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APPLICATION OF ENROBÉ À MODULE ÉLEVÉ (EME) AT THE TRUCK CRAWLER LANE ON NATIONAL ROUTE 1 SECTION 1

(CONTRACT N001-010-2014/1F)

Between the Huguenot Plaza (km 56.10) and Huguenot Tunnel West Portal (km 61.50) and the Truck Inspection Station at km 66.80

12 May 2015
Road Pavements Forum (RPF)

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1. PROJECT INFORMATION

1.1 Introduction

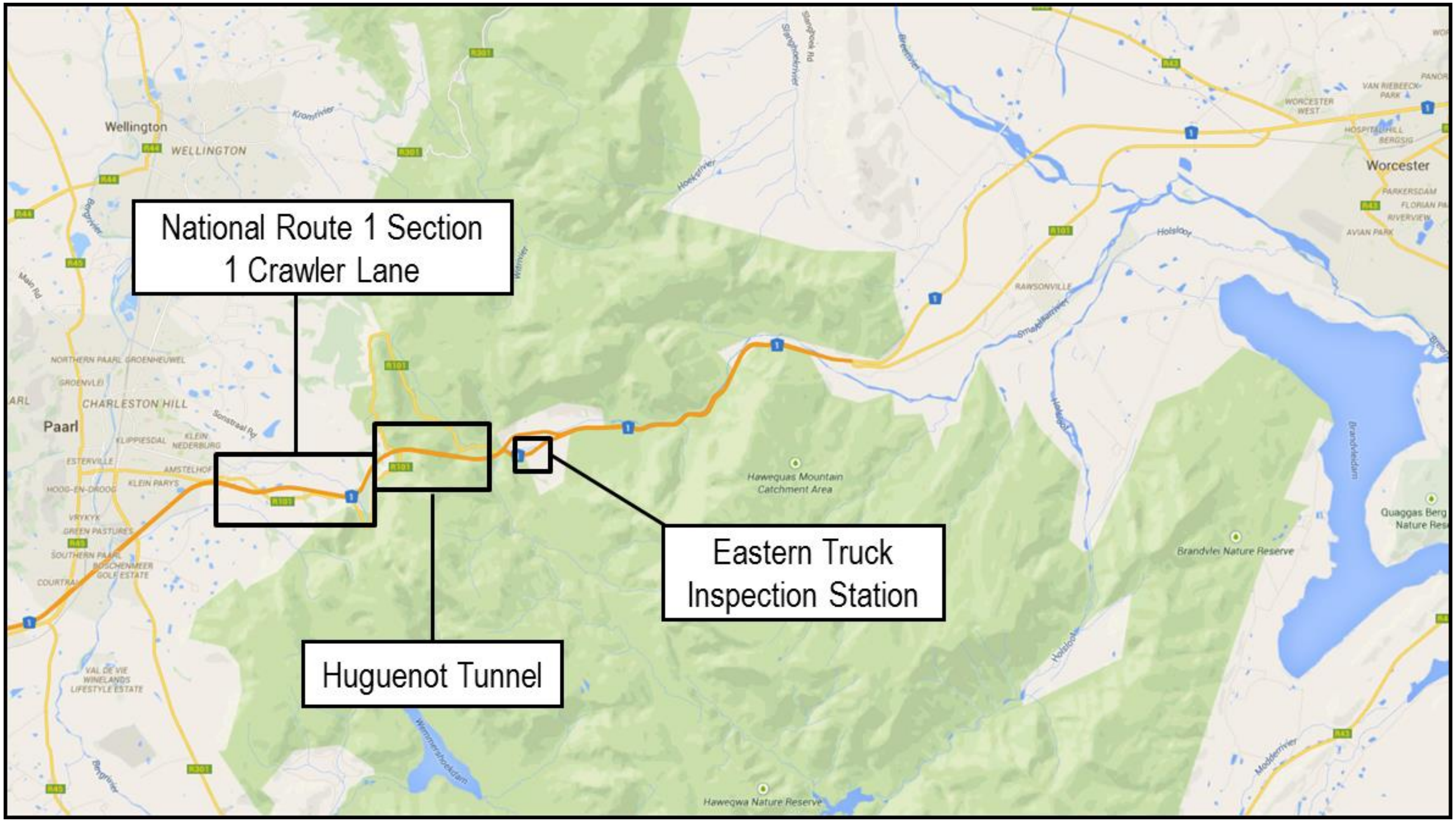
- Royal HaskoningDHV (Pty) Ltd was appointed as a service provider by the South African National Roads Agency SOC Ltd (SANRAL) for the provision of consulting engineering services in terms of the Special Maintenance of the Truck Crawler Lane on National Route 1 Section 1.

1.2 Project Locality

- The project is located north east of Paarl in the Western Cape on National Road 1 Section 1, between Huguenot Toll Plaza (km 56.10) and Huguenot Tunnel West Portal (km 61.50) as well as the truck inspection station at km 66.80.

1. PROJECT INFORMATION

Project Locality: Truck Crawler Lane on National Route 1 Section 1



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1. PROJECT INFORMATION

1.3 Project Background

- National Road 1 Section 1, between the start of the proclaimed toll road near the Huguenot Toll Plaza at km 56.10 and the western portal of the Huguenot Tunnel at km 61.50 was originally constructed around 1986 to 1988.
- These sections of road was rehabilitated and widened in 2009 to 2010.
- As part of the rehabilitation works, the truck crawler lane was constructed as an experimental section.
- This experimental pavement consisted of an 50 mm thick Ultra-Thin Continuous Reinforced Concrete Pavement (UTCRCP).
- Sections of the experimental UTCRCP have failed prematurely and consequently need to be replace.

1. PROJECT INFORMATION

Failed Sections along the of the Experimental UTCRCP

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Failed Sections along the of the Experimental UTCRCP

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2. PROJECT DESCRIPTION

2.1 Project Objective

- To replace the failed experimental UTCRCP sections on the truck crawler lane along the westbound section of the National Route 1 Section 1 between km 56.10 and km 61.50 with:
  - New Generation Ultra-Thin Continuous Reinforced Concrete Pavement (UTCRCP) and/or
  - Enrobé à Module Élevé (EME) Asphalt Base Layer

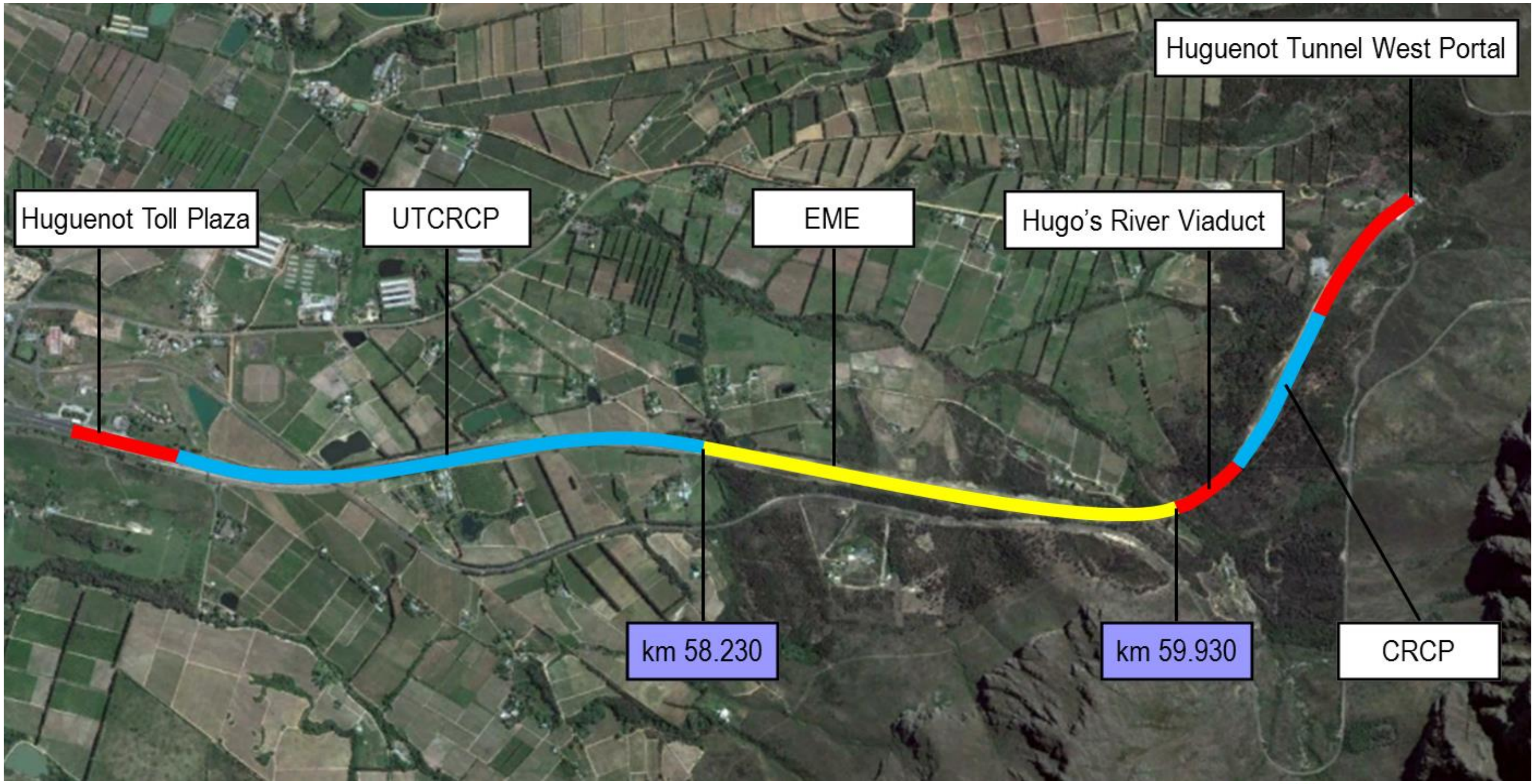
2.2 Project Implementation Strategy

- To implement both remedial actions (to include UTCRCP and EME) at different locations along the failed experimental UTCRCP section, to enable the long term performance comparison of both UTCRCP and EME under traffic loading.

2. PROJECT DESCRIPTION

Project Implementation Strategy :

Truck Crawler Lane: National Route 1 Section 1



3. PAVEMENT REHABILITATION DESIGN

3.1 Structural Analysis

- As part of the initial and detail assessment, Falling Weight Deflectometer (FWD) measurements were conducted by Specialised Road Technologies (SRT) (Pty) LTD along the truck crawler lane at 20 meter intervals.

- Layer stiffness's that resulted in a calculated deflection bowl close to the measured FWD deflection bowl were back-calculated.

- A mechanistic-empirical model was used as the primary pavement response model to calculate the critical response parameters (in terms of stress and strain) for each material layer in the pavement structure under loading.

3. PAVEMENT REHABILITATION DESIGN

3.1 Structural Analysis

- The critical response parameters in terms of stress and strain were then used to calculate the bearing capacities of the individual layers and ultimately the pavement system through the use of transfer functions.
- Initially (at tender stage) the 3000 (MPa) fatigue transfer function for thick (> 75 mm) asphalt bases was used to calculate the bearing capacity of the EME base layer.
- Subsequently a provisional transfer function for fatigue failure of EME layers developed by Prof Steyn (2014) was used to compare the initial calculated bearing capacities.

3. PAVEMENT REHABILITATION DESIGN

3.1 Structural Analysis

- It was found that the fatigue transfer function developed by Prof Steyn (2014) resulted in much higher bearing capacities as compared to the 3000 (MPa) fatigue transfer function for thick (> 75 mm) asphalt bases.

3. PAVEMENT REHABILITATION DESIGN

3.2 Design Research

- This provisional EME fatigue transfer function was developed at a referance temperature of 10° C and a range of current South African EME mix designs.

- It was however, reported that the in-situ winter temperatures of the EME layer on the R104 range between 16° C and 58° C in the middle of the EME layer.

- It therefore recommended that additional in-situ temperature measurements of operational EME layers be investigated in other environmental regions of the country.

- This information will assist in the refinement of the provisional EME fatigue failure transfer function.

3. PAVEMENT STRUCTURAL ANALYSIS

3.2 Design Research

- The project design team is therefore currently in consultation with Prof Steyn (2014) to investigate the possible installation of pavement monitoring equipment along the truck crawler lane on National Route 1 Section 1.

- It is envisaged that the pavement monitoring equipment will assist in the further development of the provisional EME fatigue failure transfer function.

4. Material Design Process (Sabita Manual 33)

4.1 Application of EME

- The purpose of designing an Enrobé à Module Élevé (EME) is to provide an extremely stiff asphalt layer derived from the properties of a low penetration, very hard bitumen binder.

- The superior load spreading characteristics of these layers, together with a high resistance to permanent deformation, enable the construction of a relatively thin asphalt base layers for roads exposed to severe traffic loading.

- This product has proved it self as a viable alternative to concrete base pavements in accelerated road pavement testing in France as well as through experience of its use in airport pavements.

4. Material Design Process (Sabita Manual 33)

4.2 Specification of the EME Base Layer

- EME Class 2 Asphalt Base (NMPS = 14) was specified in accordance with Sabita Manual 33 "Interim Design Procedure for High Modulus Asphalt" to replace a section of the failed experimental UTCRCP on the truck crawler lane along the National Route 1 Section 1 between km 58.23 and km 59.93.

- Sabita Manual 33 (Sabita, 2013) provided guidelines for performance requirements of EME layers in terms of workability, durability, resistance to permanent deformation, dynamic modulus and fatigue.

- The EME base course is currently being designed by Much Asphalt (Pty) Ltd. Central Laboratory in accordance with the performance related method as recommended by Sabita Manual 33.

4. Material Design Process (Sabita Manual 33)

4.3 Design Process (Enrobé à Module Élevé (EME))

- The performance related design process entails 11 steps:

Required Testing Performed by:

Required Testing Performed by	Step	Description
Much Asphalt - Task Completed	1.	Component Selection
Much Asphalt - Task Completed	2.	Developing a Suitable Grading
Much Asphalt - Task Completed	3.	Binder Content Selection
Much Asphalt - Task Completed	4.	Compaction of Gyratory Specimens
Much Asphalt - Task Completed	5.	Assessment of Workability Criteria (Yes / No)
Much Asphalt	6.	Assessment of Durability Criteria (Yes / No)
CSIR (Specialised Testing)	7.	Assessment of Rut Resistance Criteria (Yes / No)
CSIR (Specialised Testing)	8.	Assessment of Dynamic Modulus Criteria (Yes / No)
Much Asphalt	9.	Slab Compaction
CSIR (Specialised Testing)	10.	Assessment of Fatigue Criteria (No)
Much Asphalt	11.	Implementation

4. Material Design Process (Sabita Manual 33)

4.3.1 Component Selection: (Manual 33:Table 1): Aggregate and Filler

The aggregate and filler selection process was conducted in terms of the guidelines outlined in Sabita Manual 33:

- 13.2mm & 9.5mm crushed stone (Hornfels): were acquired from Lafarge Quarry.
- Crusher Dust: was acquired from Afrisam Quarry.
- Hydrated Lime Filler: was acquired from Cape Lime.

Aggregate and Filler Selection Criteria:

Component Selection

Property	Test Description	Unit	Test Method	Sabita Manual 33 Criteria	Test Performed by
Hardness	Fines Aggregate Crushing Test 10% FACT	kN	SANS 3001 - AG10	≥ 160	389 kN (13.2mm Stone) - SRT
	Aggregate Crushing Value ACV	%	SANS 3001 - AG10	≤ 25	10.9 % (13.2mm Stone) - SRT
Particle Shape and Texture	Percentage of Fully Crushed Coarse Aggregate (>5mm)	%		100	Much Asphalt
	Flakiness Index Test		SANS 3001 - AG4	≤ 25	22.1 / 19 (13.2mm / 9.5mm Stone) - Much Asphalt
	Particle Index Test (measure of aggregate angularity and surface texture)		ASTM D3398	> 15	Much Asphalt
Water Absorption	Coarse Aggregate (>4.75mm)	%	SANS 3001 - AG20	≤ 1.0	0.4% - Much Asphalt
	Fine Aggregate	%	SANS 3001 - AG21	≤ 1.5	0.1% - Much Asphalt
Cleanliness	Sand Equivalent Test		SANS 5838*	≥ 50	52 - Much Asphalt

4. Material Design Process (Sabita Manual 33)

4.3.2 Component Selection:(Manual 33:Table 3): Binder

The binder selection process was conducted in terms of guidelines outlined in Sabita Manual 33:

- Either a 10/20 or 15/25 unmodified penetration grade bitumen binder can be used for EME asphalt mixes.
- 10/20 unmodified penetration grade bitumen: acquired from Shell (Sapref).

Requirements for Hard Penetration Grade Binder:

Component Selection

Property	Test Description	Unit	Test Method	Sabita Manual 33 Criteria		Test Performed by
Before:				10/20	15/25	
Rolling Thin-Film	Penetration at 25°C	0.1mm	EN 1426	10-20	15-25	18 (1.8 mm) - Much Asphalt
Oven Test	Softening Point	°C	EN 1427	58-78	55-71	62°C - Much Asphalt
	(Brookfield) Viscosity at 60°C	Pa.s	/ ASTM 4402	>700	>550	>1000 Much Asphalt
After:				10/20	15/25	
Rolling Thin-Film	Increase in Softening Point	°C	EN 1427	<10	<8	6°C - Much Asphalt
Oven Test	Retained Penetration	%	EN 1426	-	>55	83% - Much Asphalt
	Mass Change	%	ASTM D2872	-	<0.5	0.05% - Much Asphalt

4. Material Design Process (Sabita Manual 33)

4.3.3 Design Grading Formulation: (Manual 33:Table 5): Grading

The process of developing a suitable grading from different aggregate fractions was conducted in terms of guidelines outlined in Sabita Manual 33:

- Four key sieve sizes, provides a target grading that can be used as a point of departure in developing a suitable mix grading.

Target Grading Curves and Envelopes for EME Base Course:

	Percent Passing Sieve Size	D= 10			D= 14			D= 20			Test Performed by
		Min.	Target	Max.	Min.	Target	Max.	Min.	Target	Max.	
		mm	mm	mm	mm	mm	mm	mm	mm	mm	
Grading	7.1 mm	48	56	68	53	56	73	47	55	66	57 mm - Much Asphalt
	5.0 mm	-	53		44	50	64	42	50	62	49 mm - Much Asphalt
	2.0 mm	28	33	38	25	33	38	25	33	38	31 mm - Much Asphalt
	0.075 mm	6.4	6.9	7.4	5.5	6.9	7.9	5.5	6.9	7.9	6.8 mm - Much Asphalt

4. Material Design Process (Sabita Manual 33)

4.3.4 Binder Content Selection: (Manual 33:Table 7)

The binder content was determined based on a min richness modulus K:

- The richness modulus K is a measure of the thickness of the binder film surrounding the aggregate.
- The mass of the binder is expressed as a percentage of the total dry mass of aggregate, including filler.

Richness Modulus Requirements:

	Test Description	EME Class		Binder Content	Test Performed by
		Class 1	Class 2		
Binder	Richness Modulus K	≥ 2.5	≥ 3.4	5.7% / (6.0%)	3.8 - Much Asphalt
Binder	Richness Modulus K	≥ 2.5	≥ 3.4	6.0% / (6.4%)	4.0 - Much Asphalt
Binder	Richness Modulus K	≥ 2.5	≥ 3.4	6.3% / (6.7%)	4.2 - Much Asphalt

- EME is hot-mix asphalt consisting of hard, unmodified bitumen, blended at high concentrations of up to 6,5%.

4. Material Design Process (Sabita Manual 33)

4.3.5 Workability: (Manual 33:Table 8)

The workability of the trail mix was assessed by monitoring the effort required to compact the material in the gyratory compactor:

- A compactive effort of 45 gyrations was used to determine the maximum allowable air voids of 6% for an EME Class 2.

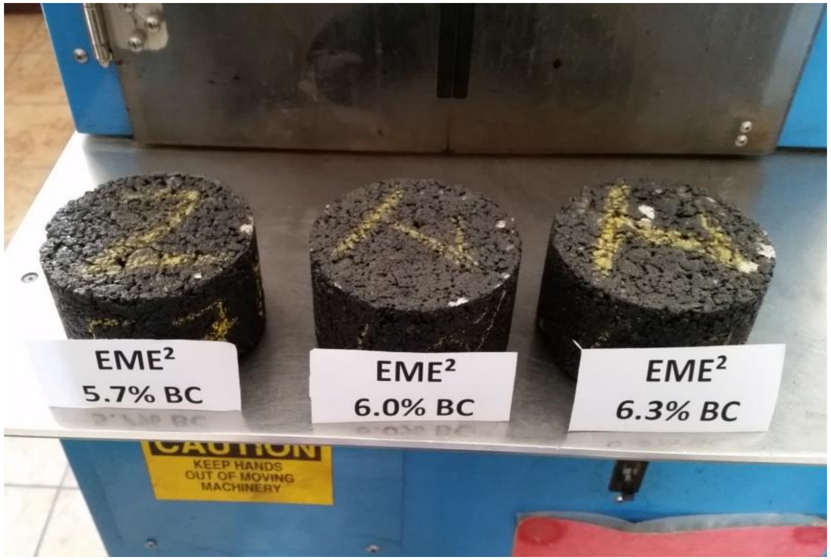
Workability Requirements:

Test Description	No. Specimens	Method	Requirements		Binder Content	Test Performed by
			Class 2	Class 2		
Gyratory compactor Air Voids after 45 Gyrations	3	ASTM D6926	≤ 10%	≤ 6%	5.7% / (6.0%)	4.8 - Much Asphalt
Gyratory compactor Air Voids after 45 Gyrations	3	ASTM D6926	≤ 10%	≤ 6%	6.0% / (6.4%)	3.5 - Much Asphalt
Gyratory compactor Air Voids after 45 Gyrations	3	ASTM D6926	≤ 10%	≤ 6%	6.3% / (6.7%)	2.8 - Much Asphalt

4. Material Design Process (Sabita Manual 33)

4.3.5 Workability: (Manual 33:Table 8)

The trail mix with 5.7% (6.0%) binder and 4.8% Air Voids at 45 gyrations was selected to conclude the performance requirements for EME layers in terms of durability, resistance to permanent deformation, dynamic modulus and fatigue.



4. Material Design Process (Sabita Manual 33)

4.3.6 Outstanding Performance Requirements to Date:

Performance requirements for the EME base layer in terms of durability, resistance to permanent deformation, dynamic modulus and fatigue are still outstanding:

Summary of Outstanding Performance Requirements:

Property	Test	No. Specimens	Method	Requirements		Binder Content	Test Performed by
				Class 1	Class 2		
Durability	Modified Lottman, (Tensile Strength Ratio)	6	ASTM D4867	≥ 0.80	≥ 0.80	5.7% / (6.0%)	Much Asphalt (Specialised Testing)
Resistance to Permananet Deformation	Repeated Simple Shear Test at Constant Height (55°C, 5 000 reps)	3	AASHTO T320	≤ 1.1% strain	≤ 1.1% strain	5.7% / (6.0%)	CSIR (Specialised Testing)
Dynamic Modulus	Dynamic Modulus (10 Hz, 15°C)	3	AASHTO TP 62	≥ 14 Gpa	> 14 Gpa	5.7% / (6.0%)	CSIR / SRT (Specialised Testing)
Fatigue	Beam Fatigue test at 10 Hz, 10°C, to 50% stiffness reduction	9	AASHTO T321	≥ 10^6 reps @ 300µƐ ≥ 10^6 reps @ 220µƐ	≥ 10^6 reps @ 390µƐ ≥ 10^6 reps @ 260µƐ	5.7% / (6.0%)	CSIR / SRT (Specialised Testing)

Resistance to Permanent Deformation (CSIR); Dynamic Modulus (CSIR & SRT); Fatigue (CSIR & SRT)

4. Material Design Process (Sabita Manual 33)

4.4 EME Mix Design Research

- Performance tests are used to relate laboratory mix designs to actual field performance.

- Sabita Manual 33 (Sabita, 2013) provided guidelines for performance requirements for EME layers in terms of workability, durability, resistance to permanent deformation, dynamic modulus and fatigue.

- These performance requirements are based on standard mechanistic analysis using a dynamic EME modulus at a loading frequency of 10 Hz and three representative temperature.

4. Material Design Process (Sabita Manual 33)

4.4 EME Mix Design Research

- It is however, important to investigate the potential effect of the actual loading and temperature conditions at the specific location where the EME is being applied, as this may affect the EME stiffness values significantly.
- The binder viscosity is related to the layer temperature profile through the viscosity-temperature relationship, which in turn determines the stiffness of the mix in combination with the load-pulse duration.
- Thus to verify the effect of actual traffic speeds and loading as well as the ambient and pavement temperature on the performance requirements for EME layers, the following is recommended by the project design team:

4. Material Design Process (Sabita Manual 33)

4.4 EME Mix Design Research

It is Recommended:

- That binder DSR testing be performed at 0, 20, 40, 55 and 70° C to confirm the linear relationship assumed for the viscosity-temperature relationship;
- That the mix dynamic modulus model calibration be performed from frequency sweep tests for combinations of the following variables:
  - Temperature: from -5 to 55° C
  - Frequency: from 25 to 0.1 Hz
- That fatigue testing be performed for combinations of the following variables:
  - Strain: from 50 to 300 micro strain;
  - Temperature: from 0 to 20° C;

5. Conclusions

IT IS IMPORTANT:

1. Achieve the project objective by successful implementing both remedial actions to enable the long term performance comparison of the UTCRCP and EME under traffic loading.

2. Assist in the further development of the provisional EME fatigue failure transfer function with the installation of pavement monitoring equipment at the Truck Crawler Lane on National Route 1 Section 1.

3. Contribute towards the revision of Sabita Manual 33 through experience gained as part of the Special Maintenance of the Truck Crawler Lane on National Route 1 Section 1.