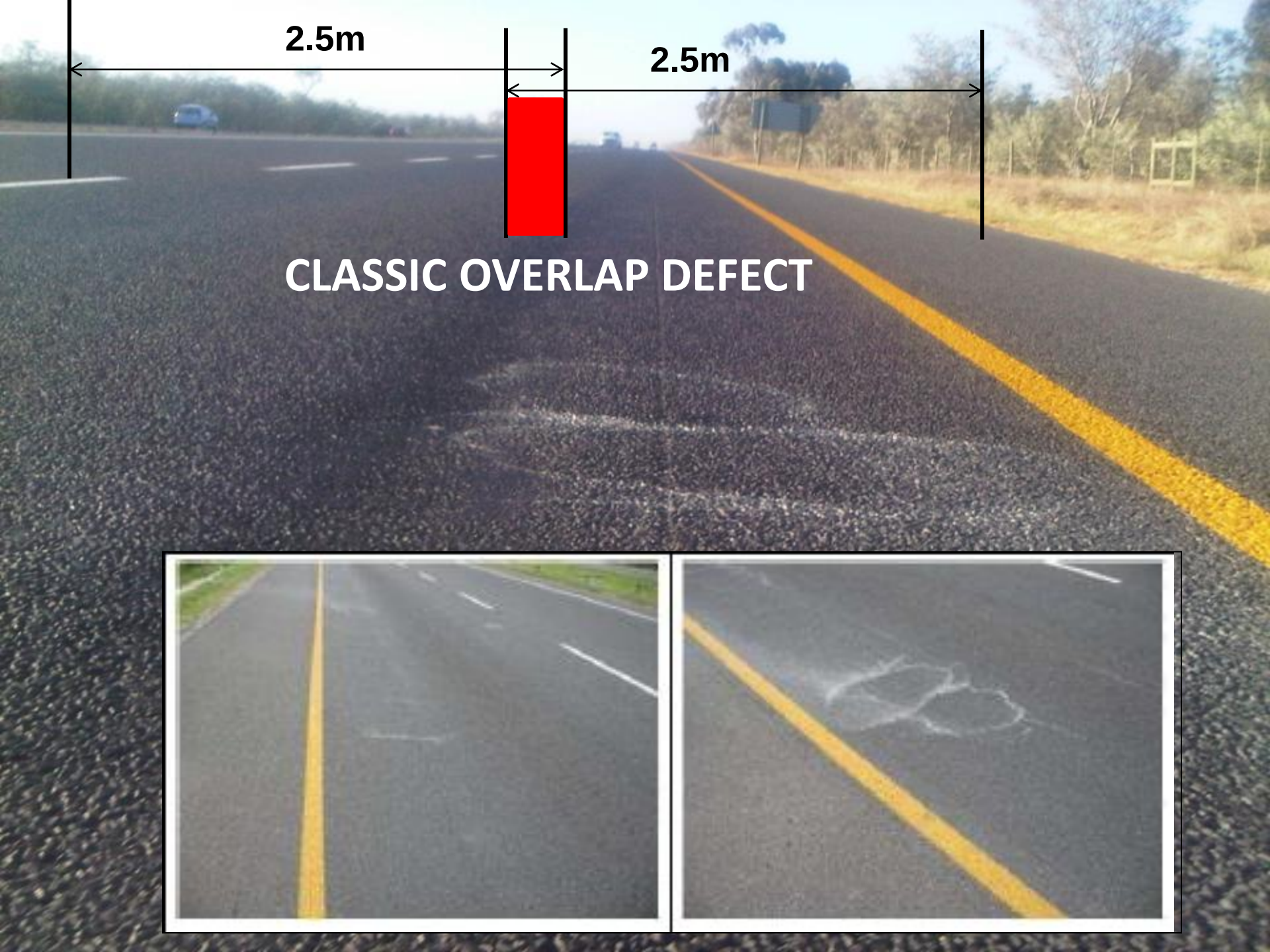
+ 22 LTPP / HVS data sets

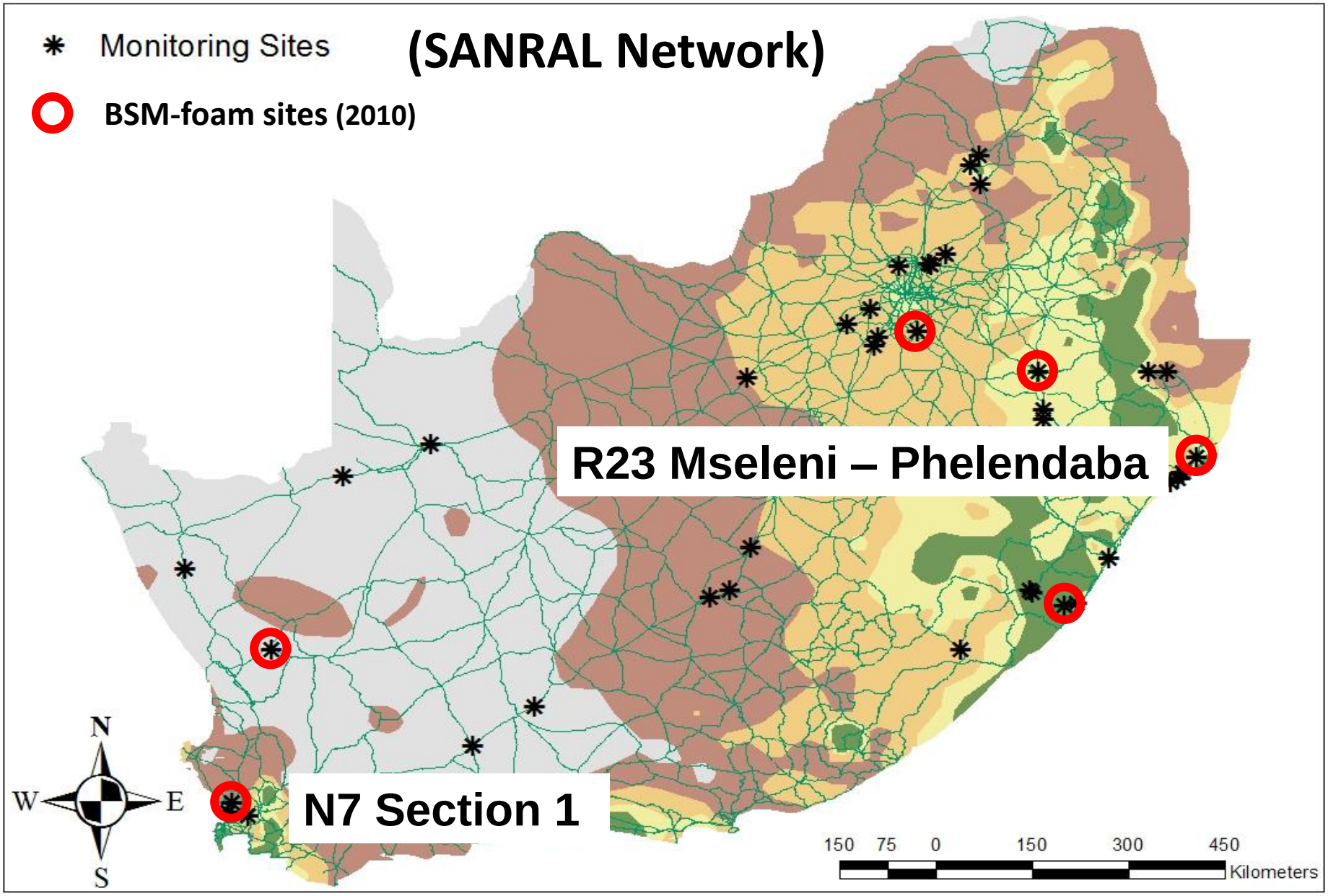
2011 observations:

“Cracks observed”

“Start of fatigue failure”

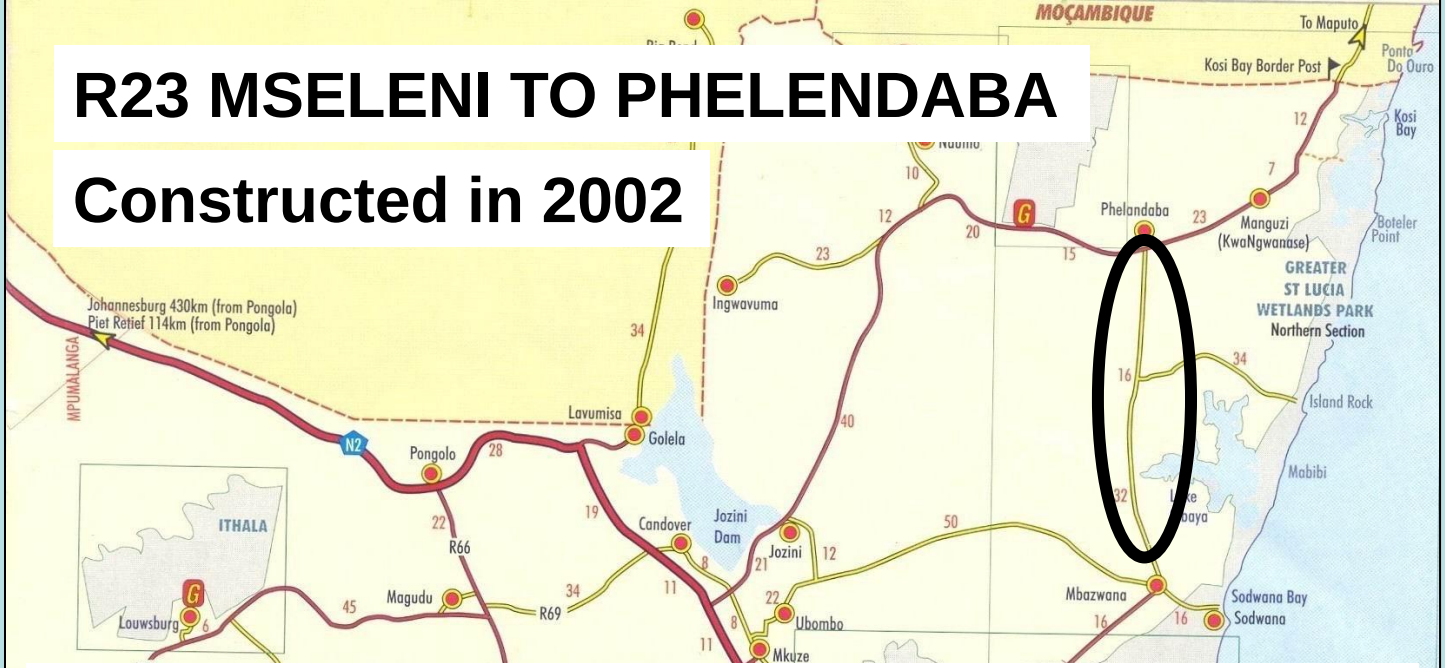
Reality: ± 200m settlement / isolated cracking


2.5m
2.5m
CLASSIC OVERLAP DEFECT


Monitoring Sites
(SANRAL Network)
BSM-foam sites (2010)
R23 Mseleni – Phelendaba
N7 Section 1
N
W
E
S
150 75 0 150 300 450
Kilometers

R23 MSELENI TO PHELENDABA

Constructed in 2002



AA Loudon & Partners / Space Construction

KEY COMMUNITY ACCESS ROAD

+100km to closest G5 material source


19 / 6.7 mm double seal (after 3 years)
Double slurry seal
250 mm BSM base
(Blends of sand / gravel /
silty-sand / crusher dust)
Sand subgrade

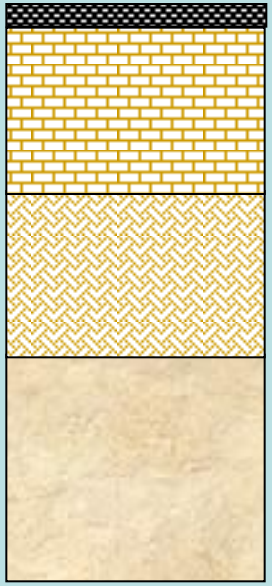
Rutting on in-service sections

- R22 Mseleni – Phelendaba
  - 250 mm sand and calcrete mixture
  - 4 % binder, 2 % lime
  - Constructed 2002 - rut survey 2008
    - 90th percentile rut = 18 mm

?

FATIGUE CRACKING

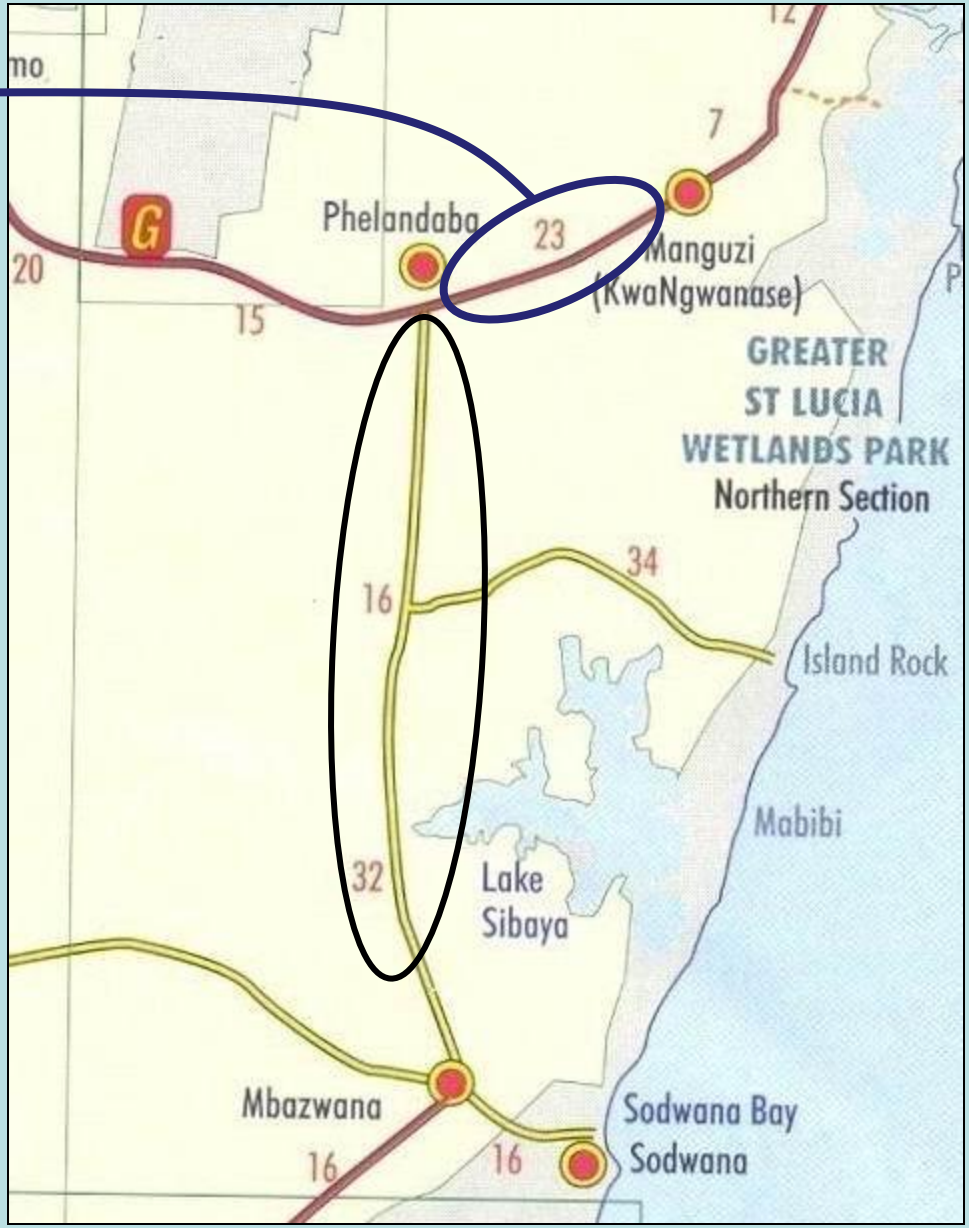
19 / 6.7 mm double seal



150 mm C4 base (Doorbank)

150 mm C4 subbase (recycled gravel wearing course)

Sand subgrade




25 4 2006


25 4 2006

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    - Based on laboratory data and field observations, not philosophical argument

Philosophical argument ?

South Africa: **KZN DoT (since 1996)**

KZN: MR 63 (2004)

Philosophical argument ?

South Africa: KZN DoT (since 1996)

Ethekwini Metro (since 1997)

- Old Main Road, Pinetown
- M5 Westmead Industrial Area
- M5 Queensburgh
- FIFA World Cup projects
- Many many more...


BSM1 (RA material)
In plant mixed / paved
BSM1 In situ recycled

Philosophical argument ?

South Africa: KZN DoT (since 1996)

Ethekwini Metro (since 1997)

Other Provincial Main Roads


MPUMALANGA
BETHAL – KRIEL
RECYCLED / BSM-FOAM (JUNE 2005)


BLEEDING : SUMMER 2005 / 6
HIGH TEMPERATURES / HEAVY LOADS (COAL)

BETHAL – MIDDELBURG

BETHAL – MORGENZON


BETHAL – KRIEL
7 years later...


3km HMA Section
(Kriel Town – Power Station)
(25mm HMA)

Philosophical argument ?

South Africa: KZN DoT (since 1996)

Ethekwini Metro (since 1997)

Other Provincial Main Roads

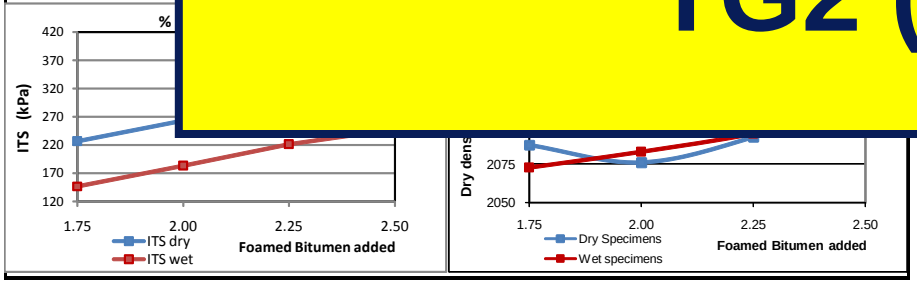
Specialist laboratory for BSMs

BSM LABORATORIES (PTY) LTD
Bitumen Stabilised Materials Testing Laboratories
Reg. No. 2009/023623/07 VAT No. 4630255141
25 Westmead Road, WESTMEAD, 3608 KZN, South Africa
Telephone No. +27 (0)31 700 1333 FAX No. +27 (0)31 700 1909

Client:	EXAMPLE PROJECT	Job Card No	123
Project:	A Typical Main Road	Date Received	05 January 2011
Sample Number:	1111	Date Tested:	10 January 2011
Sample Delivered By:	Contractor	Date Reported	14 January 2011

FOAMED BITUMEN MIX DESIGN REPORT - LEVEL 1

MATERIAL TO BE STABILISED	Aggregates	Bitumen	Active Filler
Description	Pa P Br Otz Pebbles + Gravel + PA	80/100	Lime
Location / Source:			
Maximum Dry Density			
FOAMED BITUMEN ST			
Compactive effort			
Date moulded			
Foamed Bitumen adde			
Bitumen foaming condit			
Type and percent filler a			
Moulding moisture conte			
TEST RESULTS			
ITS dry			
Moisture content at break			
Dry Density			
Temperature at break			
ITS wet			
Moisture content at break			
Dry Density			
Temperature at break			
Tensile Strength Retair			
TG2 (2009) Material Cl			
BASED ON ITS_{DRY} AN			



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Telephone No. +27 (0)31 700 1333 FAX No. +27 (0)31 700 1909

Client:	EXAMPLE PROJECT	Job Card No	123
Project:	A Typical Main Road	Date Received	05 January 2011
Sample Number:	1111	Date Tested:	21 January 2011
Sample Delivered By:	Contractor	Date Reported	26 January 2011

FOAMED BITUMEN MIX DESIGN REPORT - LEVEL 3 : TRIAXIAL TESTS

					Active Filler
					Lime
					Northern Lime
				(%):	8.0
					diameter
				(°C)	175
					152
					298.1
					8.0
					2072
					200
					42.5
					3.8
					24.7
					2339.4
Major Principle Stress at failure ($\sigma_{1,f}$)	**(kPa)**	**1284**	**1419**	**1816**	**2339**

SHEAR PROPERTIES:
COHESION (C) (kPa) 297
TG2 (2009) Material Classification: **BSM 1**
ANGLE OF FRICTION (φ) 43.8

BSM-emulsion & BSM-foam

Mix Designs / QA / Research

> 200 BSM MIX DESIGNS

TG2 (2009)

Philosophical argument ?

South Africa:

- KZN DoT (since 1996)
- Ethekwini Metro (since 1997)
- Other Provincial Main Roads
- Specialist BSM laboratory

Offshore:

- North America (Canada, Alaska, USA,etc.)
- South America (Brazil, Chile, Peru, etc.)
- Africa (Zambia, Namibia, Kenya, etc.)
- Asia (Mainly China)
- Europe (Greece, Italy, Croatia, etc.)

KENYA. 100km "Rift Valley project" (2008)

Mau Escarpment – 4km steep gradient
Hot daytime temperatures

19mm Cape Seal

175mm BSM 1 base

300mm C3 cemented subbase (UCS < 3MPa)

150mm selected subgrade CBR > 15

Subgrade CBR 10

Athens – Corinth Rehab Project

± 100 000 vpd 15% heavy

7 500 heavies / day

(13 ton legal axle load)

ADE ± 30 000 / day

(4 ESALs / heavy)

9 000 000 ESALs / year

8 years :

> 50 000 000 ESALs

ALASKA, 2002


Chukchi Sea
Red Dog Mine
Kotzebue
Arctic Circle
Nome
Yukon River
Fairbanks
Alaska
Anchorage
COMING
to
Red Dog
Airport
elev. 985 ft.
616 air miles
from Anchorage
196 miles North
of the
Arctic Circle

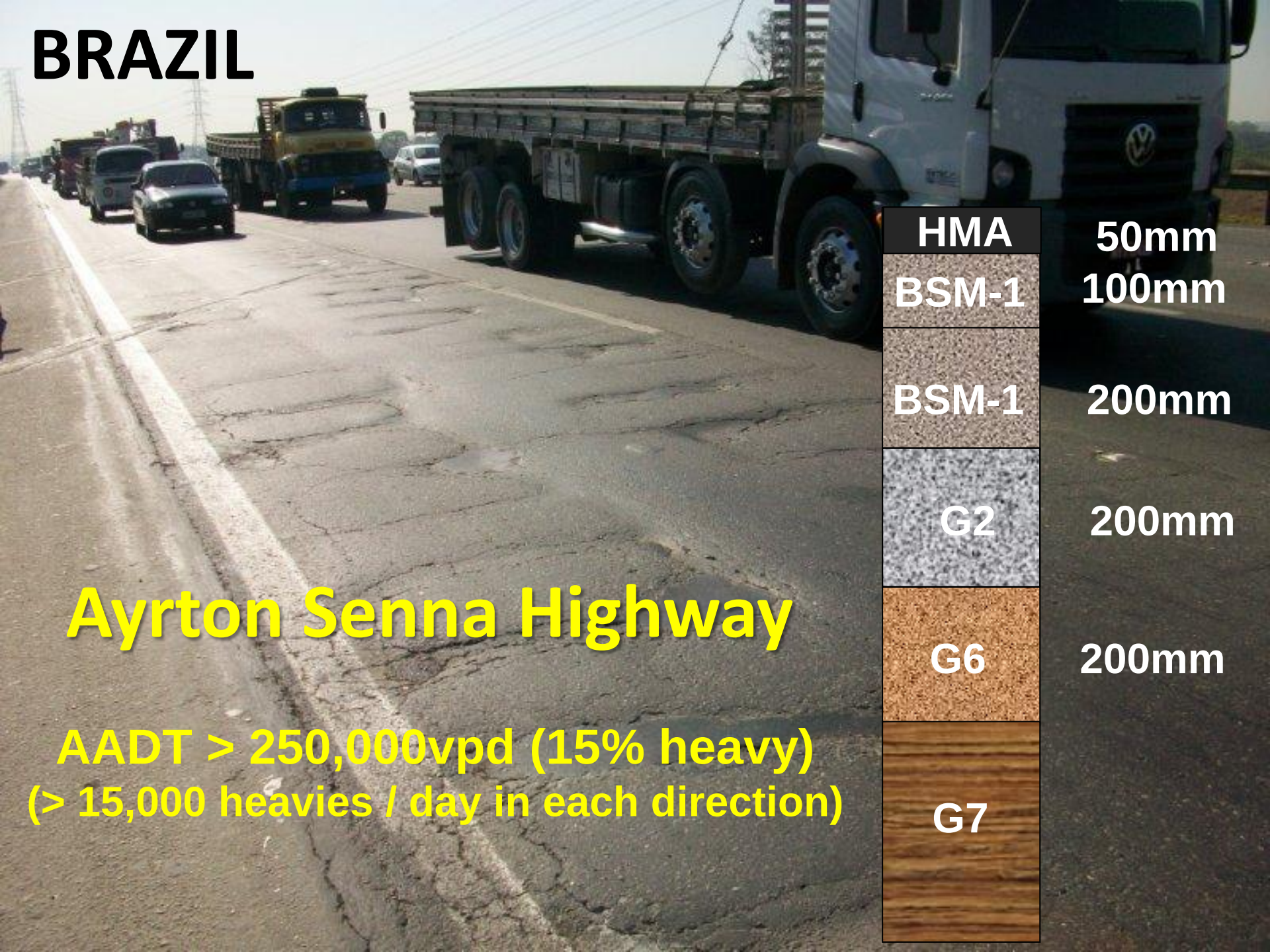
Stabilised 200mm imported G2 material

Foamed bitumen addition: 2.5%

No active filler added (cement or lime)

Completed BSM base before surfacing (chip seal)

BRAZIL



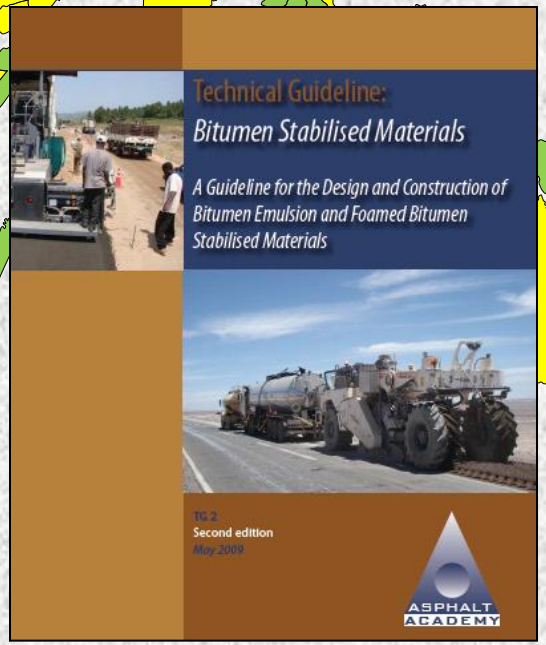
Ayrton Senna Highway

AADT > 250,000vpd (15% heavy)
(> 15,000 heavies / day in each direction)


AADT > 250,000vpd (15% heavy)
(> 15,000 heavies / day in each direction)
After 6 months...
> 3 x 10⁶ ESALs

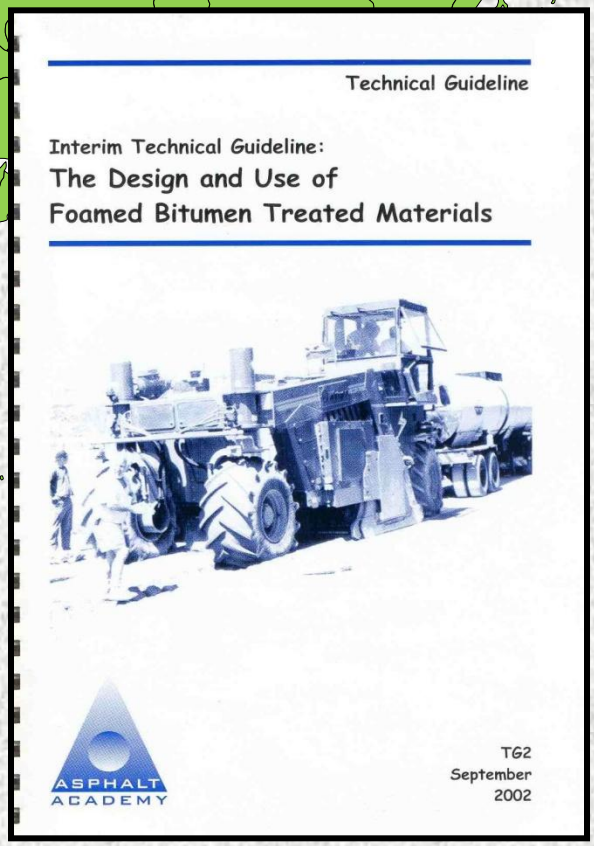
Philosophical argument …

> 5 000 km successful projects



Based on laboratory data and field observations….

< 100 km data set




Still need a meeting of the minds...
THANK YOU !