South African asphalt mix design manual

Sabita asphalt manual

25th ROAD PAVEMENTS FORUM

Ocean View Hotel, Strand, Western Cape
7 & 8 May 2013

Joseph Anochie-Boateng, Benoit Verhaeghe
CSIR Built Environment

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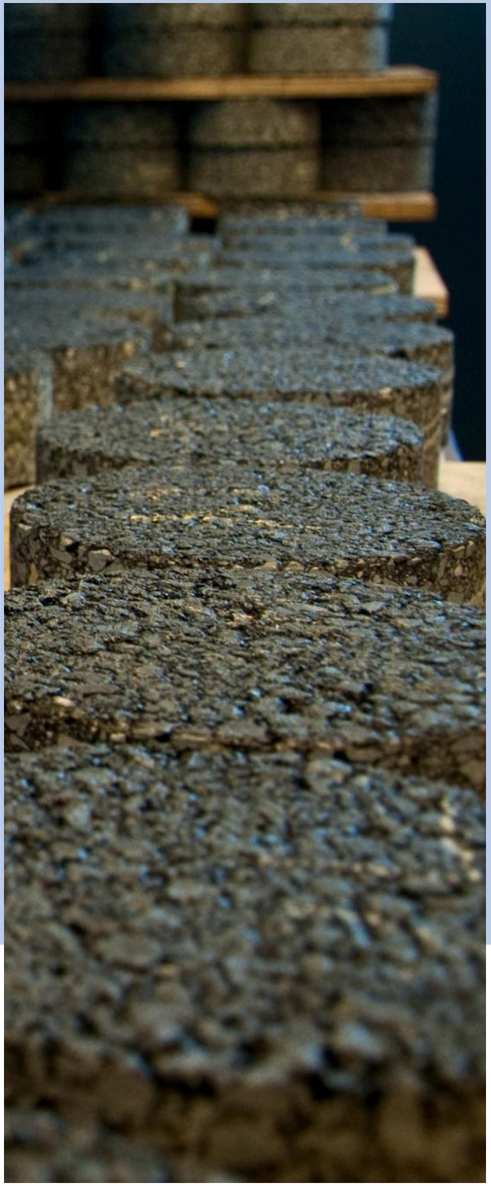
Introduction

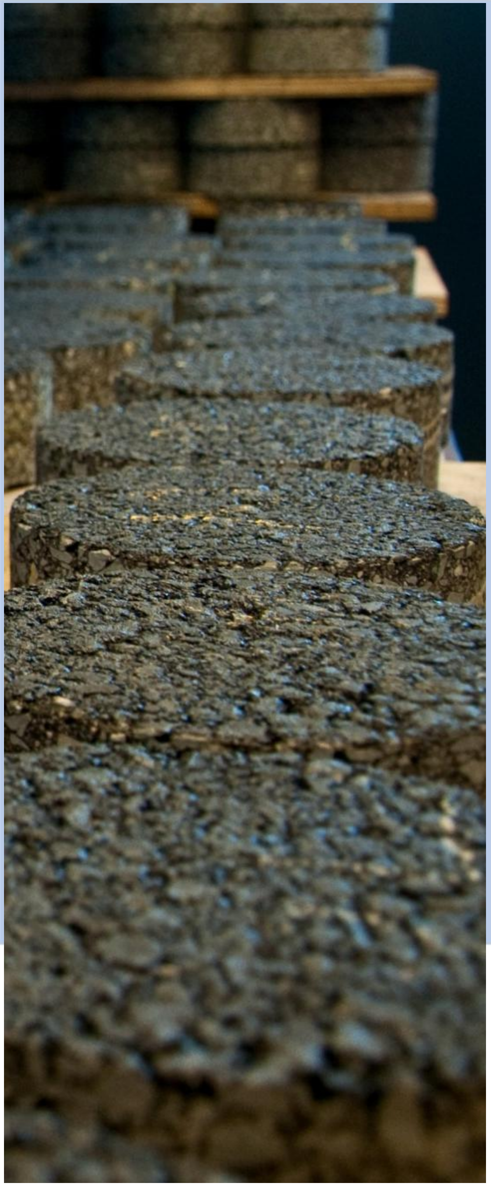


- Manual will replace existing guidelines for the design of asphalt mixes in South Africa
- Overall intention is to move from empirical-based design towards performance related design of asphalt materials
- Move is in line with international best practice and also enables the formulation of national specifications

Highlights

Item	Current practice	Proposed
Binder specification	Penetration (Pen)	Performance grade (PG)
Aggregate grading	COTO	Bailey method
Mix types	COTO (e.g., coarse/medium continuous; open graded; gap/semi-gap; SMA etc)	Only few mix types (*Coarse, Fine, SMA*)
Binder content	Film thickness	Richness modulus
Optimum binder content	Marshall strength, VMA, voids, density, etc.	Superpave volumetrics; permanent deformation and fatigue characteristics
Mix performance evaluation	Marshall flow, stability, ITS,TSR, dynamic creep, etc.	Workability, durability/TSR, dynamic modulus, flow number, fatigue
Lab compaction	Marshall	Gyratory

Traffic classification



Design traffic [ESALs]*	Description
< 0.3 million	Low/Light
0.3 to 3 million	Medium
3 to 30 million	Heavy
≥ 30 million	Very heavy

** ESAL = Equivalent Single Axle Load*

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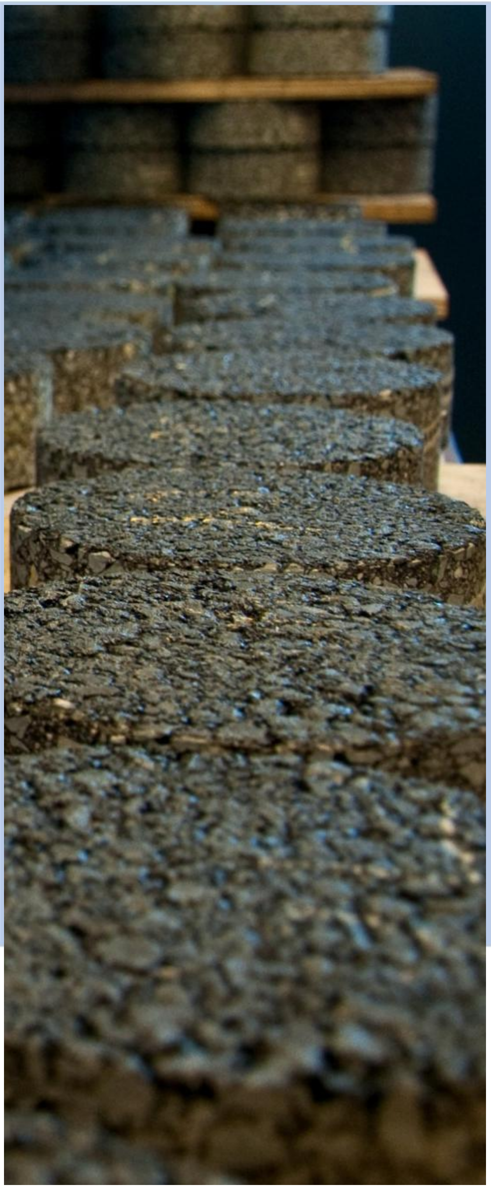
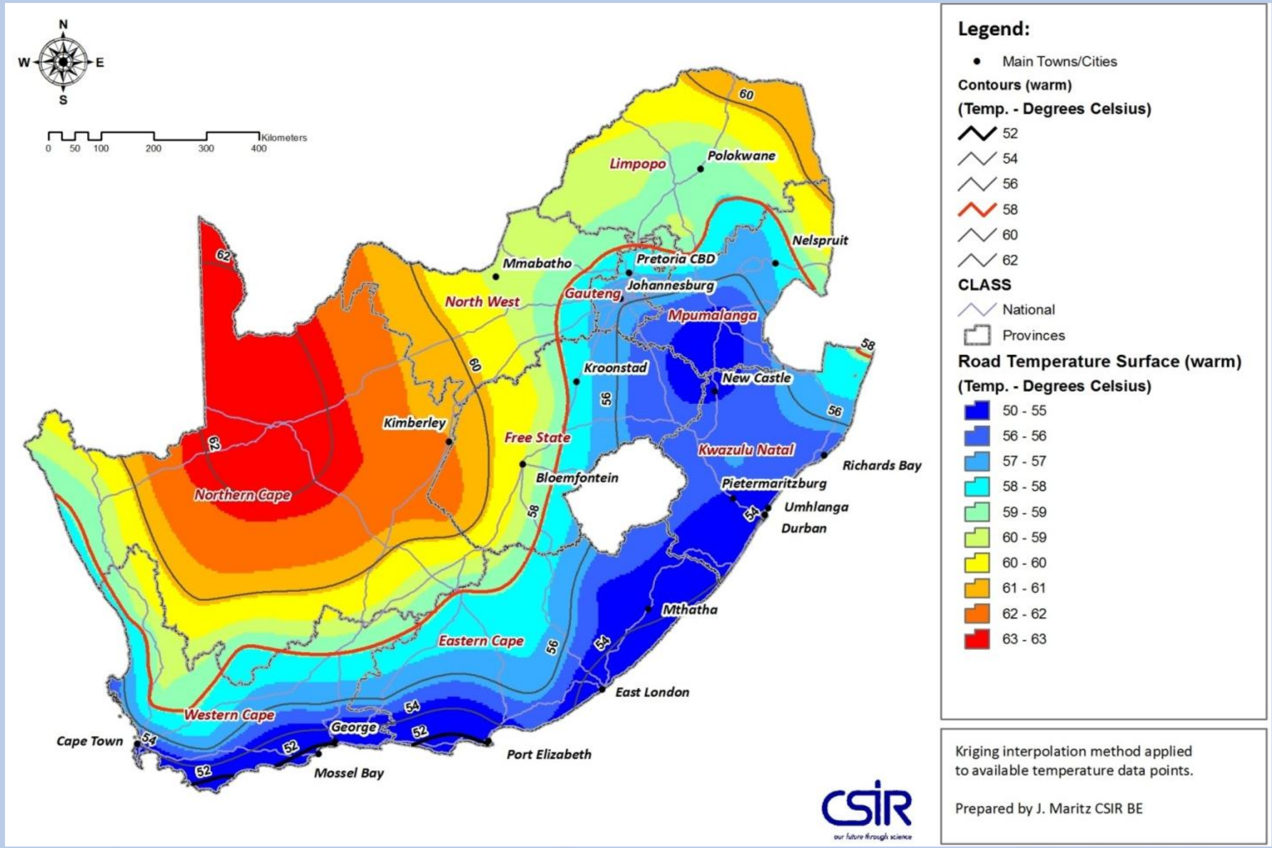
Binder selection



7-Day average maximum asphalt temperatures



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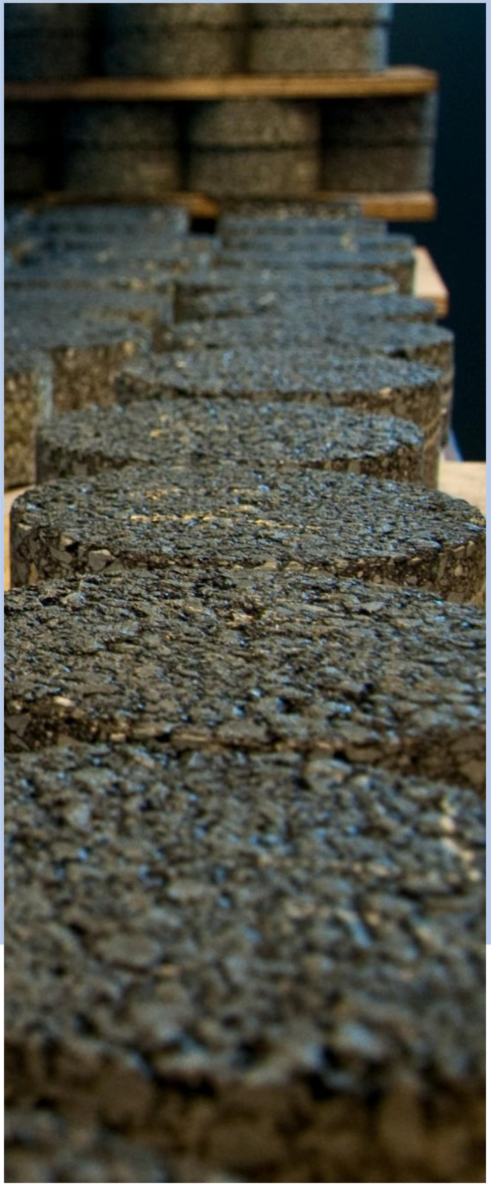
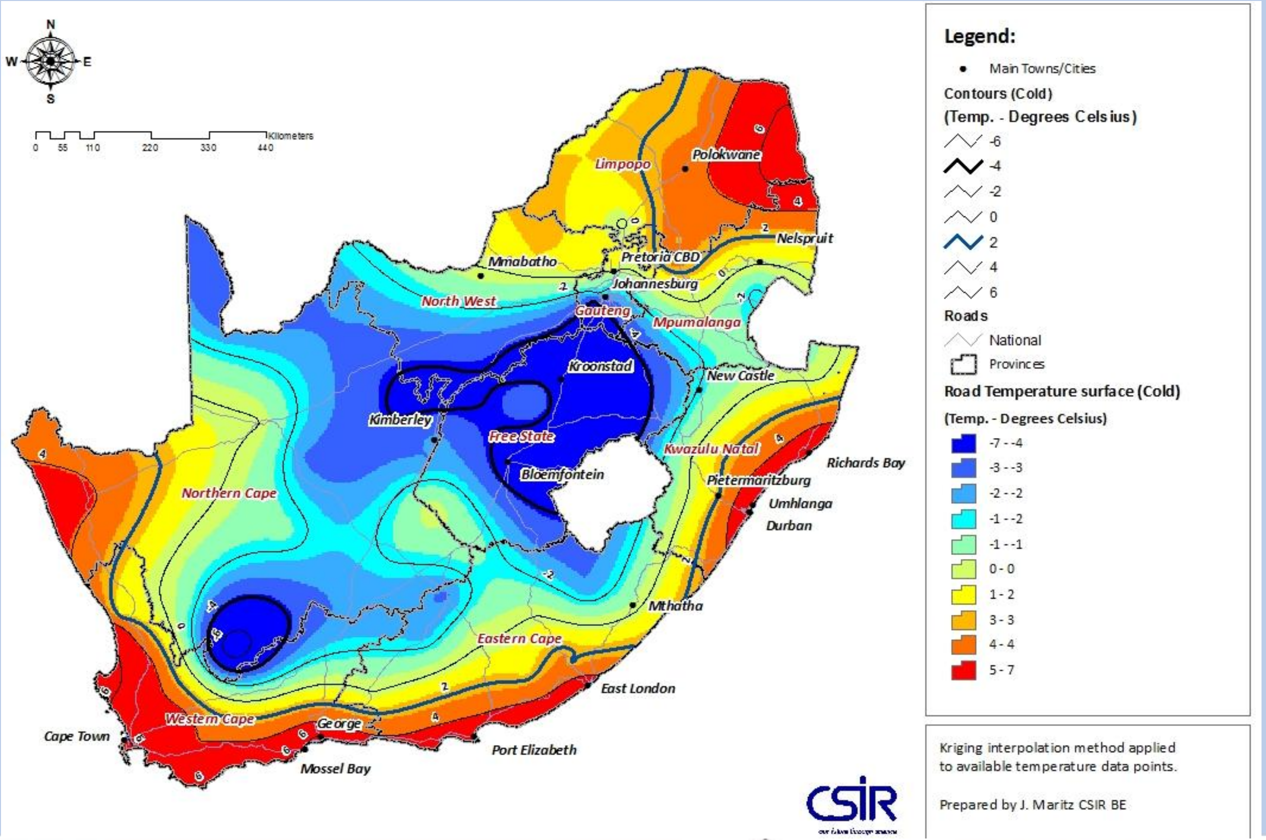
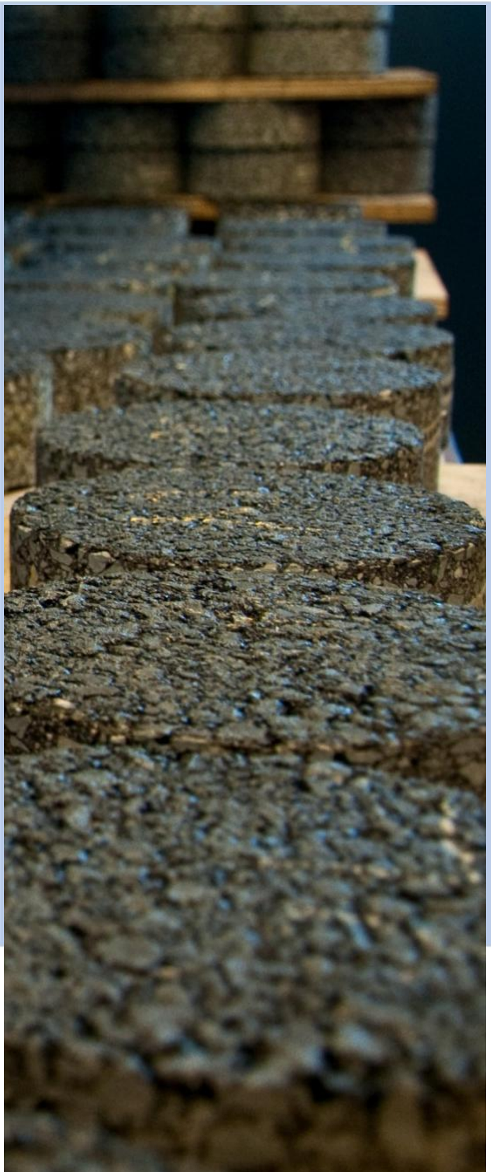
Binder selection



Minimum asphalt temperatures



Binder selection



PG Binder selection guideline

Binder classes: ▪ PG 64-10 ▪ PG 58-10 (Based on climate)	S	< 10 million ESALs
		AND Traffic speed > 70 km/h
	H	10 – 30 million ESALs
		OR Traffic speed 20-70 km/h
	V	> 30 million ESALs
		OR Traffic speed < 20 km/h
	E	> 30 million ESALs
		AND Traffic speed < 20 km/h

S = standard; H = heavy; V = very heavy; E= extreme

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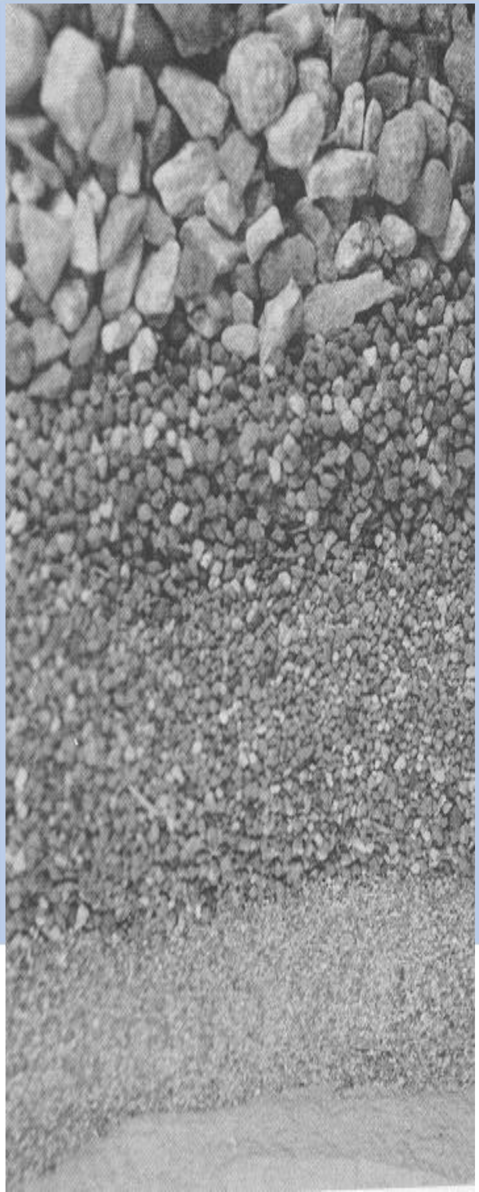
Aggregate selection



- Based on number of recommended tests and criteria
- Bailey method - grading and packing analysis
  - *Criteria are set based on unit weights, coarse and fine aggregate ratios*

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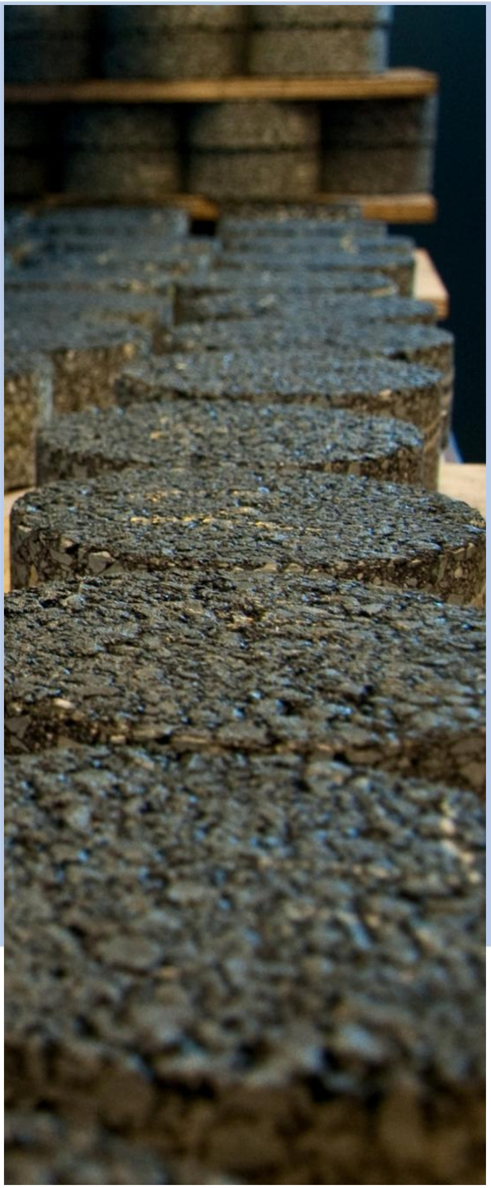
Mix design levels



Level IA: Low volume roads

Level IB: Modified Marshall

- Low to medium safety and economic consequences in case of premature mix failure
- IA: < 0.3 million ESALs
- IB: 0.3 to 3 million ESALs
- IA: Modified Marshall asphalt design
- IB: Volumetric design with empirical asphalt performance tests
- IB: PG selection of binder; Bailey method for aggregate design

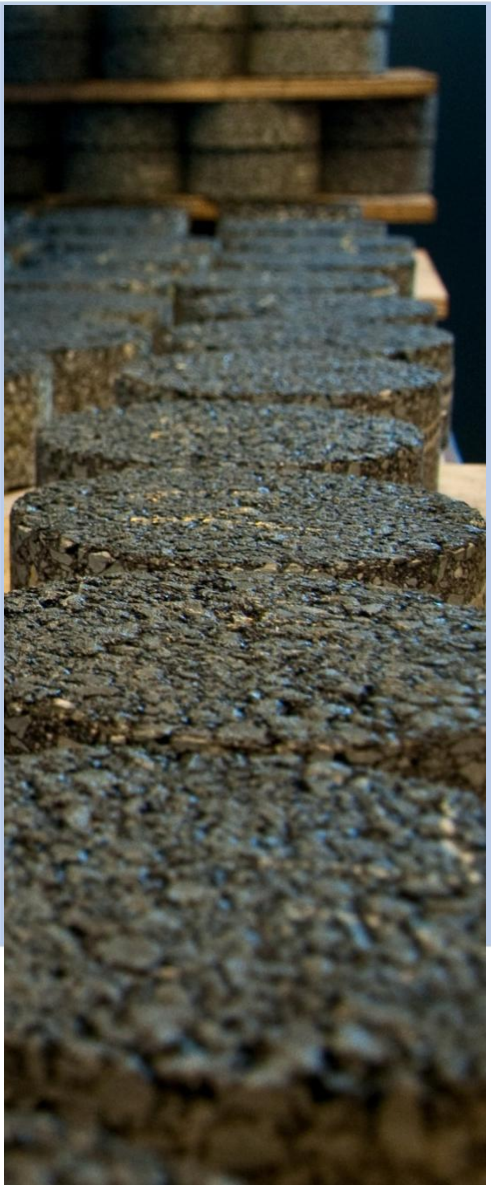
Level II : Performance-related for medium to high volume roads

- Medium to high safety and economic consequences in case of premature mix failure
- 3 to 30 million ESALs
- Involves Level IB volumetric design
- PG selection of binder; Bailey method for aggregate design
- Performance-related laboratory testing to select optimum mix design

Level III : Performance-related for high volume roads

- High safety and economic consequences in case of premature mix failure
- >=30 million ESALs
- Involves Level IB volumetric; full scale Level II laboratory testing
- Pavement analysis to select optimum mix design

Mix design process – Level I



Select mix type	
Design objectives	Design situation

↓

Evaluate components	
Select PG binder	Select suitable aggregate

↓

Determine aggregate structure	
Perform aggregate packing analysis	Bailey criteria

↓

Determine minimum binder content	
Richness modulus (guideline)	Minimum binder content (guideline)

↓

Produce trial mixes

check volumetrics (VIM, VMA, VFB)

↓

Select optimum design

Optimum design is based on modified Marshall criteria (IA) and immersion index, permeability, TSR, ITS, creep (IB)

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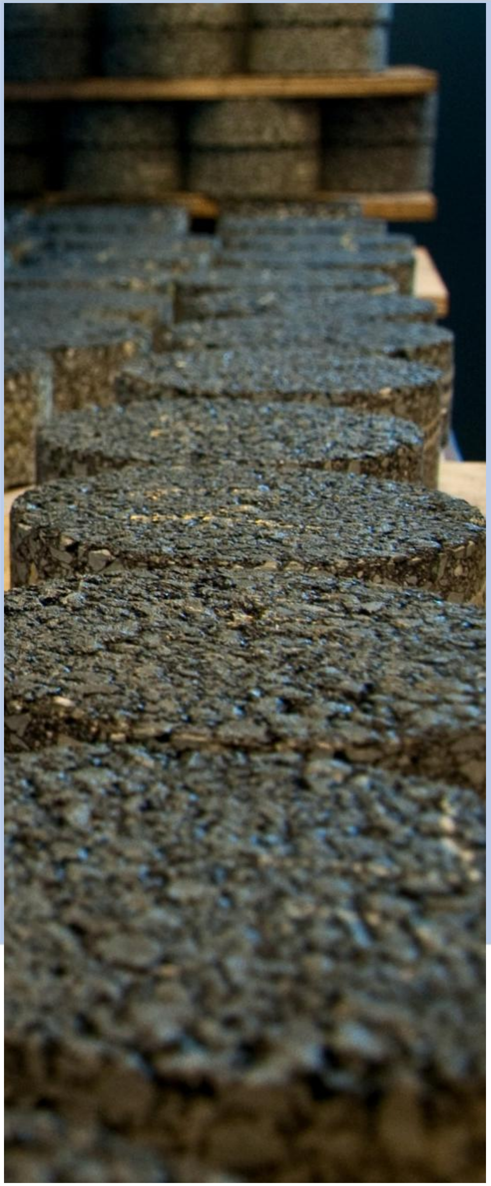
Mix design process – Levels II & III



Select mix type
- Design objectives
- Design situation

↓

Evaluate components
- Select PG binder
- Select suitable aggregate

↓

Determine aggregate structure
- Perform aggregate packing analysis
- Bailey criteria

↓

Determine minimum binder content
- Richness modulus (guideline)
- Minimum binder content (guideline)

↓

Produce trial mixes
- check volumetrics (VIM, VMA, VFB)

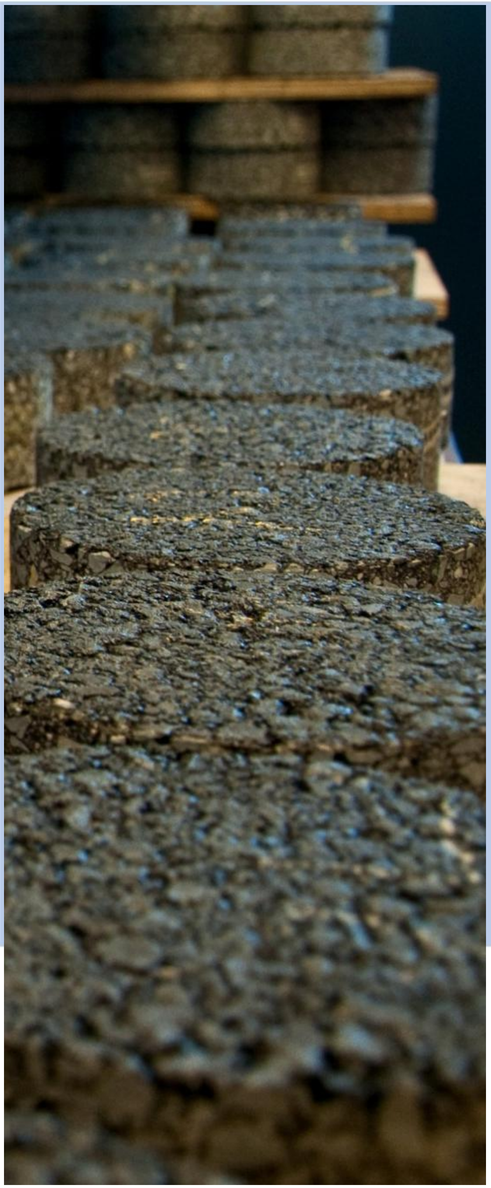
↓

Select optimum design
- Iterative design process to meet permanent deformation and fatigue criteria;

↓

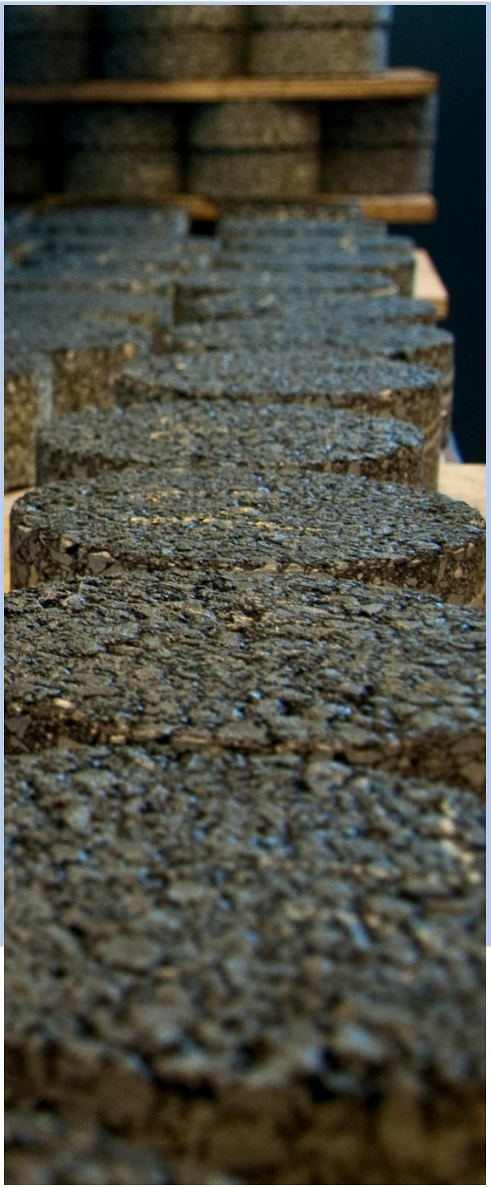
Evaluation of the final mix design
- Evaluate mix against workability, durability and stiffness requirements
- Level II requires reduced Lab tests; Level III requires full scale Lab tests

Performance related tests



Property	Test conditions	Min no. of specimens	Test method
Workability	Superpave gyratory compaction	3	ASTM D 6925
Durability	Modified Lottman test conditions	6	ASTM D 4867M
Stiffness	Dynamic modulus at chosen test temperature and frequency	5	AASHTO TP 79
Permanent deformation	Flow number (FN) permanent deformation at chosen test temperature and loading frequency	3	AASHTO TP 79
Fatigue	Four-point beam fatigue test at chosen test temperature, frequency and strain levels	9	AASHTO T 321

Proposed workability criteria



Mix type	Gyrations	Voids
Fine	25	$0 < V_{25} – V_{des} < 2$
Coarse	25	$0 < V_{25} – V_{des} < 2$
SMA	25	$0 < V_{25} – V_{des} < 2$
HiMA-Class 1	45	$V_{45} \leq 10\%$
HiMA-Class 2	45	$V_{45} \leq 6\%$

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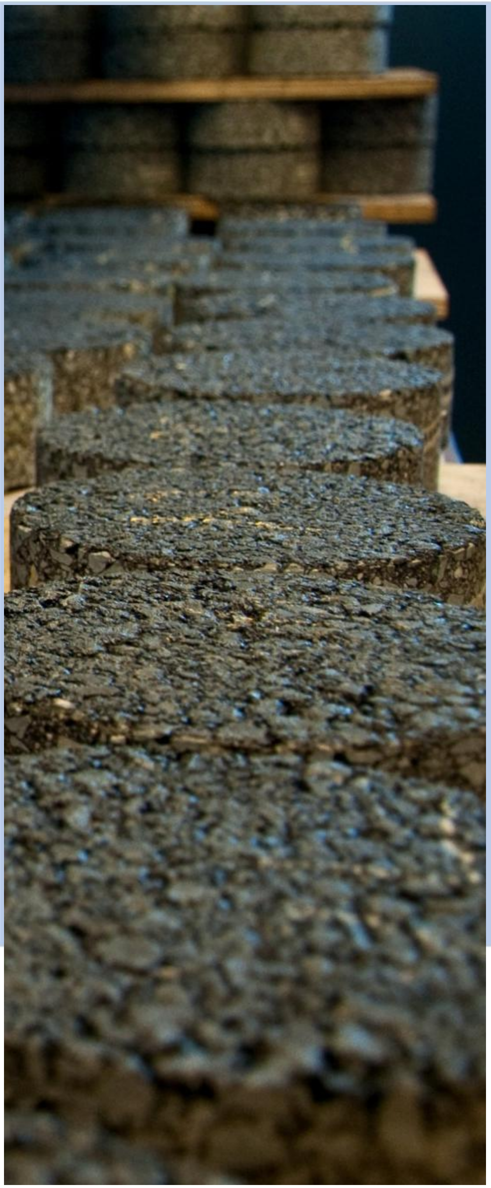
Air voids content after 300 gyrations



	Gyratory voids [%]	Corrected to actual density [%]
Mix 1: KZN BTB (A-P1)	3.6	1.4
Mix 2: W/C med continuous (60/70)	9.3	6.7
Mix 3: Gauteng 9.5 med cont. (60/70)	3.9	2.2
Mix 4: KZN Type D (60/70)	2.5	1.7
Mix 5: KZN Type D WMA (A-E2)	2.9	0.9

- Workability criteria?

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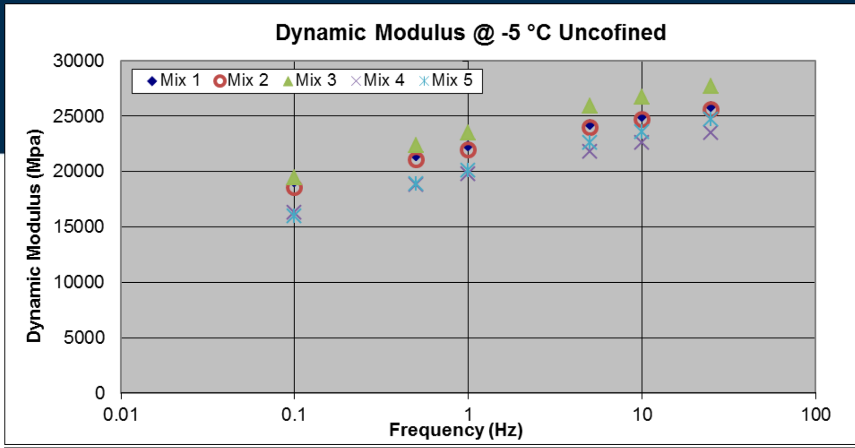
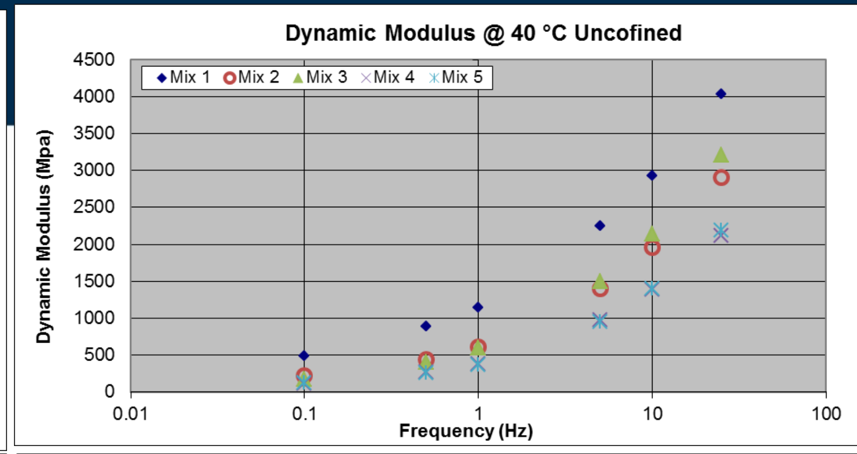
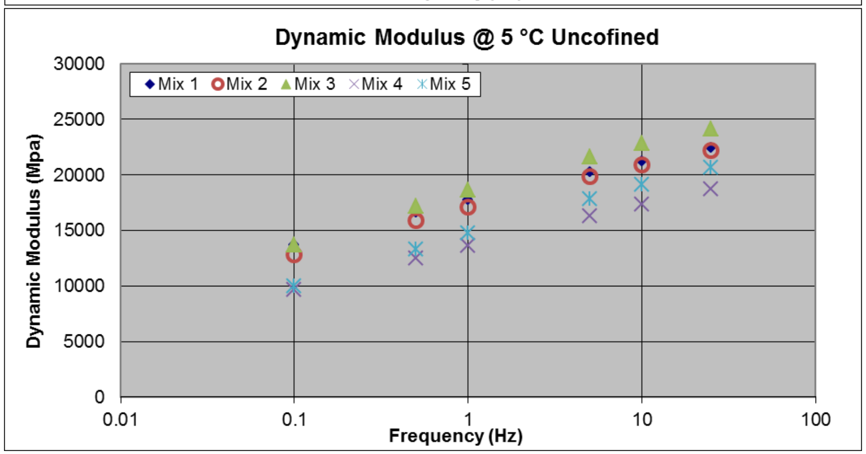
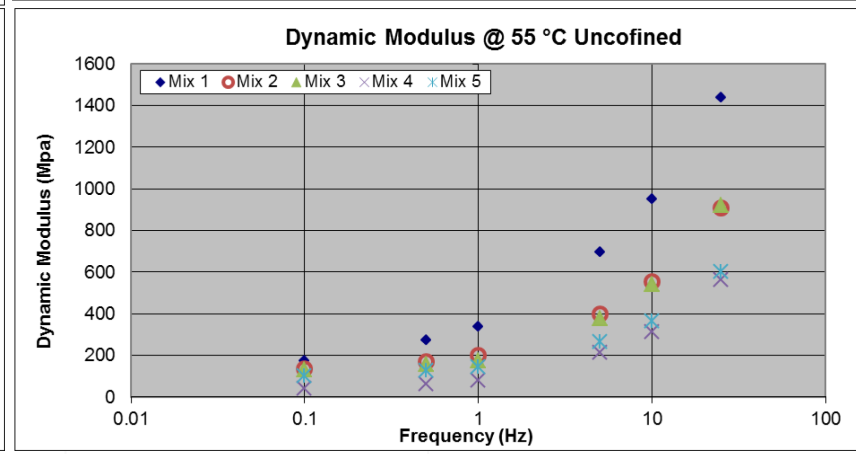
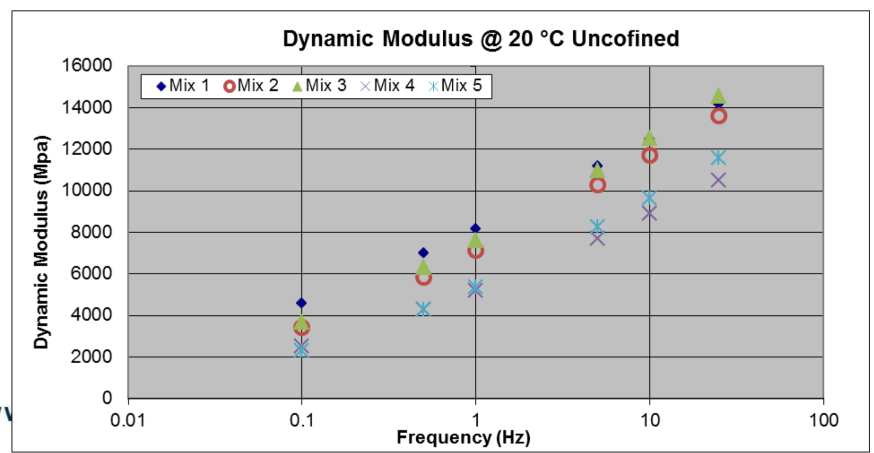
Dynamic modulus results











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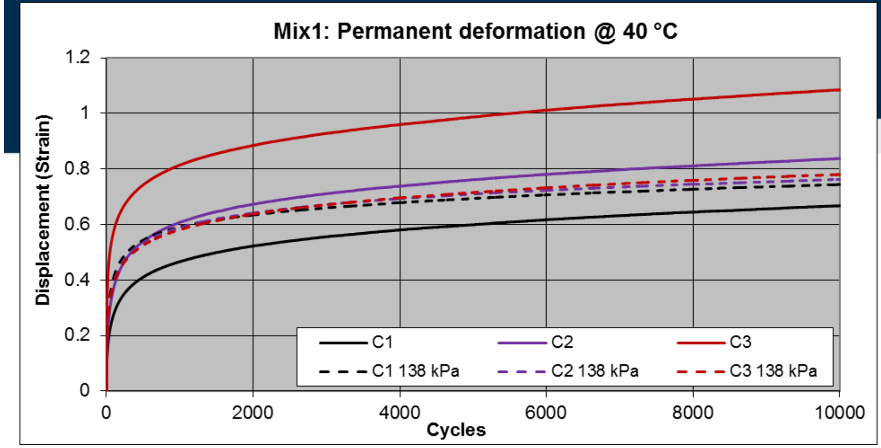
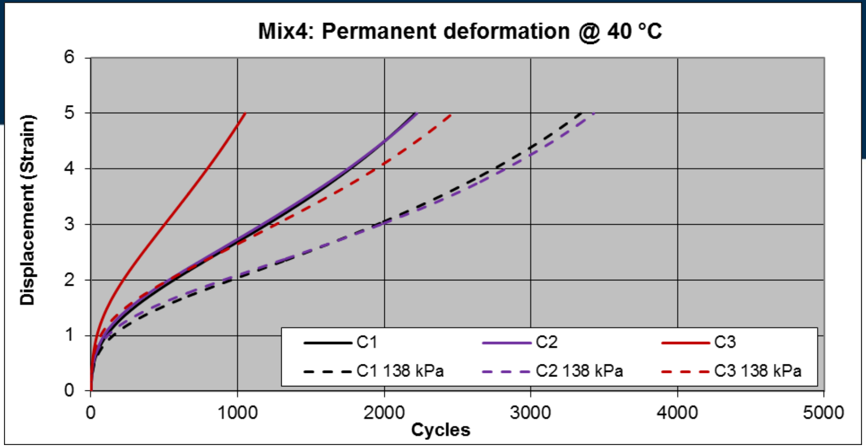
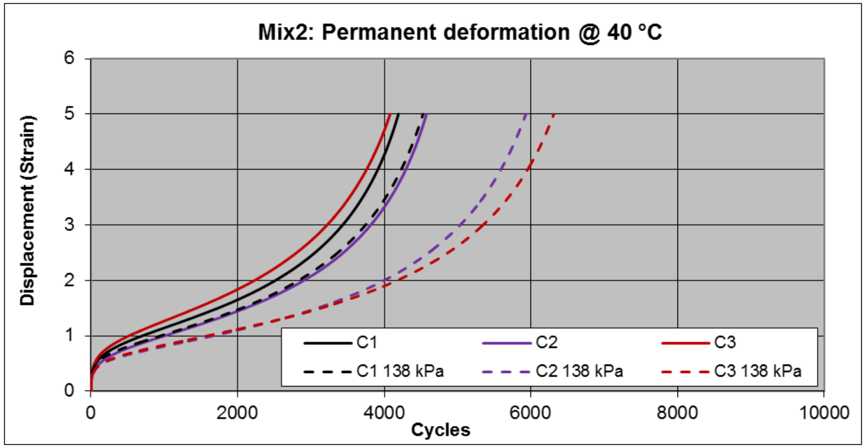
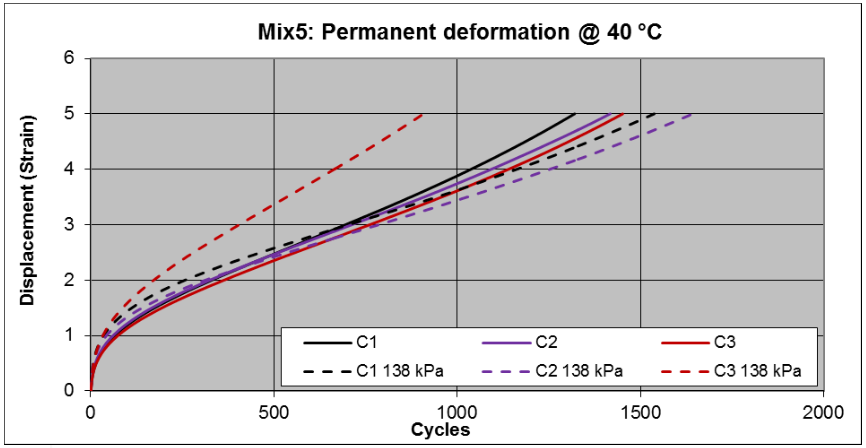
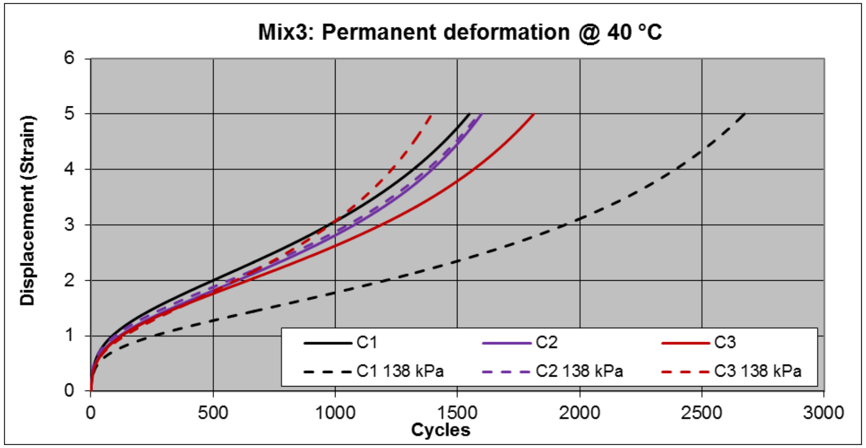
Permanent deformation @ 40°C





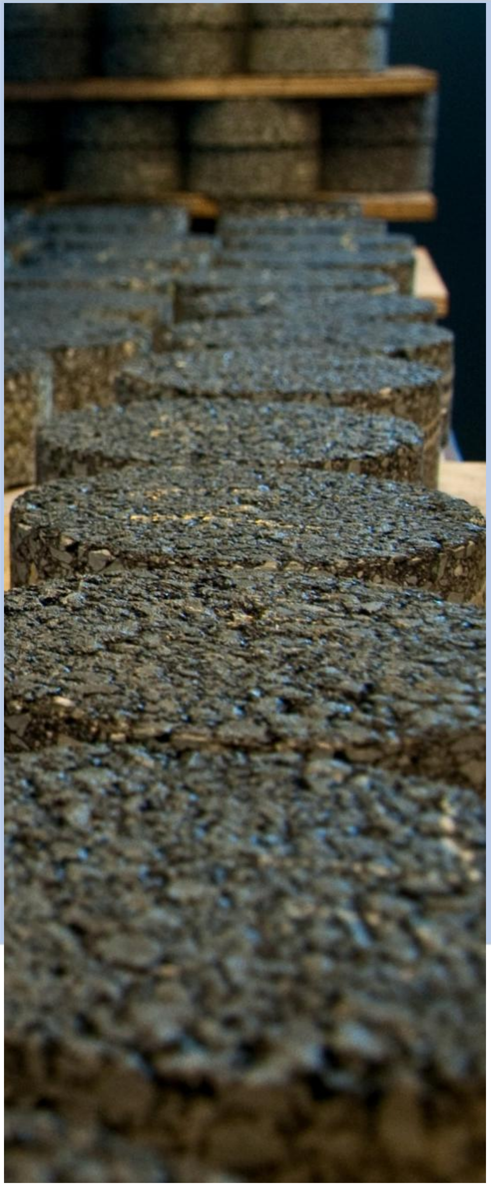


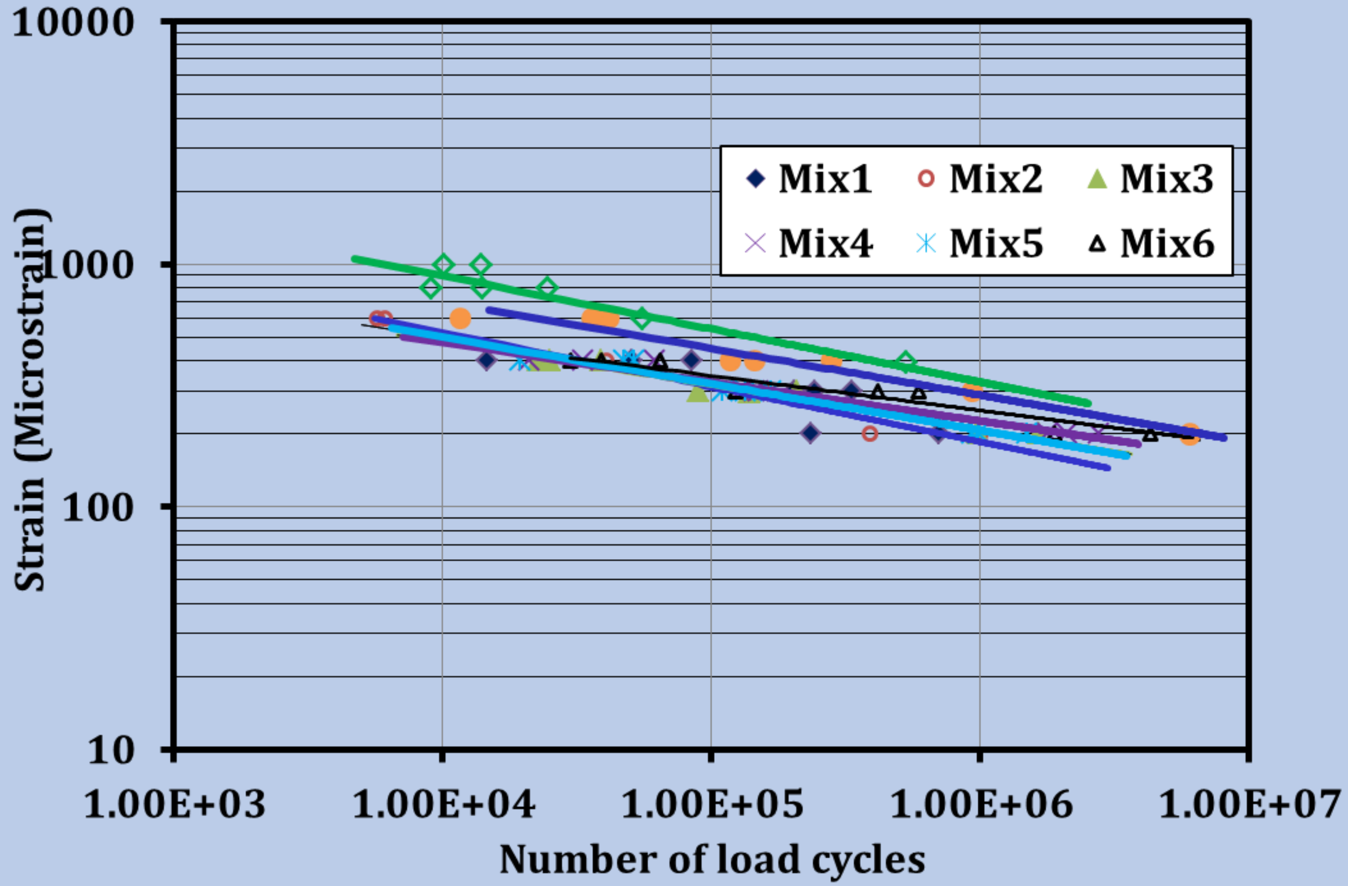




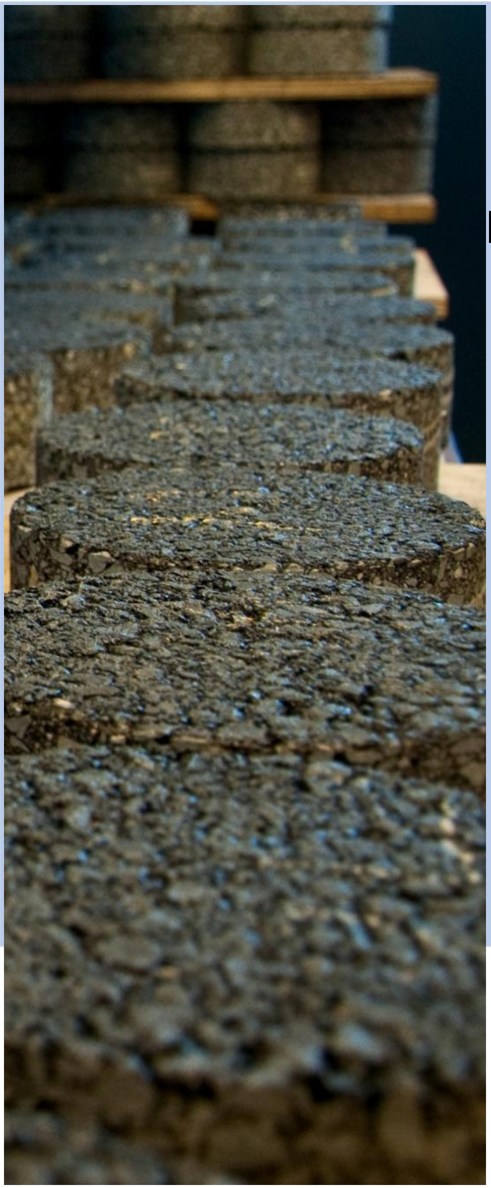
Tempearture 40℃						
		Mix1	Mix2	Mix3	Mix4	Mix5
Unconfined	Average Flow number	3993	1027	561	669	622
	Average PD at Flow (mm)	1.128	1.745	2.968	3.835	4.184
Confined	Average Flow number	6070	1107	64	1001	680
	Average PD at Flow (mm)	1.092	1.381	2.529	3.308	4.887

Mix design criteria- 4PT beam fatigue





Link to pavement design

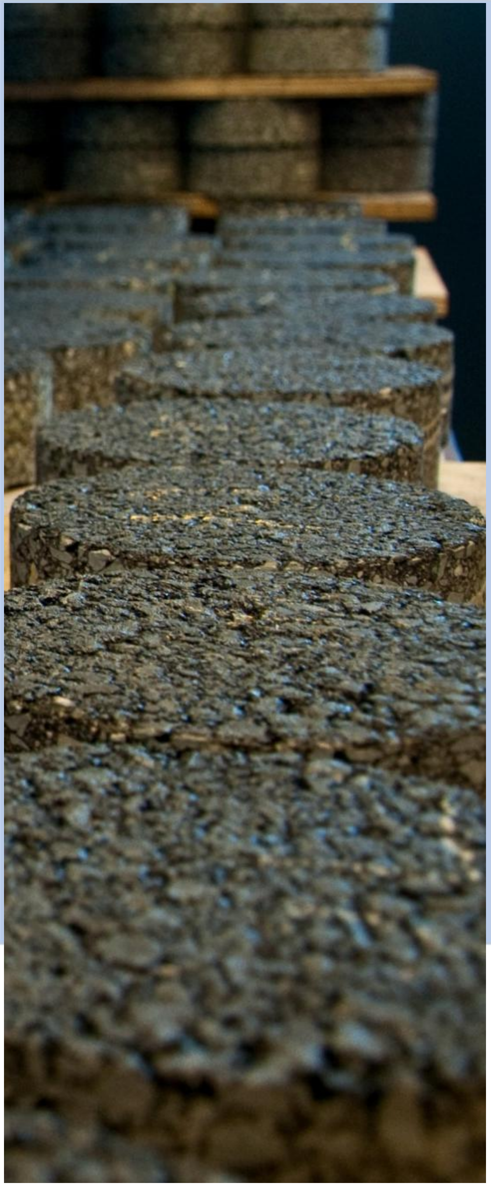


- Hirsch predictive equation for dynamic modulus

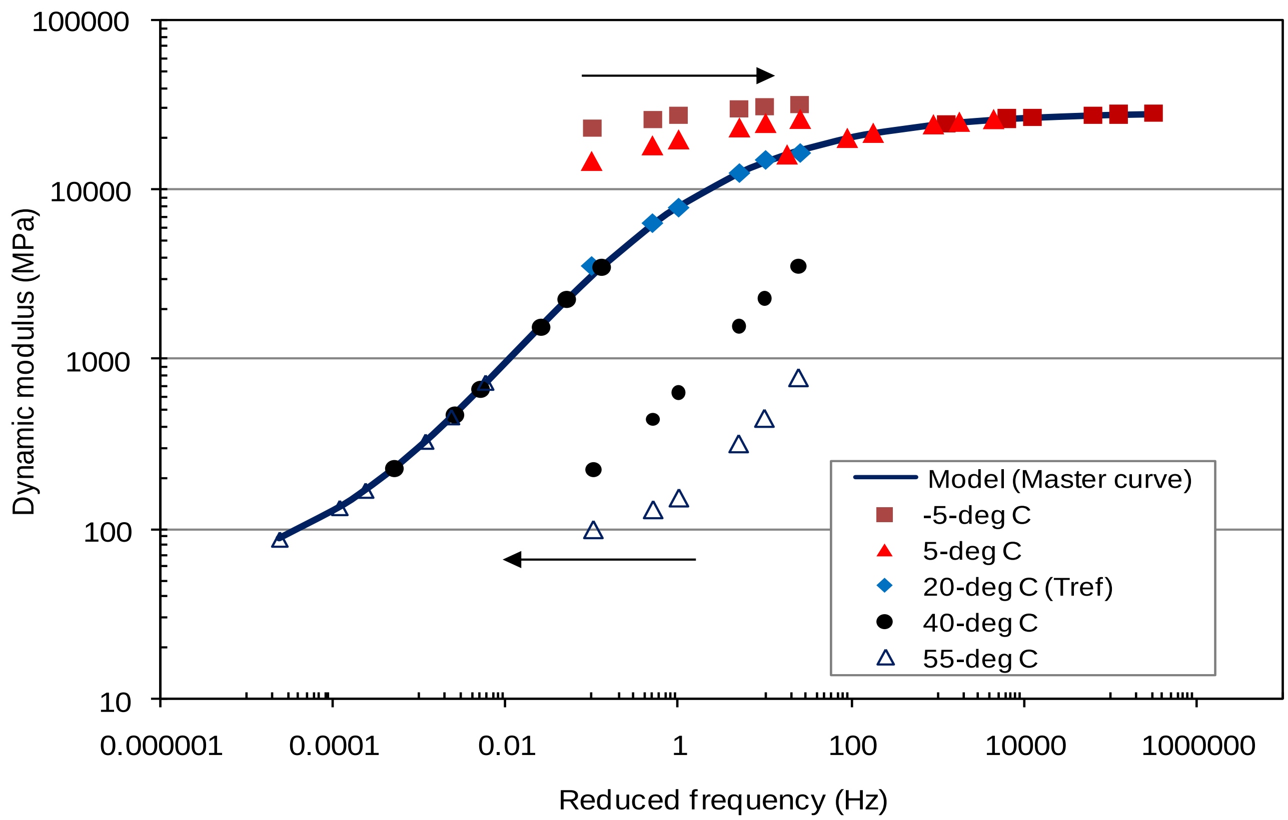
$$|E^*|_{mix} = P_c\left[4{,}200{,}000\left(1-\frac{VMA}{100}\right)+3\,|G^*|_{binder}\left(\frac{VFB\times VMA}{10{,}000}\right)\right]+\frac{1-P_c}{\left[\dfrac{\left(1-\dfrac{VMA}{100}\right)}{4{,}200{,}000}+\dfrac{VMA}{3VFB\,|G^*|_{binder}}\right]}$$

$$P_c=\frac{\left(20+\dfrac{VFB\times 3\,|G^*|_{binder}}{VMA}\right)^{0.58}}{650+\left(\dfrac{VFB\times 3\,|G^*|_{binder}}{VMA}\right)^{0.58}}$$

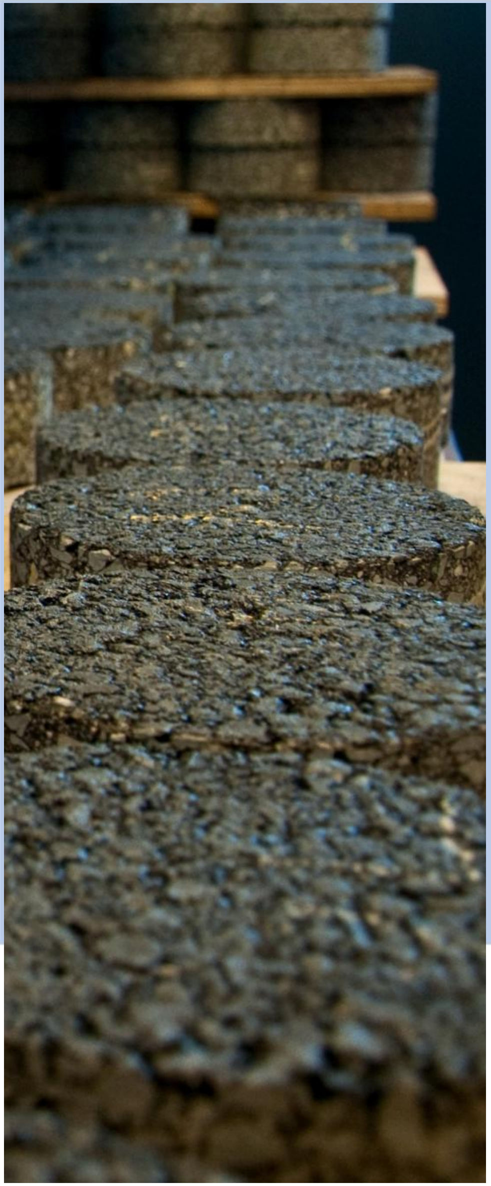
Link to pavement design



- Level III mix design – full scale laboratory testing to develop dynamic modulus master curve



Link to pavement design



- Establish model parameters (k_{is}) for permanent deformation and fatigue models

$$\varepsilon_{\mathrm{p}} = k_1 \times N^{k2} T^{k3} \sigma_d^{k4}$$

Plastic strain model

$$N_f = k_1 \left(\frac{1}{\varepsilon_t}\right)^{k_2} \left(\frac{1}{E}\right)^{k_3}$$

Fatigue model

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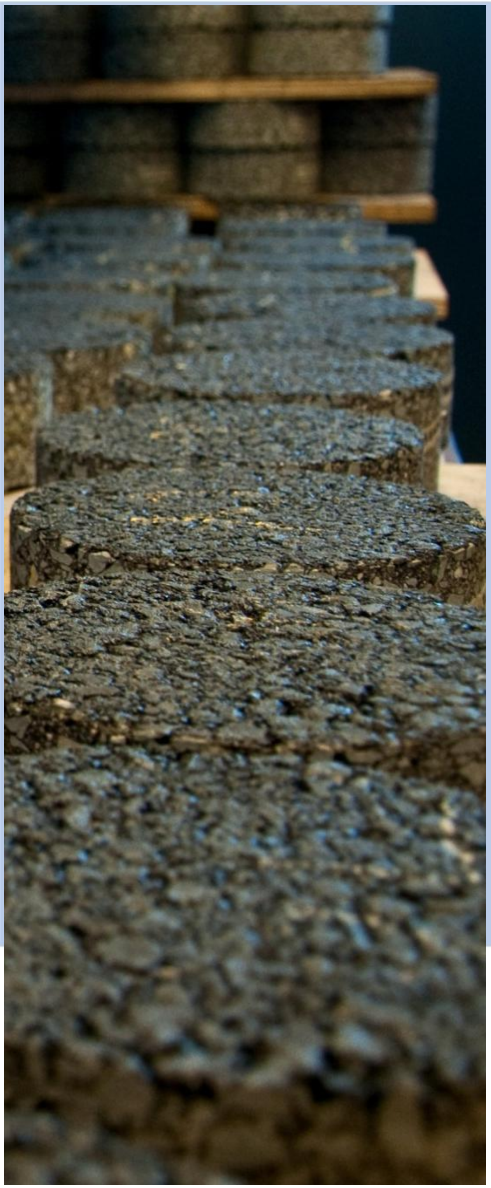
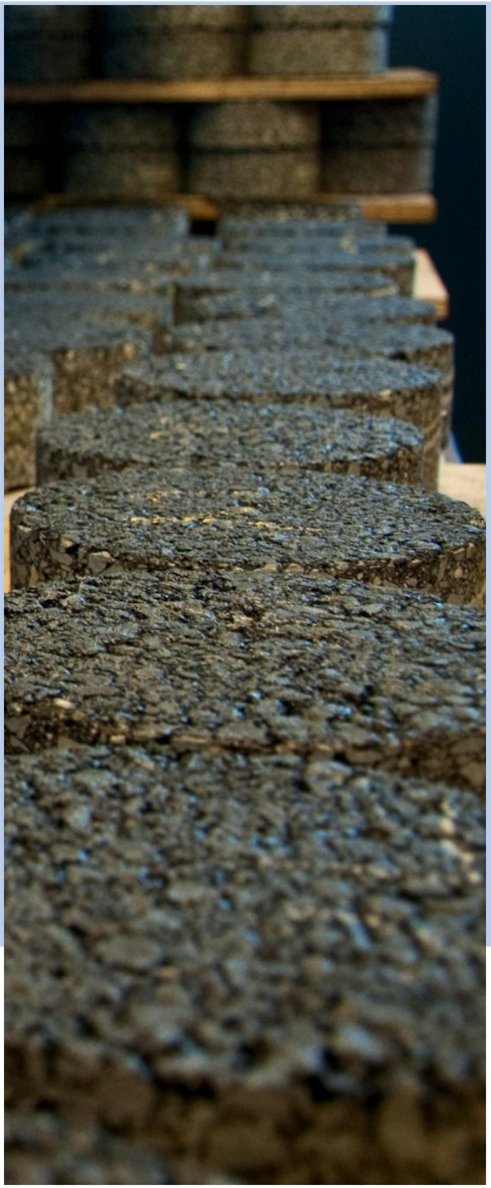
QC & QA



- QC and QA aspects cover
  - *Laboratory mix design*
  - *Plant trial*
  - *Construction of trial paving section*
  - *Site paving*

Milestones



Activity	Completion date	Status
1. Phase I (Establishment)	30 Dec 2011	Completed
2. Phase II (State-of-the-art study)	31 July 2011	Completed
3. Laboratory testing to develop criteria (seven aggregates, 13 mixes)	21 Feb 2013	Completed
4. First draft design manual	31 March 2013	Completed
5. Send draft manual for review	15 April 2013	Completed
6. Incorporate comments, suggestions in 1st draft	01 June 2013	In progress
7. Final draft	01 Sept 2013	---
8. Phase IV (Dissemination)	-- -- ----	---

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HiMA Long-Term Pavement Performance Testing

25th ROAD PAVEMENTS FORUM

Ocean View Hotel, Strand, Western Cape
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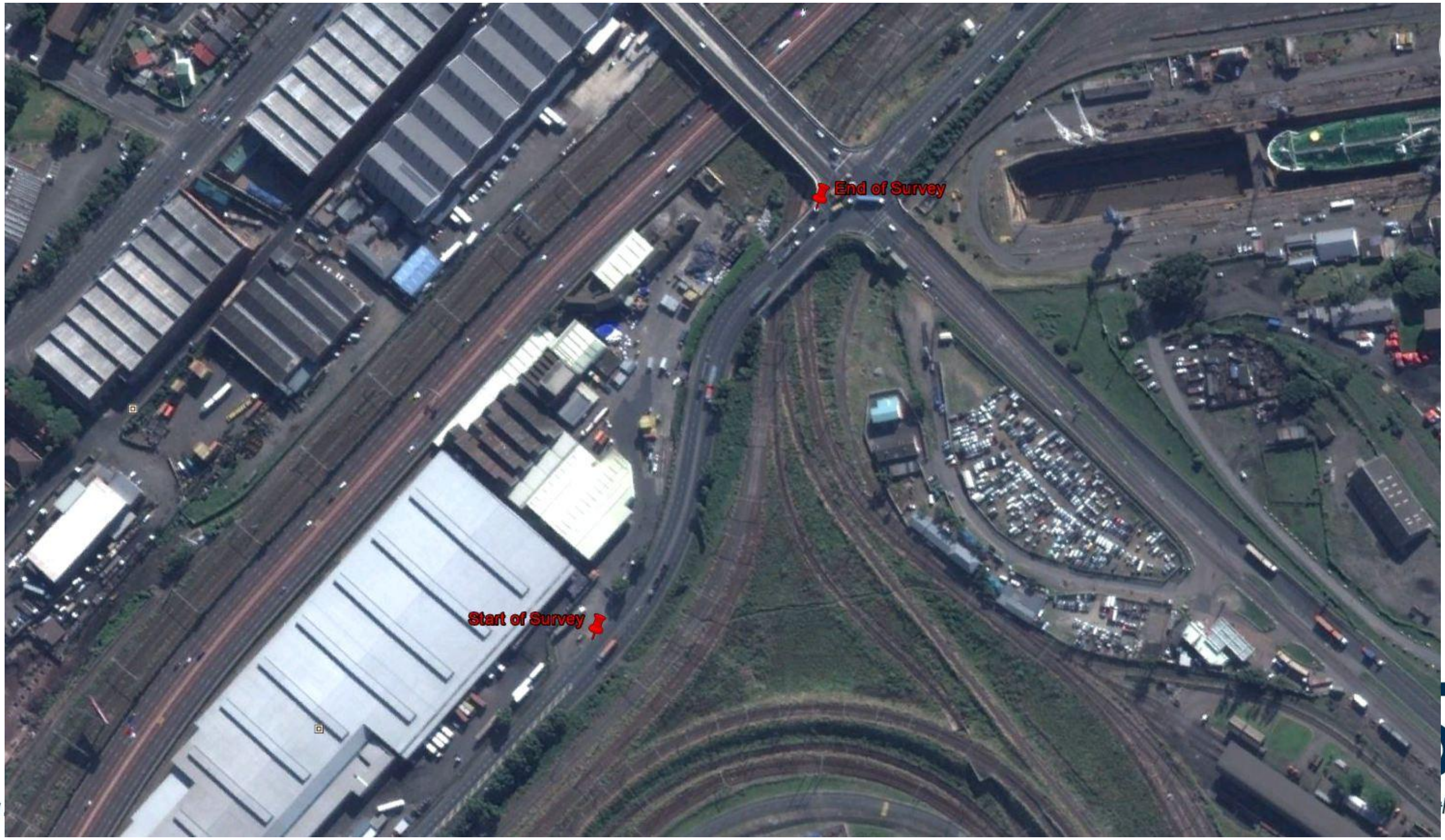
South Coast road HiMA section
Long Term Pavement Performance study

Survey performed every 6 months for 2 years

- *Visual inspection*
- *FWD and profilometer survey*



Example of visual assessment rating

VISUAL ASSESSMENT

Date	05/04/2013													
Surface Type	SMA													
Lane / Direction	Slow NorthBound													
Panel / Chainage	150 - 100 metres from intersection													
Texture	Fine													
Voids	Varying - None to Few													
	Degree						Extent					Length	Width	Number
	Slight					Severe	Slight				Severe			
Mechanical Failure	0	1	2	3	4	5	1	2	3	4	5			
Other Failure	0	1	2	3	4	5	1	2	3	4	5			
Bleeding/Flushing	0	1	2	3	4	5	1	2	3	4	5	on wheel paths		
Surface Cracks	0	1	2	3	4	5	1	2	3	4	5			
Binder Condition	0	1	2	3	4	5	1	2	3	4	5			
Aggregate Loss	0	1	2	3	4	5	1	2	3	4	5			
Cracks Blocks	0	1	2	3	4	5	1	2	3	4	5			
Cracks Longitudinal	0	1	2	3	4	5	1	2	3	4	5			
Cracks Transverse	0	1	2	3	4	5	1	2	3	4	5			
Cracks Crocodile	0	1	2	3	4	5	1	2	3	4	5			
Cracks Parabolic	0	1	2	3	4	5	1	2	3	4	5			
Pumping	0	1	2	3	4	5	1	2	3	4	5			
Rutting	0	1	2	3	4	5	1	2	3	4	5			
Undulation/Settlement	0	1	2	3	4	5	1	2	3	4	5			
Edgebreak	0	1	2	3	4	5	1	2	3	4	5			
Potholes	0	1	2	3	4	5	1	2	3	4	5			
Delamination	0	1	2	3	4	5	1	2	3	4	5			
												Number of Patchs & size		
Patching	0	1	2	3	4	5	1	2	3	4	5			
													Influencing Factors	
Riding Quality	0	1	2	3	4	5	1	2	3	4	5			
Skid Resistance	0	1	2	3	4	5	1	2	3	4	5	Bleeding		
Surface Drainage	0	1	2	3	4	5	1	2	3	4	5			
Side Drainage	0	1	2	3	4	5	1	2	3	4	5			

20 months survey (April 2013)

- *Overall condition of the pavement is still good*
- *Few defects of degree not more than 3 (condition not yet warning)*
- *SMA is flushing in places, almost voidless, loss of texture*
- *Fuel spillages are a frequent occurrence on section*
- *Drainage issues especially on the bridge*
- *No indication of structural damage to the HiMA layer yet*
- *FWD & profile measurements recently completed, analyses of data pending*

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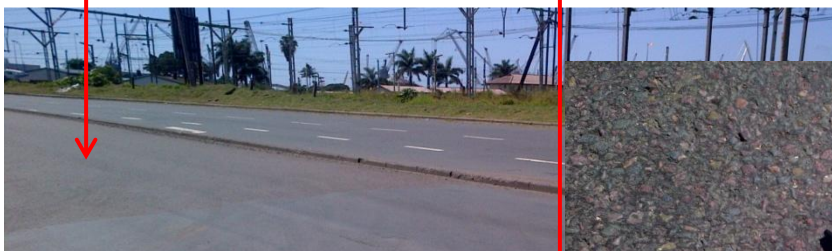
Photos taken during inspection

- *HiMA section & old section*



- *General impression*
- *Flushing in places (wheel-tracks)*
- *Texture*

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Photos taken during inspection

- *Isolated fuel spillages, resulting in bleeding*
- *Block crack with a deformation*

Photos taken at intersection

- *General impression*
- *Drainage issues*
- *Deformation with aggregate loss, just at intersection*

Thank you