Use of BSM and Triaxial Geo-grid in the Rehabilitation of a Busy Urban Arterial

Presentation to the RPF

Date: Thursday, 5 May 2016

Venue: Addo, Eastern Cape

OUTLINE OF THE PRESENTATION

- **PROJECT INFORMATION AND INVESTIGATIONS**
- **PAVEMENT DESIGN PHILOSOPHY**
- **BSM-FOAM DESIGN & CONSTRUCTION**

PROJECT INFORMATION

- NAKO ILISO appointed by the Mangaung Metro Municipality in December 2013 to examine and propose rehabilitation options for McGregor Street
- Project Limits – Dr Belcher Road to the N8
- 1.42km Dual carriageway with 2 lanes in each directions

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NON INTRUSIVE INVESTIGATIONS

In spite of the client being fairly confident that the road required heavy rehabilitation we still went through the full investigation process as outlined in TRH12

Summary of Rut Depth Measurements

Carriageway	Lane	Sound <10mm	Warning 10 to 20 mm	Severe >20 mm
Northbound	Fast		14.2	
	Slow			21.0
Southbound	Fast		11.5	
	Slow			26.2

Summary of IRI Measurements

Carriageway	Lane	Sound <3.5	Warning 3.5 to 4.2	Severe >4.2
Northbound	Fast			6.7
	Slow			6.6
Southbound	Fast			5.8
	Slow			6.0

Summary of Deflection Parameter Ratings

Data	90th Percentile (microns)		Structural Condition Rating		
	Northbound C/way	Southbound C/way	Sound	Warning	Severe
Y Max	1055	775	<200	200 - 400	>400
BLI	460	380	<100	100 - 300	>300
MLI	375	280	<50	50 - 100	>100
LLI	115	97	<40	40 - 80	>80

INTRUSIVE INVESTIGATIONS

Northbound

40-50mm Asphalt

80-130mm dolerite gravel, weathered or crushed, G4 to G5 quality

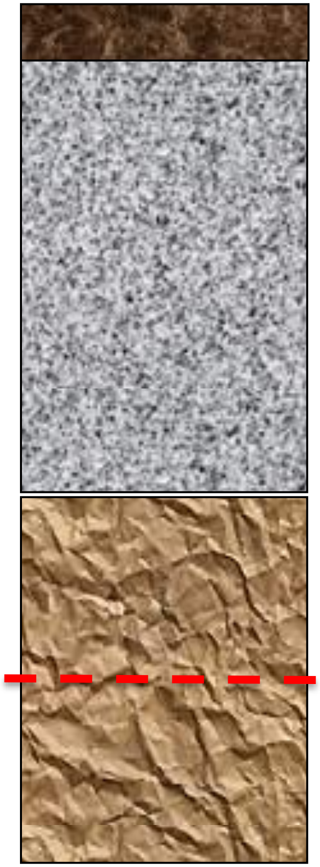
80-130mm natural of crushed weathered dolerite, G5 to G6 qulaity

150mm to 300mm G6 to G8 quality selected layer

G10 sandy clay/clayey sand quality insitu material from depths of between 460mm and 540mm

AVERAGE DEPTH OF 500MM
<G10 QUAILTY MATERIAL

Southbound



30-60mm Asphalt

150-290mm dolerite gravel, weathered or crushed, G5 to G7

G10 sandy clay/clayey sand quality insitu material from depths of between 340mm and 570mm

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TRAFFIC ESTIMATION

McKenzie St to N8 (Northern Section)

Northbound C/way		E80/Heavy			
ADT = 8353 ADTT=707(8.5%)	Growth Rate (%)		1.0	1.8	2.5
		2	6 422 642	11 560 755	16 056 605
		4	8 025 725	14 446 305	20 064 313
		6	10 105 036	18 189 065	25 262 591
Southbound C/way		E80/Heavy			
ADT = 9629 **ADTT = 866 (9%)**	Growth Rate (%)		1.0	1.8	2.5
		2	7 839 277	14 110 698	19 598 192
		4	9 795 950	**17 632 710**	24 489 876
		6	12 333 893	22 201 007	30 834 732

Dr Belcher Street to McKenzie Street (Southern Section)

Northbound C/way		E80/Heavy			
ADT = 10112 ADTT=419(4.1%)	Growth Rate (%)		1.0	1.8	2.5
		2	3 750 362	6 750 652	9 375 906
		4	4 686 448	**8 435 606**	11 716 120
		6	5 900 616	10 621 110	14 751 541
Southbound C/way		E80/Heavy			
ADT = 10204 ADTT=351(3.4%)	Growth Rate (%)		1.0	1.8	2.5
		2	3 138 352	5 649 034	7 845 880
		4	3 921 681	7 059 025	9 804 202
		6	4 937 713	8 887 883	12 344 282

RESIDUAL LIFE OF THE EXISTING PAVEMENT

- The existing pavement structure was evaluated in terms of the South African Mechanistic Design Method using Rubicon software for typical test pit data.
- Little, if any, residual life

SELECTION OF AN APPROPRIATE PAVEMENT DESIGN

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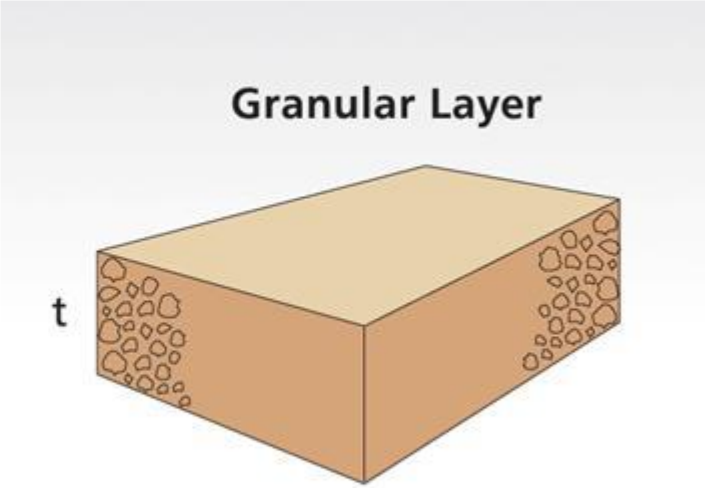
	CONDITIONS TO SATISFY	ALTERNATIVES				
		INSITU RECYCLING /STABILIZATION (CEMENT) + NEW BASE + SURFACING	DEEP INSITU RECYCLING /STABILIZATION (BSM)+ SURFACING	RIGID PAVEMENT (CRCP)	NEW FLEXIBLE PAVEMENT ABOVE THE EXISTING SURFACE	NEW FLEXIBLE PAVEMENT AFTER "BOXING" OUT EXISTING
1	ES30 Design traffic	✓	✓	✓	✓	✓
2	Poor quality materials (< G10) located on average 500mm below existing surface level	✓	✗	✓	✓	✓
3	Lane closures must be minimized for as short a time as possible	✓	✓	✗	✓	✗
4	On street parking, sidewalks and adjacent private properties levels to be maintained	✗	✓	✓	✗	✓
5	Numerous utility services located 600-1000mm below existing surface level	✓	✓	✗	✓	✗

ALTERNATIVE PAVEMENT DESIGN: MECHANICALLY STABILIZED LAYER (MSL)

- An investigation was made into a technology that uses a multi axial reinforcing geo-grid that significantly reduces the pavement thickness

- Typically the existing pavement is excavated to a shallow depth to install the geo-grid, followed by a granular stabilized or unstabilized Base and surfacing

The concept of a 'mechanically stabilised layer'



that you want to improve the material quality

The concept of a ‘mechanically stabilised layer’

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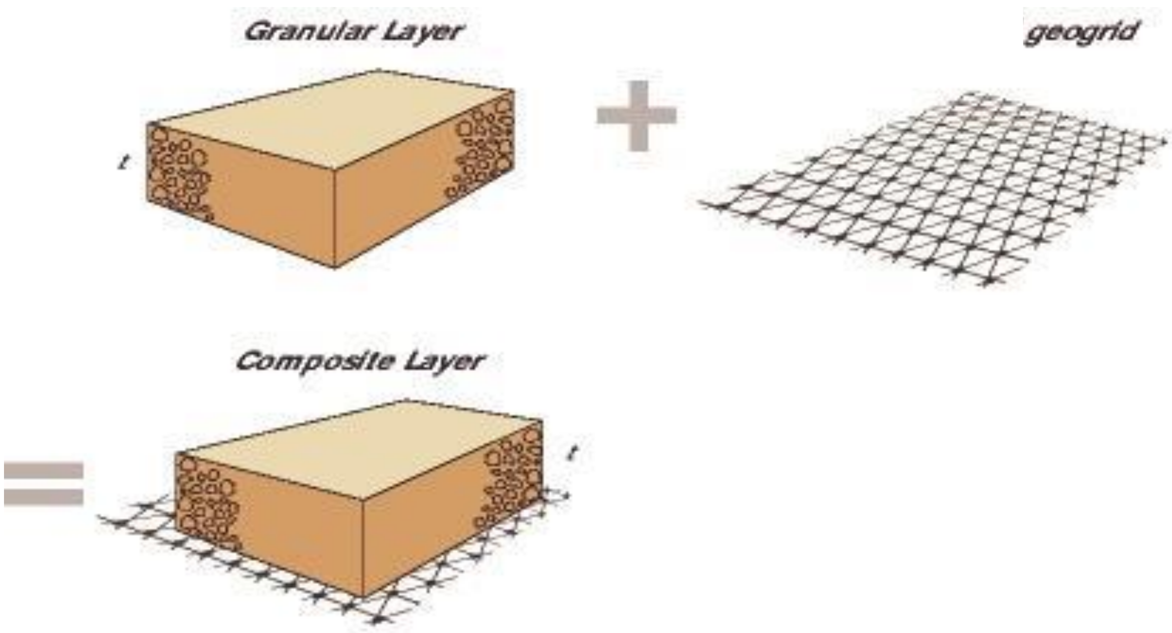
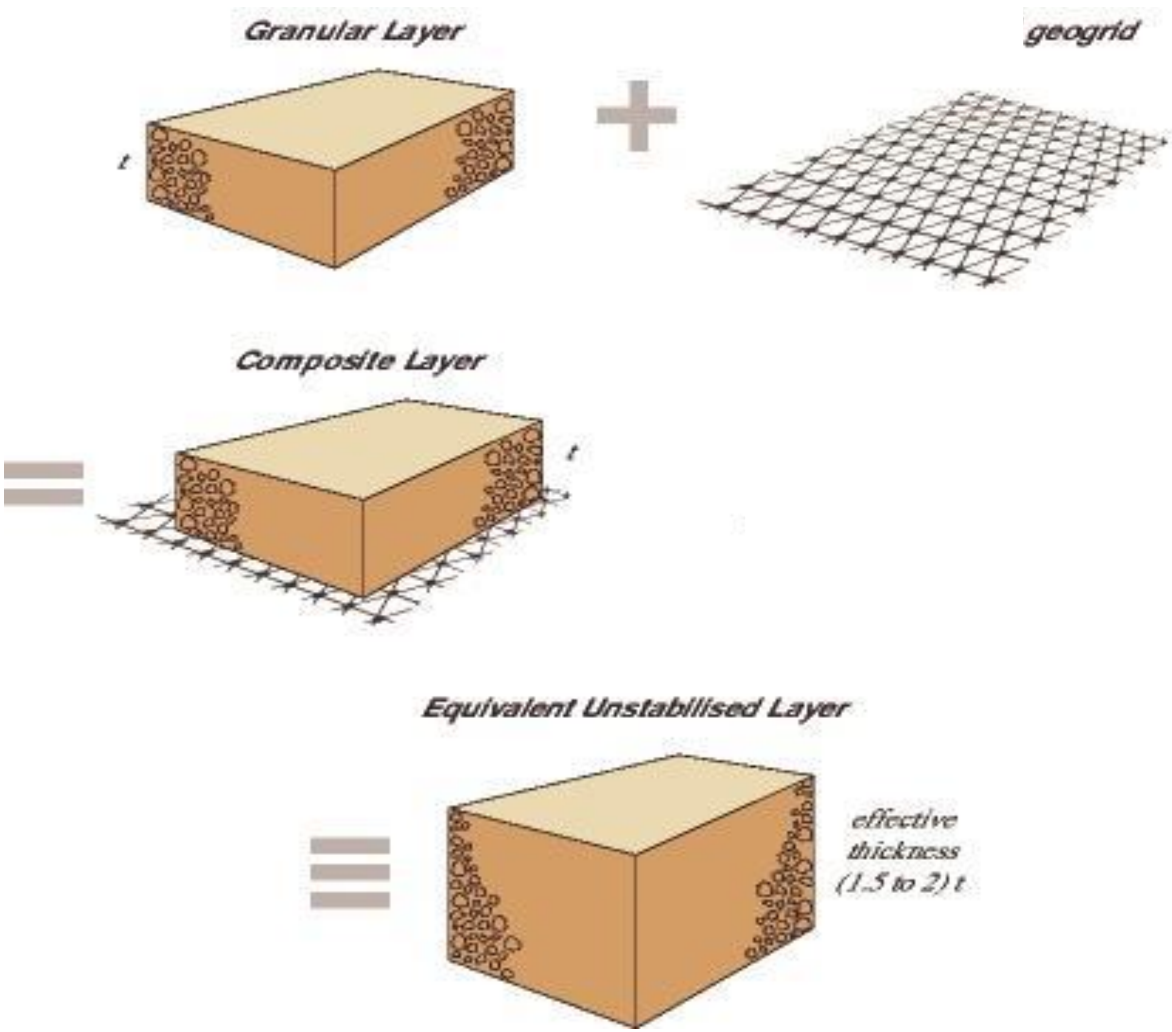


The concept of a 'mechanically stabilised layer'



Higher quality
granular material

Performance testing

- Extensive trafficking trials has been undertaken to gather knowledge about how geogrids perform

- Material properties for the MSL have been derived from rigorous analysis and interpretation of a large body of performance data that has been obtained from large scale testing, validated against 25 years of real project performance.

TENSARPAVE DESIGN PROGRAMME

- The properties of the MSL have been determined by back analysis of the data obtained from test sections using the **AASHTO Flexible Pavement Structural Design (1993) predictive model.**

- These properties have been incorporated into the suppliers pavement design software used for the design of the mechanical stabilized layer (MSL).

- The software retains the use of the AASHTO 93 Method or **STRUCTURAL NUMBER METHOD**

STRUCTURAL NUMBER METHOD

- Developed in the USA in the 1960s
- initially for one site; but
- gradually improved to accommodate other conditions through the publications of AASHTO 72; 86 and 93 resulting in the formula below

$$\log_{10}(W_{18}) = Z_R S_o + 9.36\log_{10}(SN+1) - 0.20 + \frac{\log_{10}\left[\frac{\Delta PSI}{4.2-1.5}\right]}{0.40 + \frac{1094}{(SN+1)^{5.19}}} + 2.32\log_{10} M_R - 8.07$$

Traffic

=

Reliability and Variability

+

Strength of Layerworks

+

Change in ride quality

+

Strength of Roadbed

STRUCTURAL NUMBER

$$\log_{10}(W_{18}) = Z_R S_o + 9.36\log_{10}(SN+1) - 0.20 + \frac{\log_{10}\left[\frac{\Delta PSI}{4.2-1.5}\right]}{0.40 + \frac{1094}{(SN+1)^{5.19}}} + 2.32\log_{10} M_R - 8.07$$

Strength of Layerworks

SN = Structural Number.

- Indicative of the individual layer materials, thickness and drainage conditions.

$$SN = a_1 D_1 + a_2 D_2 M_2 + a_3 D_3 M_3$$

Bituminous Surface

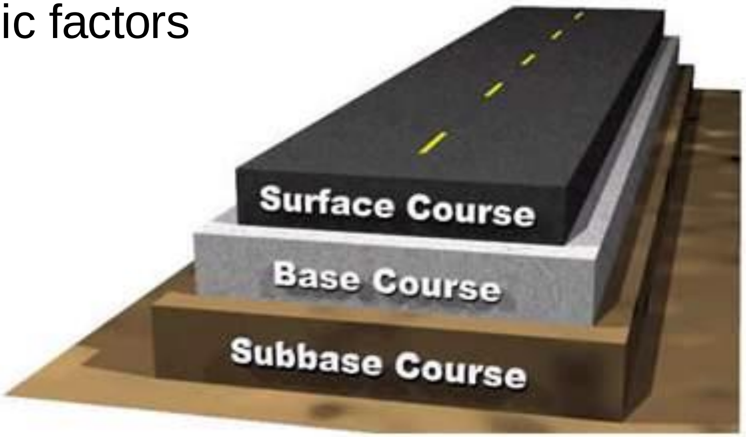
Base

Granular Sub-base

MODIFICATION FOR MECHANICALLY STABILISED LAYERS (MSLs)

Layer Coefficient Ratios (LCRs) are dynamic factors that vary depending on:

- AC thickness
- Aggregate Thickness
- Aggregate Quality
- Subgrade Resilient Modulus
- Moisture, Traffic, etc.



$$SN = a_1 D_1 + LCR\, a_2 D_2 m_2 + a_3 D_3 m_3$$

Layer Coefficient Ratio

AASHTO FLEXIBLE PAVEMENT STRUCTURAL DESIGN (1993)

South African Pavement Engineering Manual (SAPEM)

Chapter 10: Pavement Design

Material	Layer coefficients ("a"): Ranges for South African Materials
Asphalt	0.20 – 0.44
Crushed stone	0.06 – 0.14
Cement-treated material	0.10 – 0.28
Bituminous-treated material	0.10 – 0.30

Advantages of the AASHTO Method

- Models riding quality deterioration
- Models available for flexible and rigid pavement design
- Relatively simple to apply
- Applicable to new and rehabilitation design
- Principles used in the HDM IV economic analysis software
- Relatively quick and easy to use, and provides a good check of pavement designs done by other methods

Disadvantages of the AASHTO Method

- Empirical: derived from data collected at one site in the USA
- Not sensitive to quality of base
- Outdated: derived from data collected almost 50 years ago
- Developed for foreign conditions and materials
- Uses imperial units

DESIGN THE PAVEMENT INCORPORATING THE MSL

CONDITIONS TO SATISFY:

- **MAXIMUM THICKNESS** — 200mm-300mm (say 250mm)
- **INSITU SUBGRADE QUALITY** — G7 at depth 250mm
- **DESIGN TRAFFIC** — 17million E80s

ALTERNATIVES FOR THE BASECOURSE:

- **ASPHALT** — HMA cannot be placed directly on geogrid
- **CEMENT TREATED BASE** — Risk of reflective cracking
- **CRUSHED STONE** — Unlikely to meet strength required to carry 17mil E80s
- **BSM** — Appears to meet all the above conditions

CHOICE OF BSM:

Since Geogrids are installed on the subgrade, followed by the Basecourse, the BSM layer would have to be mixed in-plant and the can be paver laid

- **BSM-EMULSION** — Concerns about suitable mobile mixing plants and little time allowed between mixing and placing
- **BSM-FOAM** — High quality mobile mixing plants available (eg KMA) and can be left in stockpile for up to 3-5 days before placing

ANALYSIS AND DESIGN

INPUT DATA

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Tensar

Calculations in accordance with: AASHTO Method

Tensar software output
TensarPave Version 6.06

Traffic input data

Reliability level (%)	90.00
Standard deviation	0.49
Serviceability index - initial	4.2
Serviceability index - final	2.0
Total in-service traffic required (ESAL):	17,000,000

Pavement layer parameters

Layer	Description	d (mm)	a	m	SN	
Surface	Asphalt Wearing Course	40	0.400		0.630	
Base	BSM-Foam	250	0.240	1.000	4.075	⇐ **BSM-FOAM**
Sub-base	Gravel	150	0.089	1.000	0.526	⇐ **Insitu G7 material**

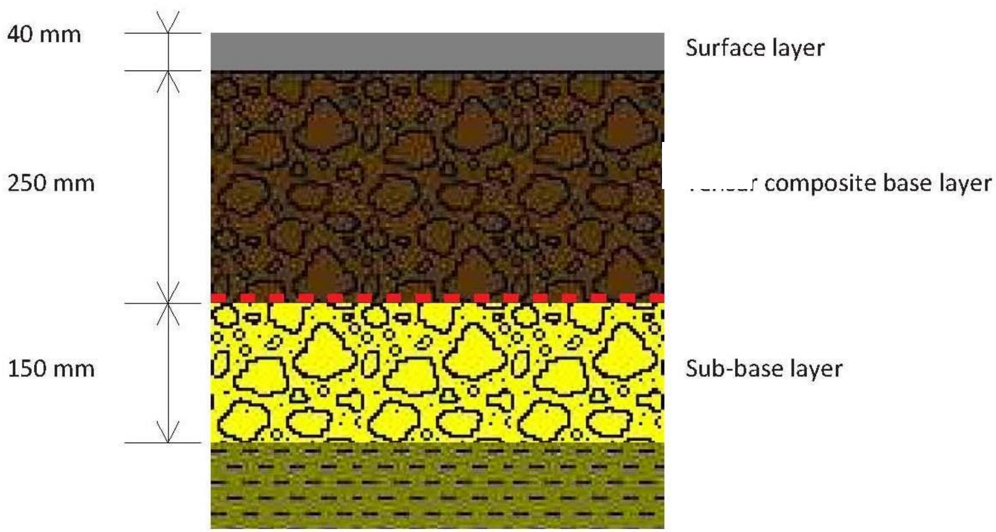
Subgrade parameters

Description	Silty Clay
CBR (%)	4.50 (estimated)
Resilient modulus (MPa)	46.540

ANALYSIS AND DESIGN

OUTPUT

Section	Project:	MacGregor Street Rehabiliation



Tensar stabilisation solution **Tensar**

Result

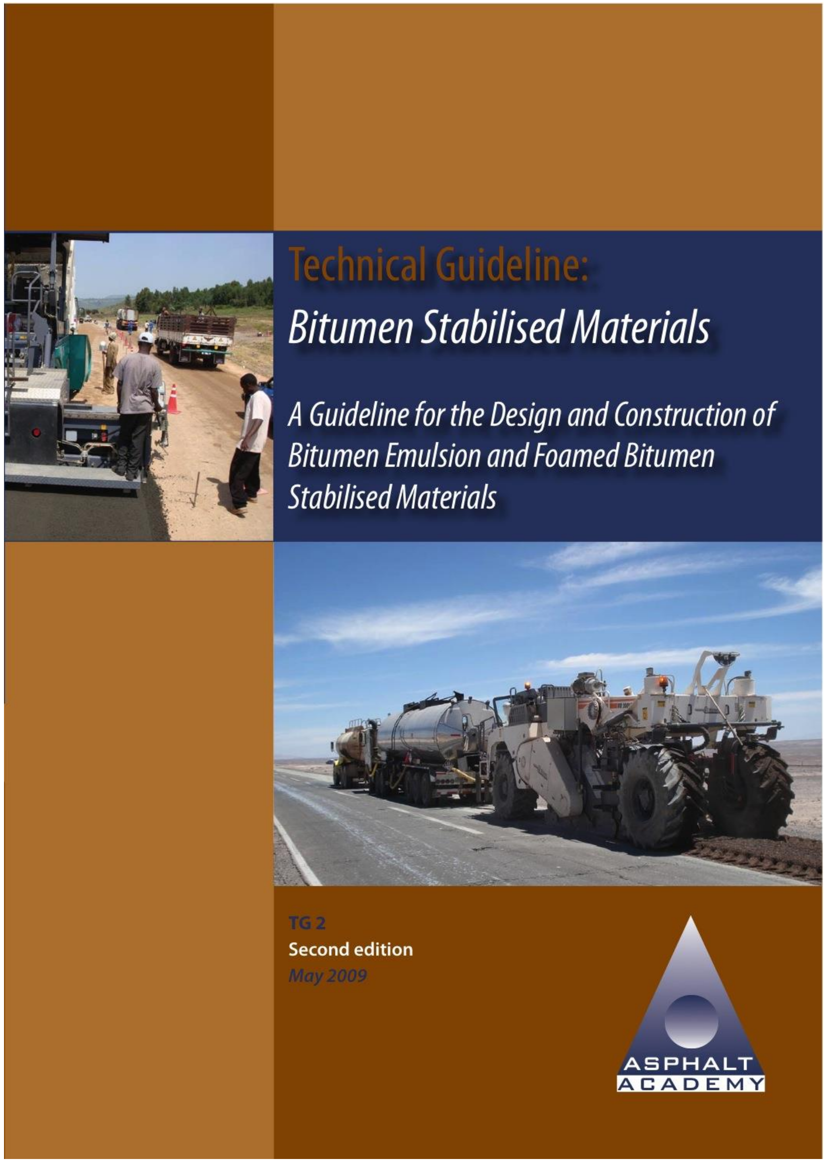
Total structural number SN	**5.230**
Total in-service traffic achieved (esal)	**17,306,462**
Specification	**MS_GeogridPe**

BSM-FOAM DESIGN & CONSTRUCTION

DESIGN GUIDELINES

TG 2 *Second addition*

May 2009



CLASSIFICATION OF BSM

BSM1 High shear strength, typically used as a base layer for design traffic greater than 6 MESA.

BSM2 **M**oderately high shear strength, typically used as a base layer for design traffic applications of less than 6 MESA.

BSM3 This material typically consists of soil-gravel and/or sand, stabilized with higher bitumen contents. As a base layer, the material is only suitable for design traffic applications of less than 1 MESA.

BSM-FOAM - SPECIFICATION

- Minimum G4 material quality before stabilization
- Allowance for imported crushed stone
- Selective milling of asphalt & crush/screen to pass 28 mm sieve to achieve a minimum 20% RA in mix

GRADING OF BSM-FOAM

SIEVE SIZE	% PASSING
37,5	100
20,0	60 – 100
5,0	30 – 70
2,0	20 – 50
0,425	10 – 30
0,075	4 - 15

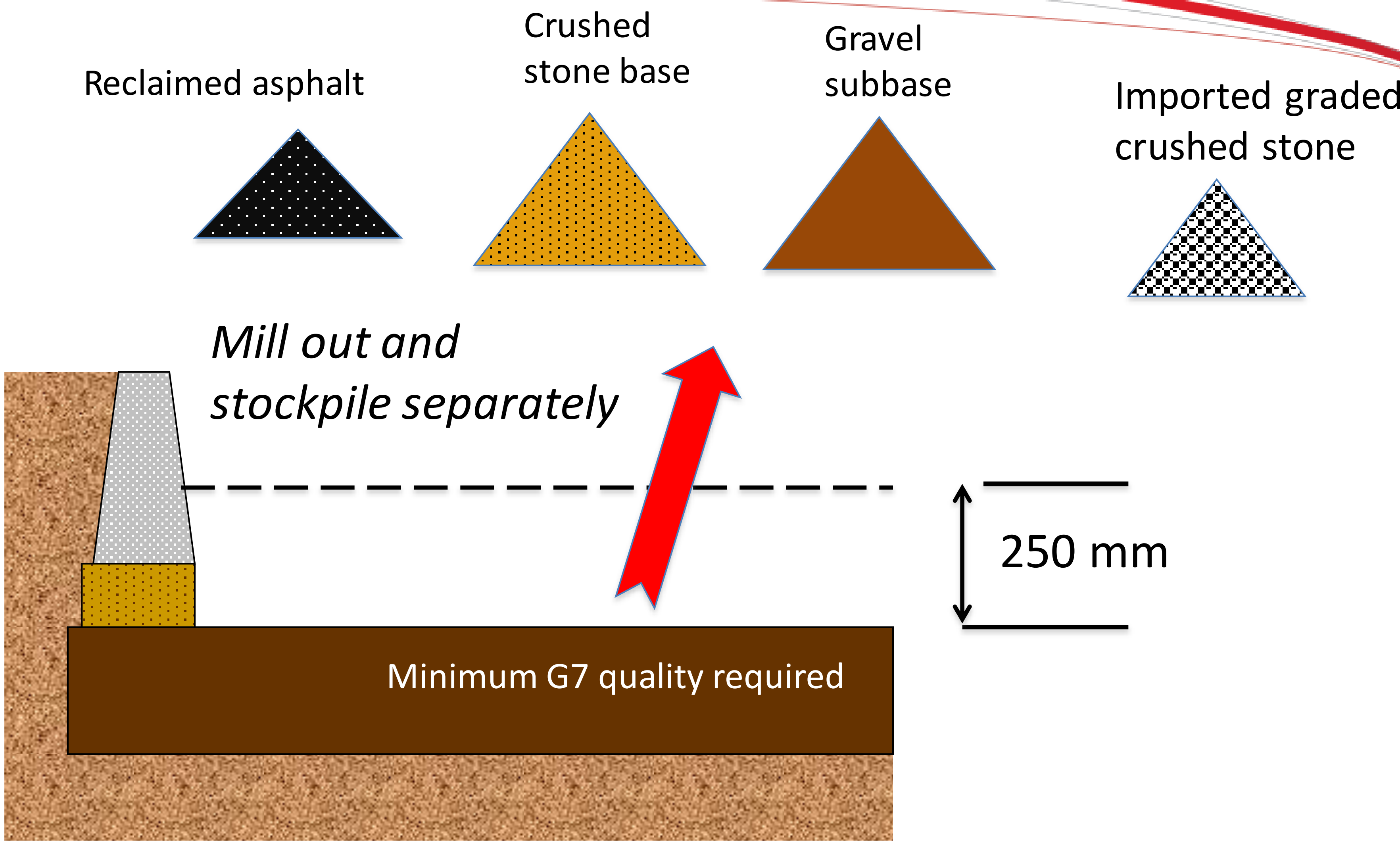
STRENGTH AND COMPACTION

Test	Requirement
ITS Dry	> 225 kPa
ITS Wet	> 100 kPa
Cohesion	> 250 kPa
Friction angle	> 40°
Field compaction	≥ 100% MDD

Mix Design (BSM Laboratories)

Optimum bitumen content		2.2%
Cement		1%
Indirect tensile strength:		
	Dry	341 kPa
	Wet	319 kPa
	Cohesion	380 kPa
	Friction	51°

CONSTRUCTION – MILLING OFF 250MM

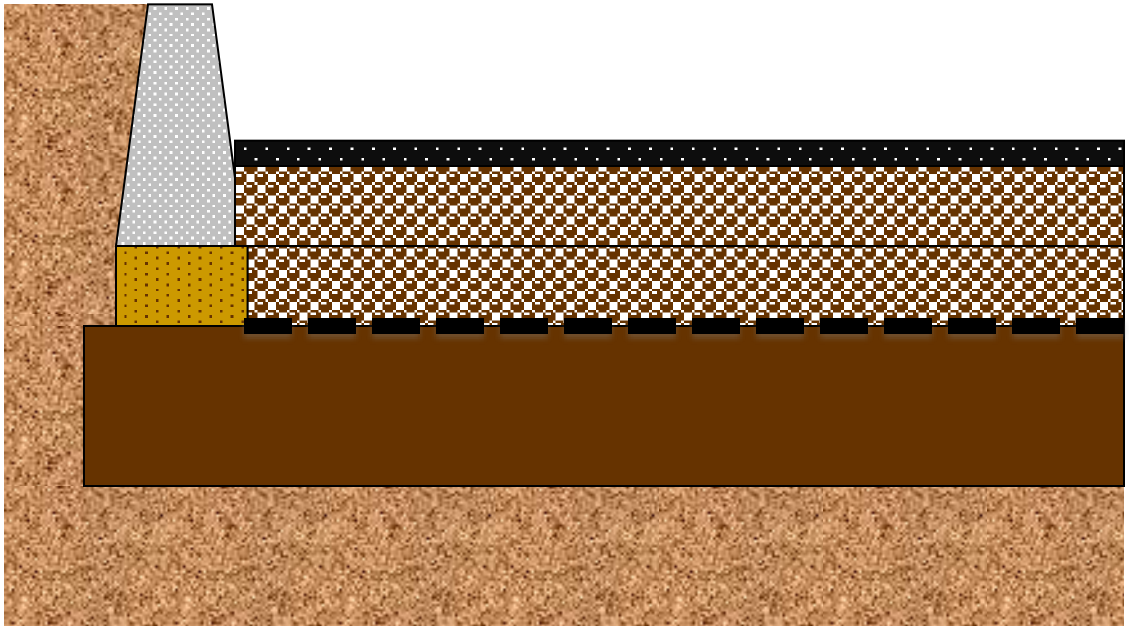


STOCKPILING OF THE MILLED AND IMPORTED MATERIAL

BSM-FOAM - MIX PROPORTIONS

Reclaimed asphalt surfacing	30%
Milled crushed stone base	20%
Milled gravel subbase	40%
Imported crushed stone	**10%**
Cement	1%
Bitumen (50/70 pen)	2.2%

CONSTRUCTION SEQUENCE



40 mm Asphalt surfacing

125 mm BSM

125 mm BSM

TriAx geo-grid

Min G7 quality
subgrade material

PROCESS & ACCEPTANCE TESTING CARRIED OUT BY SIMLAB

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INSTALLATION OF TRIAX GEOGRID

PAVING

COMPACTION

- Initial compaction using 10 ton single-drum roller with variable frequency and amplitude
- Final compaction and finishing using 20 ton PTR

A high level of compaction is essential for BSM!

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CONCLUSION

- **250mm THK BSM-FOAM LAYER, MECHANICALLY STABILIZED WITH A GEOGRID**
- **SUPPORTED ON A G7 SUBGRADE**
- **WITH A 40mm SURFACING**

PROVIDING A PAVEMENT CAPACITY OF 17 MILLION E80s!