Asphalt mix design manual for South Africa

Binder & Aggregate Selection

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CSIR CC, Pretoria

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Binder & Aggregate Selection

- Binder Selection
  - PG binder classification system
  - Temperature
  - Traffic
  - PG binder selection
  - Binder selection for specific mix types

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Binder Selection

Binder selection for an asphalt layer should be supported by the following general considerations:

- Traffic;
- Climate;
- The modes of damage expected for the asphalt layer e.g., rutting, fatigue and ravelling;
- Pavement structure and condition; and
- Availability of binder and aggregate types.

Bitumen
5% of Asphalt By Mass
10% - 15% of Asphalt By Volume

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Binder Selection

The goal is to select a binder that will, in conjunction with the aggregate configuration, contribute to the performance of the asphalt under the prevailing conditions in such a manner as to provide the best “value for money.”

SBS

EVA

Crumb tyre rubber

PG binder classification system

Performance grade specifications for binders focus on the evaluation of binder properties based on the traffic loading and environmental conditions (mainly temperature) which the binder will be subjected to in the field.

Traffic classification

Minimum asphalt temperature (-)

PG 64H/10

7-Day average maximum asphalt temperatures

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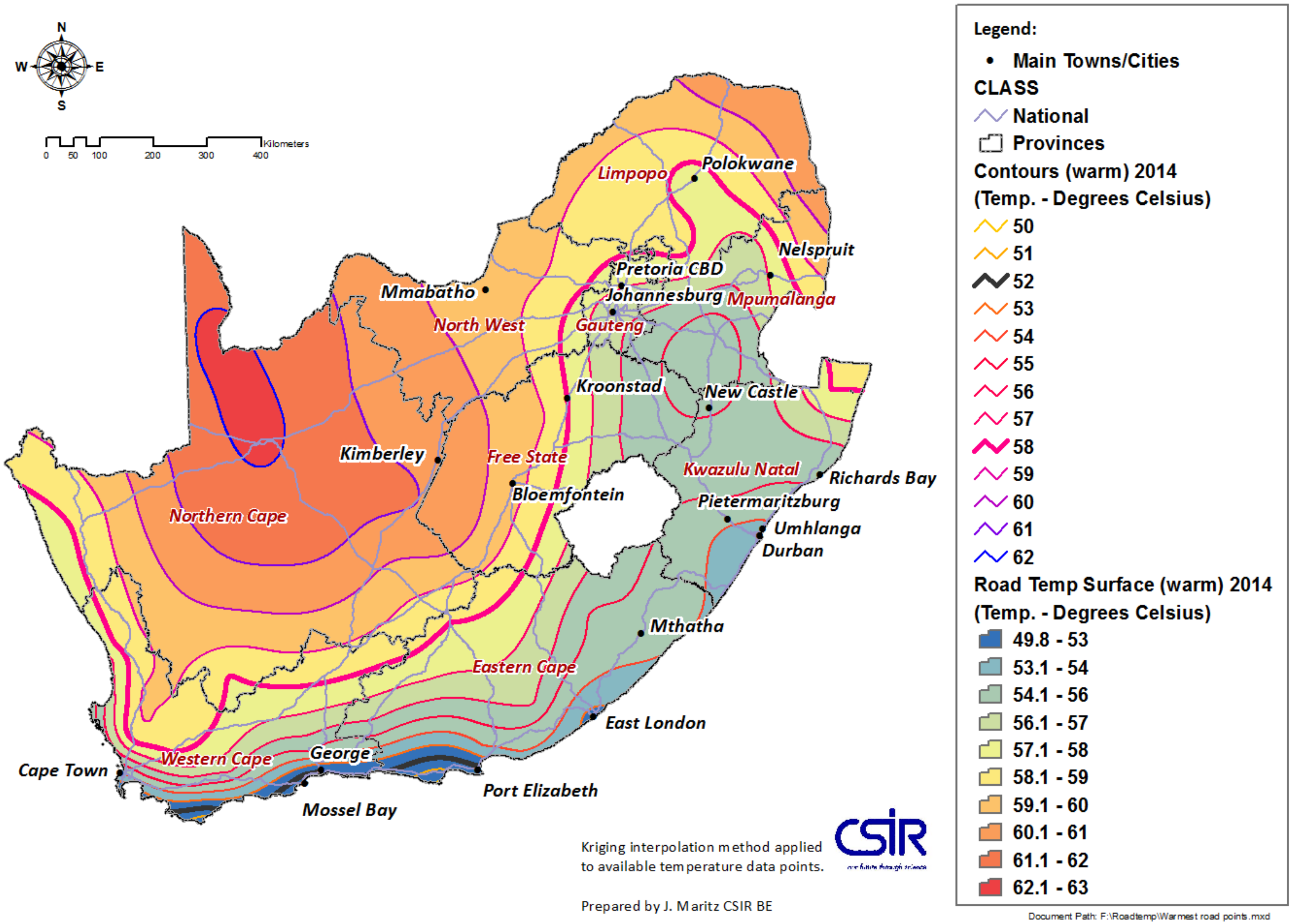
PG binder classification system - Advantages

- Improved prediction of asphalt mix performance is possible, thereby promoting more cost-effective design of mixes;
- The effects of long-term ageing on performance of the binder, and hence the mix, can now be evaluated;
- The specification is binder-blind and will promote cost effective use of costly modified binders, and
- The specification is aligned to international practice.

7-Day average maximum asphalt temperatures

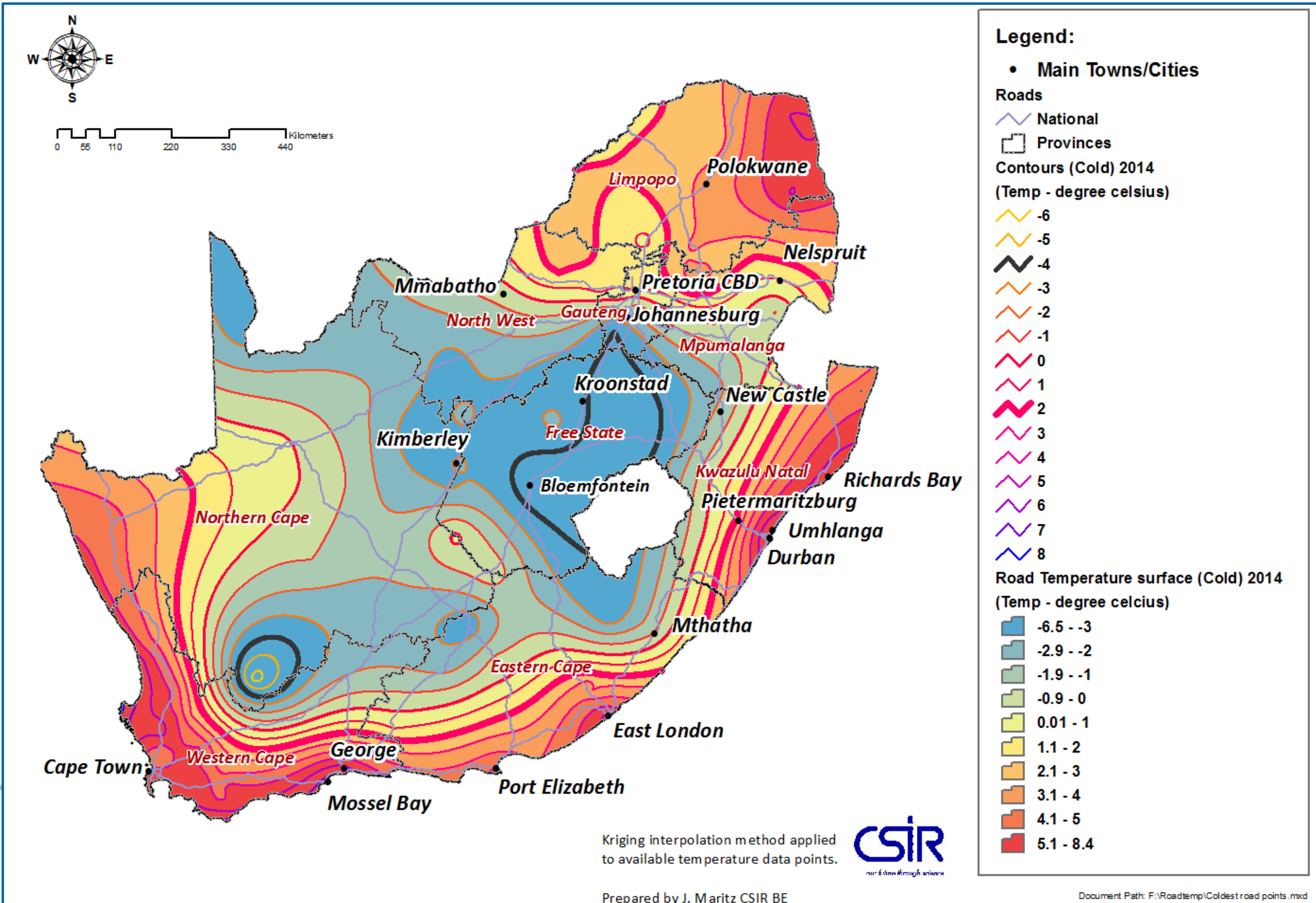


7-Day average maximum asphalt temperatures

Only Two temperature zones

- **PG 58 Zone**
  - Western Cape (except for the northern inland regions), Eastern Cape, most of KwaZulu-Natal, eastern half of the Free State, Gauteng, South Eastern part of Limpopo, and Mpumalanga (except for the eastern region bordering Mozambique
- **PG 64 Zone**
  - The rest of the country, including the Northern Cape (except for the mountainous southern region), North West, the extreme northern coastal region of KwaZulu-Natal and rest of Limpopo.

Minimum asphalt temperatures



Minimum asphalt temperatures

It is proposed that a single low temperature grade of **-10˚C** for binders will suffice to cover the entire country

Currently under revision by PG task Group as South African Binders generally comply with -16 ˚C and even -22˚C

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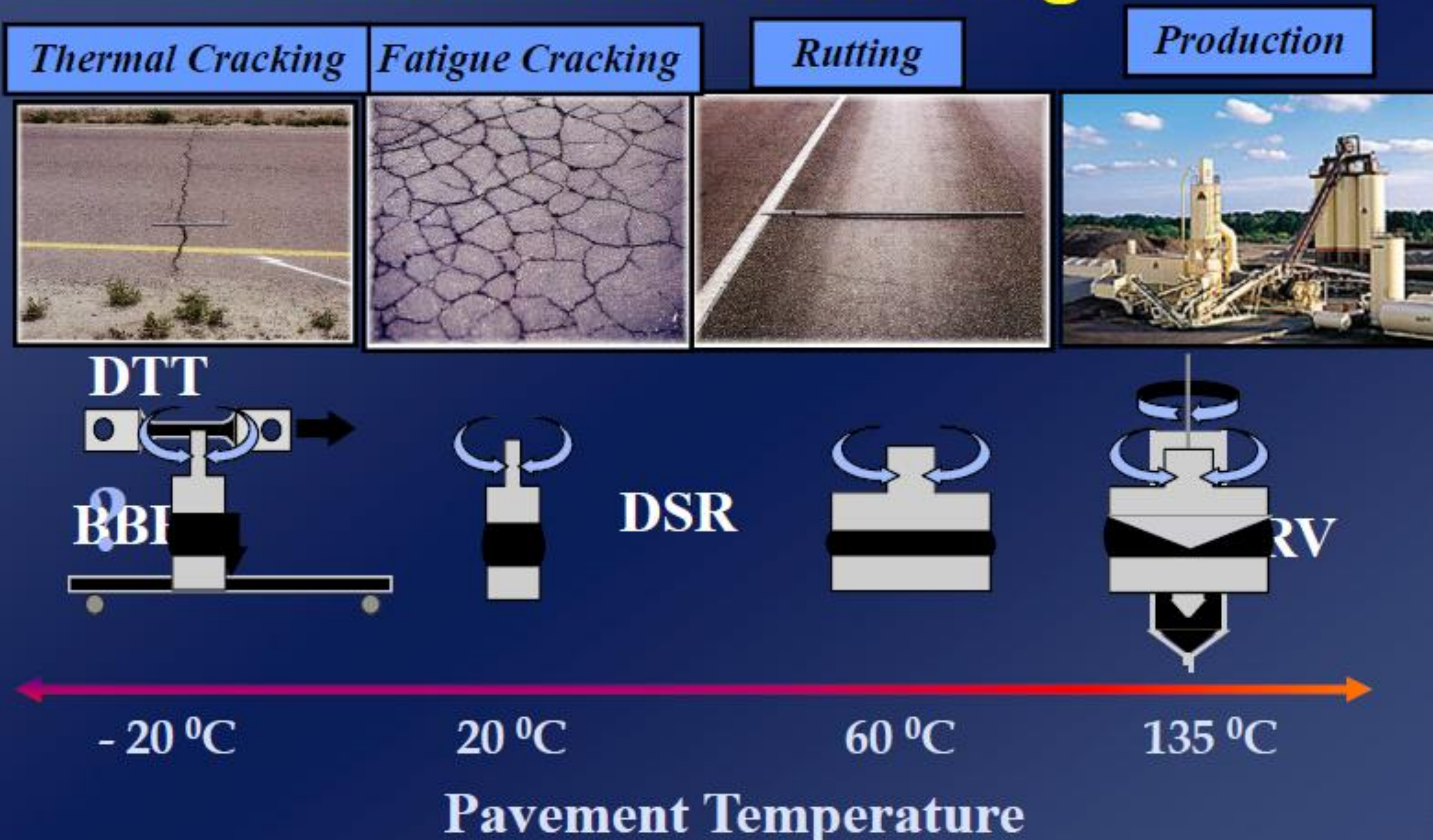
Traffic

Traffic in the PG specification is classified both in terms of **volume** or **severity** and **speed**.

Traffic Volume (million ESAL)	Traffic Speed (Km/h)		
	< 20	20 - 70	> 70
< 10	H	S	S
10 – 30	V	H	H
> 30	E	V	V

S – ‘S’ refers to standard conditions;
H – ‘H’ refers to Heavy conditions;
V – ‘V’ refers to Very heavy conditions, and
E – ‘E’ refers to Extreme conditions

Performance Grading



Current PG Specification

Binder Class	Proposed specification			
	64S	64H	64V	64E
Original binder				
Maximum pavement design temperature (°C)	64			
Non-recoverable compliance, J_{nr} at σ = xx kPa[1] @ 64 °C (kPa^{-1})	≤ 8.0	≤ 4.0	≤ 2.0	≤ 1.0
Viscosity @ 135°C (Pa.s)	≤ 3.0			
Flash Point (°C)	≥ 230			
Storage stability @ 160°C – Ratio of highest J_{nr} at σ = xx kPa[1] @ 64 °C to lowest (top and bottom)	≤ 1.5[2]			
RTFOT binder				
Mass change (m/m%)	0.3			
J_{nr} at σ = xx kPa[1] @ 64 °C (kPa^{-1})	≤ 4.0	≤ 2.0	≤ 1.0	≤ 0.5
PAV binder - @ yy°C [3]				
Fatigue [4]	TBA[5]			
Thermal fracture [6]	TBA[7]			

Current PG Specification (Notes)

- [1] The stress level of 3.2 kPa is a preliminary value. 10.0kPa will also be validated.
- [2] The storage stability specification limit is a preliminary value. A final value needs to be validated through testing and research.
- [3] The standard PAV ageing procedure will be adopted in SA until further notice.
- [4] A fatigue parameter has not been decided upon. The binder yield energy test (BYET) and the linear amplitude sweep (LAS) are possibilities to be investigated for possible specification parameters.
- [5] A specification limit needs to be determined after testing and research.
- [6] A low temperature thermal cracking parameter has not been decided upon.
- [7] A specification limit needs to be determined after testing and research.

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Current PG Specification

- Suggested that PG Specification testing be performed as compulsory "Report Only" as to build up a database to assist in finalising specification
- DSR Users Group has done 2 rounds of correlation testing and first round of Proficiency Testing in process (By NLA)
- All data that is collected of all binders tested by DSR Users Group will be given to SANRAL for detailed assessment.

Binder selection for specific mix types

- EME (SANS: 4001-BT1)
- Sand asphalt (Sabita Manual 18)
- Asphalt for lightly trafficked roads in residential areas (Sabita Manual 27)
- Porous asphalt mixes (Sabita Manual 17)
- Bitumen rubber asphalt (Sabita Manual 19)
- Warm mix asphalt (Sabita Manual 32)
- Reclaimed asphalt binder (PG Tests more suitable)

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Aggregate Selection

- Aggregate Selection
  - Aggregate materials
  - Definitions
  - Aggregate sources
  - Aggregate grading
  - Grading requirements
  - General requirements and specifications for aggregates
  - Preparation and selection of aggregate grading
  - Surface area of aggregate

Aggregate Materials

Aggregate
95% of Asphalt by Mass
85% - 90% of Asphalt by Volume

- Aggregate consists of hard material which is generally derived from the crushing of solid rock or boulders.
- The structural and functional performance of an asphalt mix in the pavement layer is largely influenced by the physical properties and characteristics of the aggregate blend.

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Aggregate Definitions

- Coarse aggregates – materials retained on the 5 mm (4.75 mm) sieve;
- Fine aggregates – materials passing the 5 mm (4.75 mm) sieve but are retained on the 0.075 mm sieve;
- Filler – materials passing the 0.075 mm sieve.
- In SMA, >2 mm sieve deemed Coarse; the balance being the fine material, which together with the filler makes up the mortar.

Aggregate sources

- Natural Aggregates
  - Unprocessed aggregates - River, Aeolian or glacial deposits without further processing
- Processed aggregates
  - Aggregates have been quarried, crushed and screened
- Manufactured aggregates
  - industrial slag, calcined bauxite, reclaimed asphalt, recycled concrete aggregate

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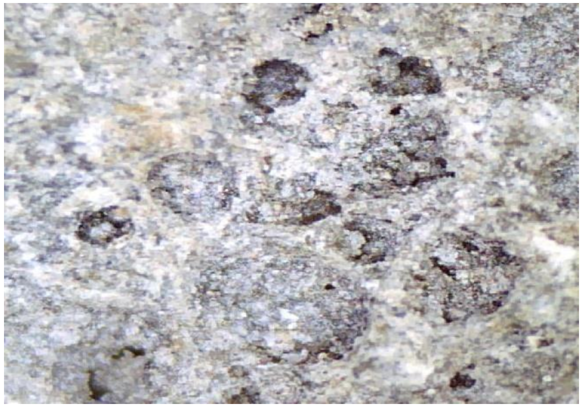
Manufactured Aggregates

- Steel Slag
  - Steel manufacturing process determines quality as asphalt aggregate
  - Free lime could be problematic – proper hydration is required
  - High binder demand
  - Good track record on N3
- Ferro-chrome slag
  - Generally no free lime
  - Varying porosity (blow holes) relates to varying surface area and BRD
  - High binder demand
  - Lack of fines
  - Good track record in Mpumalanga
- RA Aggregate
  - If more than 20% is used aggregate properties to be determined

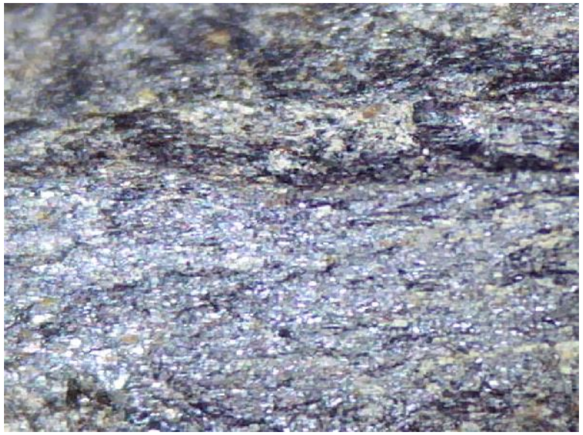
Steel Slag

50X Magnified



Ferro-Chrome Slag

50X Magnified



Fillers

In an asphalt mix, the filler generally serves the following purposes:

- Acts as an extender for binder to stiffen the mastic and the mix, thereby improving stability.
- Acts as a void-filling material which can be used to adjust gradings and volumetric properties.
- Some fillers e.g. lime are used to improve the bond between the binder and the aggregate.
- Specific fillers such as fly ash can be used to improve mix compactability

Active Fillers

<table>
<tr><th>Type of filler/origin</th><th>Characteristics</th><th>Test method / Criteria</th></tr>
<tr><td>Hydrated lime (active filer)</td><td>Improves adhesion between binder and aggregate
Improves mix durability by retarding oxidative hardening of the binder
Low bulk density and high surface area
Relatively high cost
Monitor effect on stiffness to ensure compactability</td><td rowspan="2">Grading (% passing 0.075 mm) (SANS 3001-AG1): minimum 70
Bulk density in toluene (BS 812): 0.5 – 0.9 g/ml
Voids in compacted filler (BS 812): 0.3 – 0.5%
Methylene blue test (SANS 6243): maximum value 5</td></tr>
<tr><td>Portland cement (active filler)</td><td>Relatively high cost
Monitor effect on stiffness to ensure compactability</td></tr>
</table>

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Non-Active Fillers

Type of filler/origin	Characteristics	Test method / Criteria
Baghouse fines	• Variable characteristics require control • Some source types may affect mix durability • Some types may render mixes sensitive to small variations in binder content	N/A
Limestone dust	• Manufactured under controlled conditions and complies with set grading requirements • More cost-effective than active filler • Although it is viewed as an inert filler, the high pH value reduces moisture susceptibility	N/A
Fly ash (non-active filler)	• Low bulk density • Relatively high cost • Variable characteristics require greater control	Same test methods as for active fillers (above)

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Fillers

- Filler / Binder Ratio is important
  - Too high values could stiffen mix resulting in compaction problems – especially thin surfacing layers
  - Too low values can result in low cohesion

0.075mm X 75

0.075mm X 300

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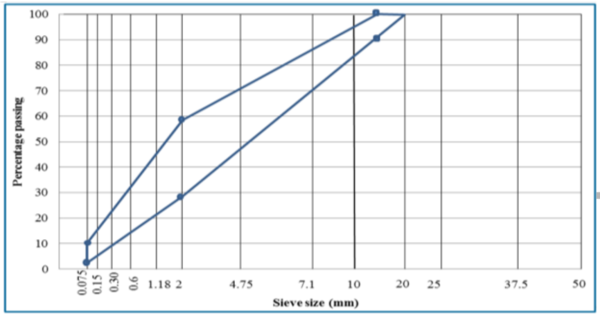
Aggregate Grading

- The SANS 3001-AG1 procedures will be followed in this manual for particle size analysis of aggregates by sieving

TMH 1 sieve sizes [mm]	SANS 3001 sieve sizes [mm]
37.5	37.5
26.5	25
19	20
13.2	14
9.5	10
6.7	7.1
4.75	5
2.36	2
1.18	1
0.6	0.6
0.3	0.3
0.15	0.15
0.075	0.075

Grading Requirements

- Grading control points
  - The maximum particle size (MPS) should be selected in accordance with Table 2 (Layer Thickness), and is the smallest sieve size through which 100 percent of the aggregate particles passes),
  - The nominal maximum particle size (NMPS); designated as one sieve size larger than the largest sieve to retain a minimum of 15 percent of the aggregate particles),
  - The 2 mm sieve, and the 0.075 mm sieve



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Grading control points (Table 13)

Sieve sizes [mm]	Percent passing nominal maximum particle size (NMPS)							
	NMPS = 25 mm		NMPS = 20 mm		NMPS = 14mm		NMPS = 10 mm	
	Min	Max	Min	Max	Min	Max	Min	Max
37.5	100							
25	90	100	100					
20		90	90	100	100			
14				90	90	100	100	
10						90	90	100
7.1								90
5								
2	19	45	23	49	28	58	32	67
1								
0.6								
0.3								
0.15								
0.075	1	7	2	8	2	10	2	10

Sand skeleton (often continuously graded) asphalt mixes in South Africa

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Grading control points

- The control points given in Table 13 should be used as guidelines only
- Not relevant to mixes such as stone skeleton types (including SMA)
- It is suggested that specific methods of aggregate proportioning, such as the Bailey method, needs to be employed (Appendix A)
- The gradation of continuously graded asphalt should not be too close to the 0.45 power maximum density curve – Low VMA/VIM

Primary control sieve (Table 14)

- The primary control sieve (PCS) controls the designation between coarse and fine aggregates
- An aggregate grading that passes above the PCS control point is classified as fine-graded
- Gradings passing below is classified as coarse-graded

NMPS	PCS	PCS control point [% passing]
25 mm	5 mm	40%
20 mm	5 mm	47%
14 mm	2 mm	39%
10 mm	2 mm	47%

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Preparation and selection of aggregate grading

1. Source samples of raw aggregate materials from stockpiles at asphalt plants as per TMH 5 C5.
2. Oven dry aggregates and riffle/quarter to required size for wet sieve analysis, Bulk and Apparent densities
3. Determine aggregate properties as given in Table 15
4. Combine the gradings of individual aggregate fractions into trial blends
5. Plot Trial blend on 0.45-power chart, and compare the gradings of the trial blends with the guidelines provided in Table 13 (i.e. control points for the design NMPS)
6. In a situation where blended aggregate fails to meet these criteria – Adjust aggregate blend

General requirements and specifications for aggregates - Table 15 (1)

Property	Test	Standard	Criteria
Hardness / Toughness	Fines aggregate crushing test: 10% FACT	SANS 3001-AG10	Asphalt surfacings and base: minimum 160 kN Open-graded surfacings and SMA: 210 kN
	Aggregate crushing value (ACV)	SANS 3001-AG10	Fine graded: minimum 25% (Fine) Coarse graded: minimum 21%
Soundness	Magnesium sulphate soundness	SANS 5839 SANS 3001-AG12	12% to 20% is normally acceptable. Some specifications requires ≤ 12% loss after 5 cycles
Durability	Methylene blue adsorption indicator	SANS 6243	High quality filler: maximum value 5 More than 5: additional testing needed

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General requirements and specifications for aggregates - Table 15 (2)

Property	Test	Standard	Criteria
Particle shape and texture	Flakiness index	SANS 3001- AG4	• 20 mm and 14 mm aggregate: maximum 25[1] • 10 mm and 7.1 mm aggregate: maximum 30
	Polished stone value (PSV)	SANS 3001–AG11	Minimum 50[2]
	Fractured faces	SANS 3001-AG4	• Fine graded: at least 50% of all particles should have three fractured faces • Coarse graded and SMA: at least 95% of the plus 5 mm fractions should have one fractured face

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General requirements and specifications for aggregates - Table 15 (3)

Property	Test	Standard	Criteria
Water absorption	Coarse aggregate (> 5mm)	SANS 3001-AG20	Maximum 1% by mass
	Fine aggregate (< 5mm)	SANS 3001- AG21	Maximum 1.5% by mass
Cleanliness	Sand equivalency test	SANS 3001-AG5	Minimum 50 total fines fraction
	Clay lumps and friable Particles	ASTM C142–97	Maximum 1%

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Surface area of aggregate

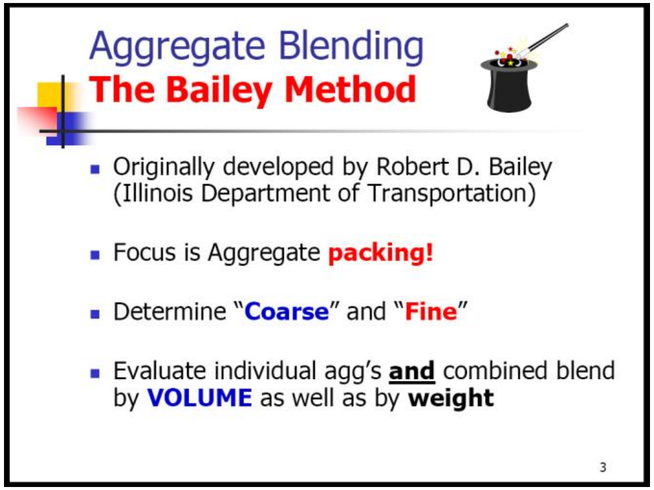
The Surface Area of an aggregate blend is important as it is required for the calculation of the binder film thickness. The finer the mix grading, the larger the total surface area of the aggregate and the greater the amount of binder required to uniformly coat the aggregate particles.

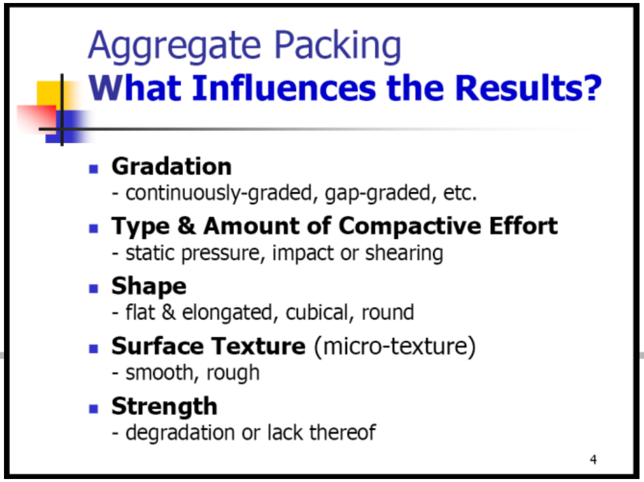
$$SA = \left(2 + 0.02\,a + 0.04\,b + 0.08\,c + 0.1\,d + 0.30\,e + 0.60\,f + 1.6g\right) \times 0.20482$$

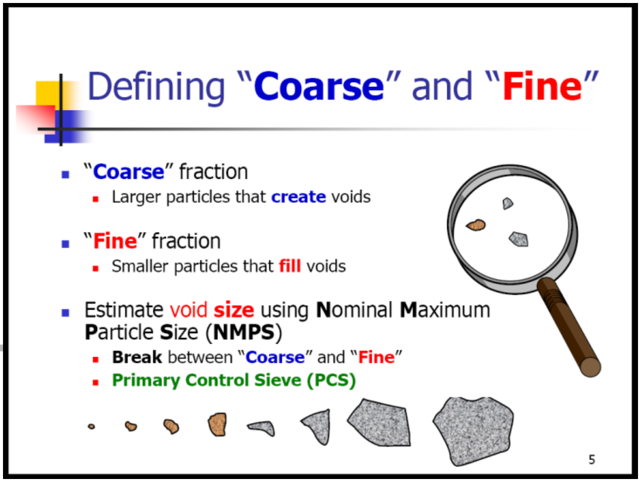
a	=	percentage passing 5 mm sieve;
b	=	percentage passing 2 mm sieve;
c	=	percentage passing 1 mm sieve;
d	=	percentage passing 0.60 mm sieve;
e	=	percentage passing 0.30 mm sieve;
f	=	percentage passing 0.15 mm sieve, and
g	=	percentage passing 0.075 mm sieve.

Appendix A

Overview of the Bailey method for determining aggregate proportions







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Appendix B

Principles of the design of Stone Mastic Asphalt