Addendum to TRH3/SABITA Manual 40

Clarification and corrections

December 2022

(Working document Revision 1.0)

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1. Introduction

Following several courses on seal selection, design and construction, results of forensic investigations into causes and mechanisms of failures and requests for clarification from practitioners, the need was identified and confirmed by the Road Pavements Forum (RPF) to update Manual 40.

A provisional list of issues to be addressed is provided in Appendix A.

Although the project cannot commence until a later stage, it was decided to immediately address urgent issues to minimise the risk of premature failures and/or poor performance. These are:

- Testing, reporting an interpretation of the Ball Penetration Test and Volumetric Texture Depth Test
- Target texture depth for seal design
- Conversion factors for modified emulsion binders
- Corrections and additional guidelines for the design and construction of:
  - 7 mm Single seals
  - 20/7 Double seals
  - 20/7/7 Double seals
  - Cape seals
- Sealing delay after rain

The document should be seen as a “Working document” requiring review, additional opinions, and information from practitioners before incorporation into Manual 40.

The intention is not to duplicate what is already provided in Manual 40.

2. Testing, reporting an interpretation

2.1 Ball penetration test (SANS 3001-BT10)

2.1.1 Background

The purpose of the ball penetration test is to estimate the embedment of the chip seal stone into the substrate. Embedment reduces the voids in the seal structure (refer Figure 1) and results in the seal binder to move up in the structure, reducing the macro texture.

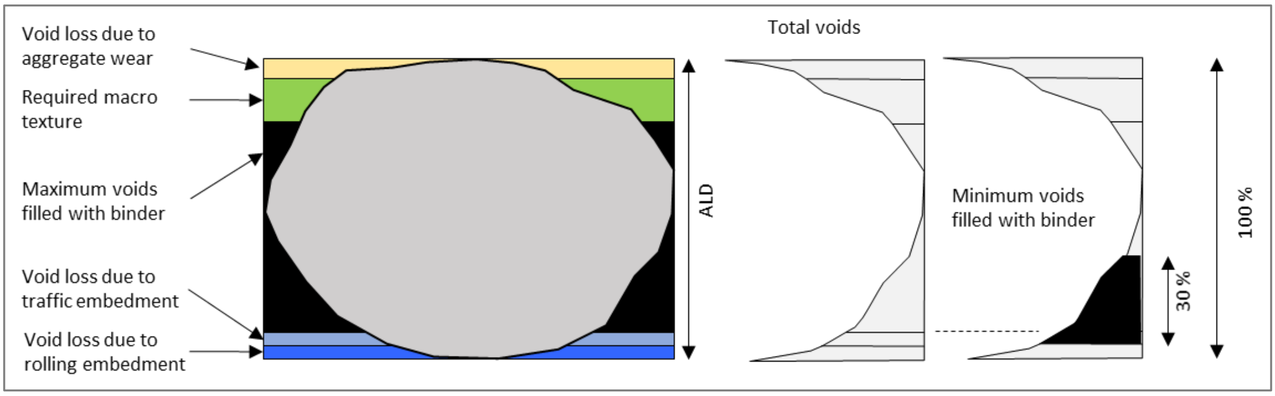


Figure 1 Volumetric design components

The initial test method was adjusted from measuring the embedment after one blow to measuring the embedment after one and two blows. The reasons are well described by Van Zyl (2015) with the main aim to improve estimation of true potential embedment. Dependent on the substrate type and the effect could be either penetration, crushing, displacement or a combination thereof.

<u>Interpretation</u>

- If only penetration is observed, the indent will have smooth halfmoon shape. In this case it is accepted that the reading after the first blow is the representative ball penetration before temperature adjustment
- If only crushing occurs, it is unlikely that the new seal will penetrate. The first blow reading is taken as a seating blow and only the reading due to the second blow is taken as the representative ball penetration before temperature adjustment
- Similarly, if only displacement is observed, only the reading due to second blow is taken as the representative ball penetration before temperature adjustment
- If a combination of penetration and displacement or crushing is observed, the average of the ball penetration due to the first and second blow is taken as the representative ball penetration before temperature adjustment

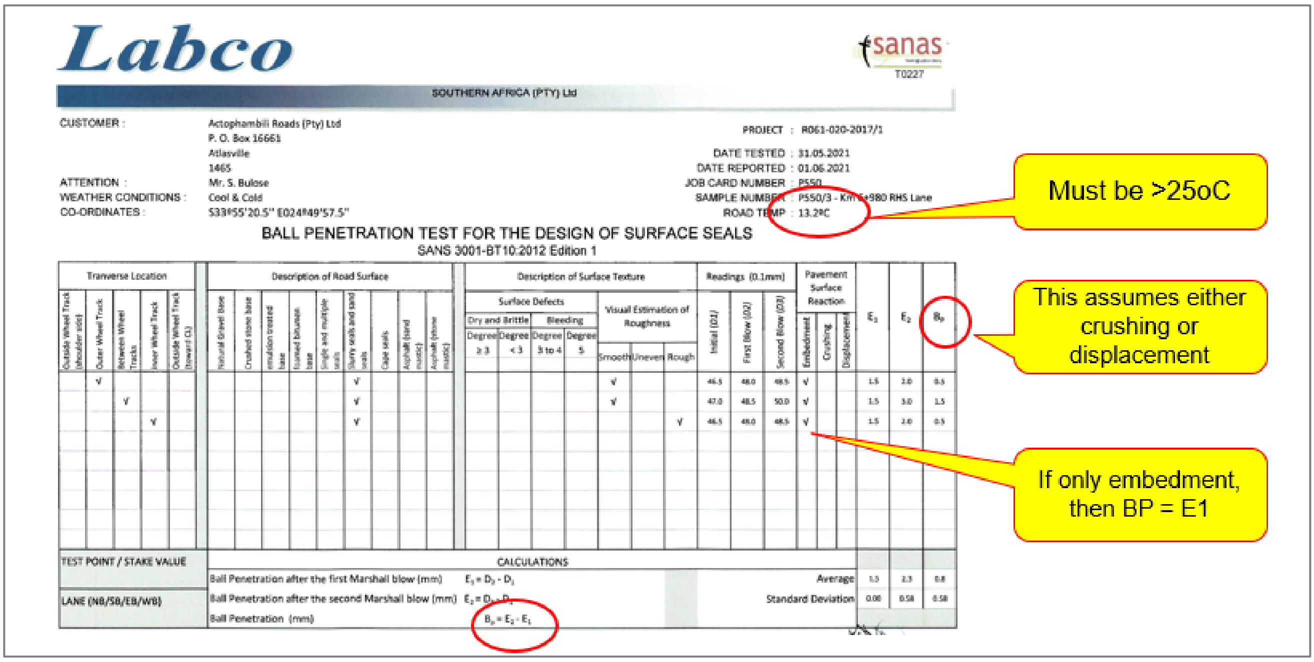
Note: It is acceptable to lift and to replace the ball after the first blow with caution to evaluate and to record the effect after the first blow.

2.1.2 Observed errors

The data provided on the report form in Figure 1 cover all the required information to make an informed decision. However, the following errors are highlighted:

1) The test was done at a road surface temperature of 13.2 °C. The temperature adjustment formulae is only valid for road surface temperatures of 25 °C and above. Therefore, for any temperature susceptible substrate, test should only be carried out when the surface temperature is above 25 °C.

2) The pavement surface reaction is recorded as "Embedment" only. This means that the representative Ball penetration should be the penetration of the first blow. However, as a standard on this reporting form, the penetration of the second blow is calculated and reported as the representative Ball penetration.



Labco

SOUTHERN AFRICA (PTY) Ltd

sanas T0227

CUSTOMER : Actophambili Roads (Pty) Ltd, P. O. Box 16661, Atlasville, 1465

ATTENTION : Mr. S. Bulose

WEATHER CONDITIONS : Cool & Cold

CO-ORDINATES : S33º55'20.5" E024º49'57.5"

PROJECT : R061-020-2017/1

DATE TESTED : 31.05.2021

DATE REPORTED : 01.06.2021

JOB CARD NUMBER : P550

SAMPLE NUMBER : P550/3 - Km [illegible]+980 RHS Lane

ROAD TEMP : 13.2ºC

BALL PENETRATION TEST FOR THE DESIGN OF SURFACE SEALS

SANS 3001-BT10:2012 Edition 1

Tranverse Location	Description of Road Surface	Description of Surface Texture: Visual Estimation of Roughness	Initial (D1)	First Blow (D2)	Second Blow (D3)	Pavement Surface Reaction	E_1	E_2	B_p
Outer Wheel Track √	Slurry seals and sand seals √	Smooth √	46.5	48.0	48.5	Embedment √	1.5	2.0	0.5
Between Wheel Tracks √	Slurry seals and sand seals √	Smooth √	47.0	48.5	50.0	Embedment √	1.5	3.0	1.5
Inner Wheel Track √	Slurry seals and sand seals √	Rough √	46.5	48.0	48.5	Embedment √	1.5	2.0	0.5

Other form columns (blank): Outside Wheel Track (shoulder side); Outside Wheel Track (toward CL); Natural Gravel base; Crushed stone base; emulsion treated base; foamed bitumen base; Single and multiple seals; Cape seals; Asphalt (sand mastic); Asphalt (stone mastic); Surface Defects – Dry and Brittle: Degree ≥ 3, Degree < 3; Bleeding: Degree 3 to 4, Degree 5; Uneven; Crushing; Displacement. Readings (0.1mm).

TEST POINT / STAKE VALUE

LANE (NB/SB/EB/WB)

CALCULATIONS

			E_1	E_2	B_p
Ball Penetration after the first Marshall blow (mm)	$E_1 = D_2 - D_1$	Average	1.5	2.3	0.8
Ball Penetration after the second Marshall blow (mm)	$E_2 = D_3 - D_1$	Standard Deviation	0.00	0.58	0.58
Ball Penetration (mm)	$B_p = E_2 - E_1$				

Figure 2 Reporting form for Ball penetration tests

3) In some cases the second blow resulted in a higher penetration than the first blow – this is not normal.

Further research is required to incorporate the stone size in determining the potential embedment.

2.2 Macro texture (Volumetric Texture Depth – SANS 3001-BT11)

2.2.1 Background

The Volumetric Texture Depth (VTD) (SANS 3001- BT11) is determined by spreading a known volume of sand or glass beads over an area. The volume divided by the area provides the VTD.

For purposes of seal type selection and design, the VTD is used to:

- Determine whether the new seal will perform well on the existing surfacing without application of a texture treatment. If the existing surface is too coarse, the applied new chip seal stone cannot lie shoulder-to-shoulder.

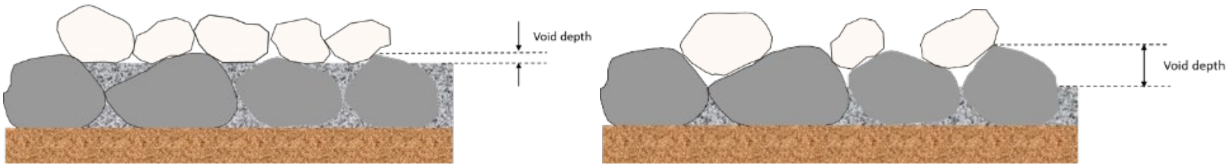


Figure 3 Effect of VTD on aggregate packing

If the VTD transversely over the road surface e.g. fine in the wheel tracks and coarse in-between, one binder application rate could result in too much binder in the wheel track and too little in-between.

- Determine how much additional binder is required to fill the voids below the new chip seal stone due to bridging

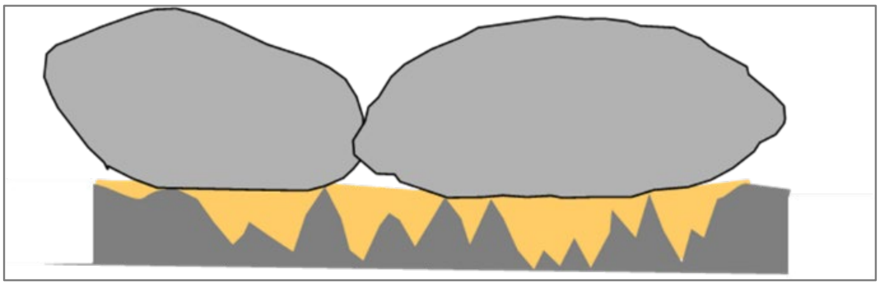


Figure 4 Bridging of chips on existing texture requiring additional binder

2.2.2 Operator and equipment errors

Testing the repeatability of volumetric texture depth measurement highlighted several factors that could influence the accuracy and repeatability namely:

- Cleaning the area before sand spreading
- Coarseness sensitivity
- Spreading the sand
- Measurement of the diameter

2.2.3 Spreading the sand

Operators require training to perform the test. Figure 5 shows a real test, executed by an operator of an accredited laboratory, resulting in an error of approximately 50%.

Figure 5 Sand not filling voids between stones

Figure 2 highlights situations where the sand should have been spread more, covering a larger area.

Figure 6 Sand not spread sufficiently

2.2.4 Measurement of the diameter

Operators often err, reporting the diameter either from the edge of sand visibility or from the top of the outermost stones of the filled circle. The correct position is to measure from the middle of the angle as shown in Figure 7. On coarse surfaces the error could easily be 10 mm - 20 mm resulting in errors of up to 50% in the VTD.

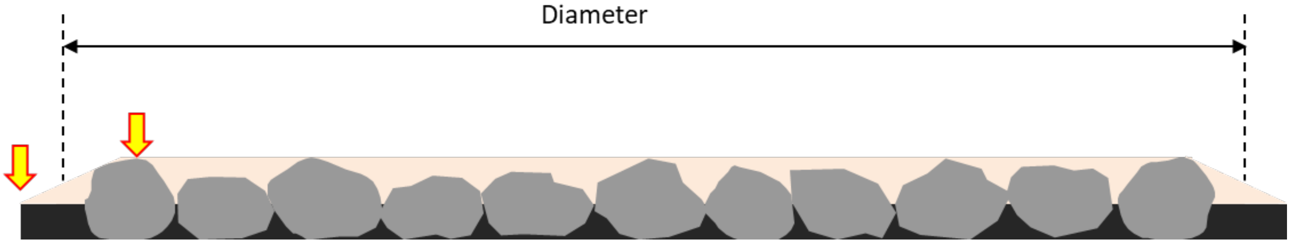


Figure 7 Correct measurement of diameter

2.2.5 Coarseness sensitivity

Measurement errors on coarse textures are more significant than on finer textures due to second power of the area equation. Figure 8 highlights the percentage error due to a 10 mm measurement error.

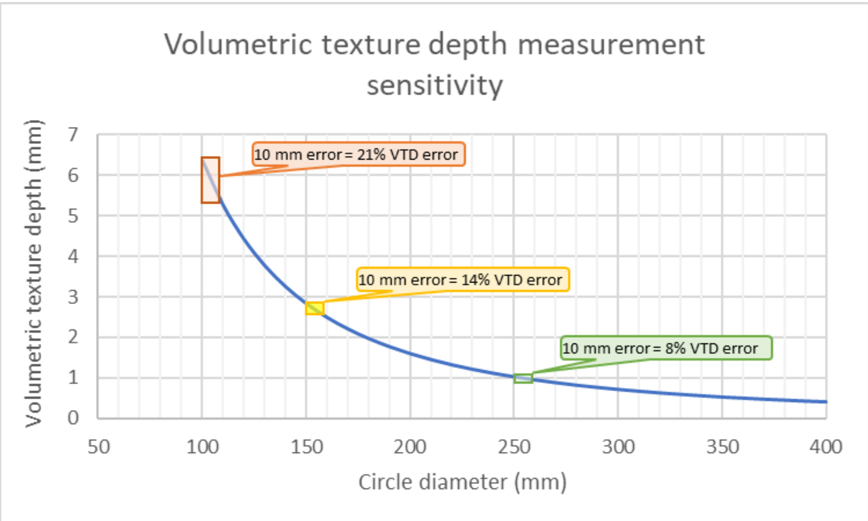


Figure 8 Effect of a 10 mm measurement error on the calculated VTD

Using 100 ml instead of 50 ml significantly reduces the sensitivity to diameter measurement errors.

2.2.6 Reporting

SANS 3001-BT11 requires recording of the existing surfacing, the location transversely over the width of the lane to be surfaced as well as the degree of dry/brittleness and bleeding in accordance with TMH9.

Table 1 Surface type

Type of Surface[a]
Single and multiple seals
Slurry seals and sand seals
Cape seals
Asphalt (sand mastic)
Asphalt (stone mastic)

Why is this important ?

Different surfacing types have different profiles e.g. regular, irregular, positive, negative (refer Figure 10). The type of profile assists the designer to motivate why a texture treatment would not be required, even if classified as coarse.

Table 2 Test position across the lane width

Transverse location
Outside wheel tracks – shoulder side
Outer wheel track
Between wheel tracks
Inner wheel track
Outside wheel tracks – towards centre line

Notes:

- Seal designs are mostly carried out per lane and separate for the surfaced shoulder (unless very narrow e.g. 0.5 m)
- It is important to determine the variation across the lane (finest to coarsest) to select an appropriate seal size or to specify a texture treatment
- An additional location could be added for a surfaced shoulder

Table 3 Recording of surface defects

1	2	3	4	5	6	7
Surface defects as described in TMH 9[a]				**Visual estimation of roughness**		
Dry and brittle		**Bleeding**		**Smooth**	**Uneven**	**Rough**
Degree ≥ 3	**Degree < 3**	**Degree 3 to 4**	**Degree 5**			
[a] Tick the appropriate column based on the degree of surface defects.						

Why is this important ?

- A very dry/brittle existing surface should ideally be treated with an enrichment spray such as a diluted anionic stable grade emulsion before sealing and/or application of a texture treatment, provided sufficient macro texture exists (Rough surface)
- The degree of bleeding/fattiness provides a good indication of the level of binder in the existing seal matrix and whether a slurry texture treatment will perform well. If the exposed binder in the seal is very soft and tacky, a slurry texture treatment will not perform well

3. Design

3.1 Target texture for seals

3.1.1 Background

The volumetric design for chip seals determines a minimum binder volume in the stone matrix to provide sufficient binder/stone contact area to prevent stripping and a maximum to ensure sufficient macro texture for skid resistance purposes. The macro texture assists with displacement of water in front of vehicle tyres to prevent hydroplaning and increases friction.

Although skid resistance is influenced by other factors as well, macro texture is used world-wide as a surrogate to identify risks.

3.1.2 Specifications

Previous TRH3 documents did not state the target textures for different speeds or risk zones and there is still a reluctancy to do this due to possible claims as a result of skid accidents. However, to determine the upper limit of binder volume for seal design purposes, it is necessary to select a target macro texture for the conditions at hand.

TMH13, AUTOMATED ROAD CONDITION ASSESSMENTS, Part E: Skid Resistance and Texture, highlights recommendations in terms of Mean Profile Depth (MPD) by Cook, 2005 as shown below.

Table 4 Typical macro texture requirements

Table E.5 Typical Macrotexture Requirements (Cook, 2005)

Facility	Texture Depth (MPD, mm)	
	New Surfacings	Existing Surfacings
Urban; legal and operating speed equal or less than 50 km/h	0.5	0.5
Urban; legal speed less than 70 km/h	0.7	0.5
Rural; legal speed 70 km/h or higher	0.9	0.5
Note: Values represent minimum threshold levels and not investigatory levels		

Cook further states that at the minimum nominal sand patch derived texture depth of 0.9 mm, there is a 50 per cent reduction in wet friction for a doubling in slip speed from 50 km/h to 100 km/h.

The Western Cape Materials Manual (Volume 6) provides French guidelines as below and refers to TRRL recommendations "for zero decrease in skid characteristics from 50 to 130 km per hour, the texture depth for bituminous surfacings should be > 2 mm"

Table 5 French texture depth guidelines (cited Western Cape Materials Manual, Volume 6)

Table 6-16: French texture depth guidelines	
SURFACING	TEXTURE DEPTH mm
Fine textured where speed ≤ 80 km/h	0,2 - 0,4
Medium textured normal conditions; speeds 80 - 120 km/hr	0,4 - 0,8
Coarse textured for traffic speed >120 km/hr	0,8 - 1,2
Very coarse textured - high risk areas	>1,2

Table 6 Requirements for initial texture depths

Volume 1 Series 900
Specification for Highway Works Road Pavements - Bituminous Bound Materials

Table 9/3: (08/08) **Requirements for Initial Texture Depth for Trunk Roads including Motorways**

Road Type	Surfacing Type	Average per 1,000 m section, mm	Average for a set of 10 Measurements, mm
High speed roads Posted speed limit ≥ 50 miles/hr (80 km/hr)	Thin surface course systems to Clause 942 with an upper (*D*) aggregate size of 14mm or less:	Not less than 1.3	Not less than 1.0
	Chipped hot rolled asphalt, surface dressing and all other surfacings:	Not less than 1.5	Not less than 1.2
Lower speed roads Posted speed limit ≤ 40 miles/hr (65 km/hr)	Thin surface course systems to Clause 942 with an upper (*D*) aggregate size of 14mm or less:	Not less than 1.0	Not less than 0.9
	Chipped hot rolled asphalt, surface dressing and all other surfacings:	Not less than 1.2	Not less than 1.0
Roundabouts on high speed roads Posted speed limit ≥ 50 miles/hr (80 km/hr)	All surface course materials	Not less than 1.2	Not less than 1.0
Roundabouts on lower speed roads Posted speed limit ≤ 40 miles/hr (65 km/hr)	All surface course materials	Not less than 1.0	Not less than 0.9

Note: The guidelines in Table 5 and Table 6 are based on VTD.

Before making provisional recommendations for target texture, it is necessary to provide more information on:

- Correlation between Mean Profile Depth (MPD) and Volumetric Texture Depth (VTD).
- Loss of macro texture

3.1.3 Correlation between Mean Profile Depth and Volumetric Texture Depth

Class 1 laser profilers provide quick and repeatable data to describe macro texture along a road. Therefore, it could be used to identify potential skid resistance risks at the network level and could be used in performance-based contracts (refer COTO 2020 specifications in Table 7, Table 8 and Table 9.

Table 7 Acceptance criteria (Minimum) for initial surface macro-texture

Seal Type	10 mm	14 mm	14/7	20/10	20/7/7	20/7	20 Cape	14 Cape
5th Percentile MPD	1.8	1.95	1.5	1.8	1.55	1.7	NA	NA

Table 8 Acceptance criteria for surface macro-texture performance – double seals

Time	Percentage retention of initial Mean profile depth (%)[2]	Maximum (%) of 1 km segment with surface macro-texture retention worsethan limit value
Year 1[1]	85.0	20 %
	80.0	5 %
	75.0	0 %
Year 2[1]	80.0	20 %
	75.0	5 %
	70.0	0 %

Table 9 Acceptance criteria for surface macro-texture performance – single seals

Time	Percentage retention of initial Mean profile depth (%)[2]	Maximum (%) of 1,0 km segment with surface macro-texture retention worse than limit value
	70.0	20%
	60.0	5%

Year 1[1]	55.0	0%
Year 2[1]	60.0	20%
	55.0	5%
	45.0	0%

The correlation between MPD and Volumetric Texture Depth (VTD) is currently argued. The PIARC published transform states:

$$VTD = 0.8MTD + 0.2$$

It should be known that this equation was developed from correlation studies, mainly on asphalt surfacings with VTD less than 1.2 mm. A correlation study on surface treatments (chip seals) in South Africa (van Zyl & Van der Gryp), complemented with laboratory measurements (Von Beneke) confirmed that the PIARC transform is not applicable for chip seals, especially with texture depths mostly above 1.0 mm.

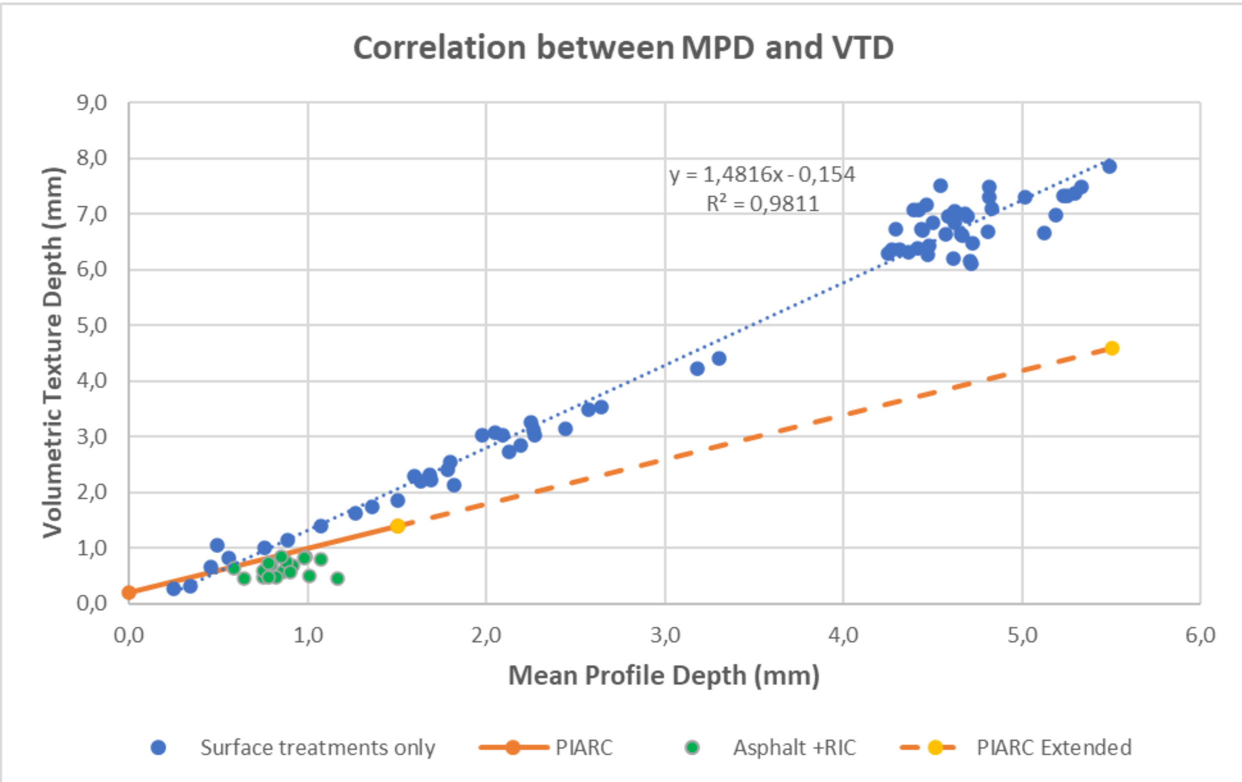


Figure 9 Correlation between MPD and VTD

Further investigation into the controversy (Van Zyl, 2023) highlighted logical reasons for the differences e.g.:

- Irregular positive surface profiles of chip seals versus regular negative surface profiles for asphalt surfacings

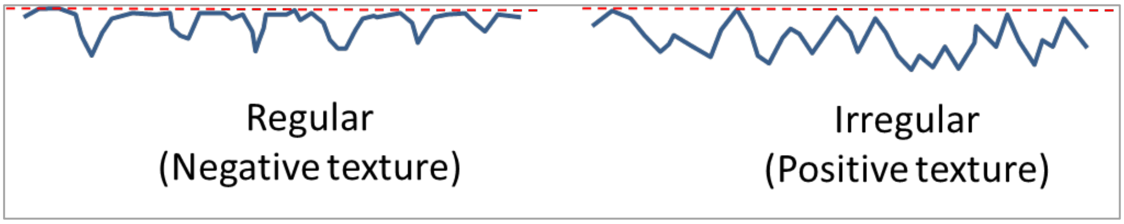


Figure 10 Typical profile differences between asphalt surfacings and chip seals

- Volumetric measurement (glass beads) fills voids in the structure not visible with vertical laser measurements

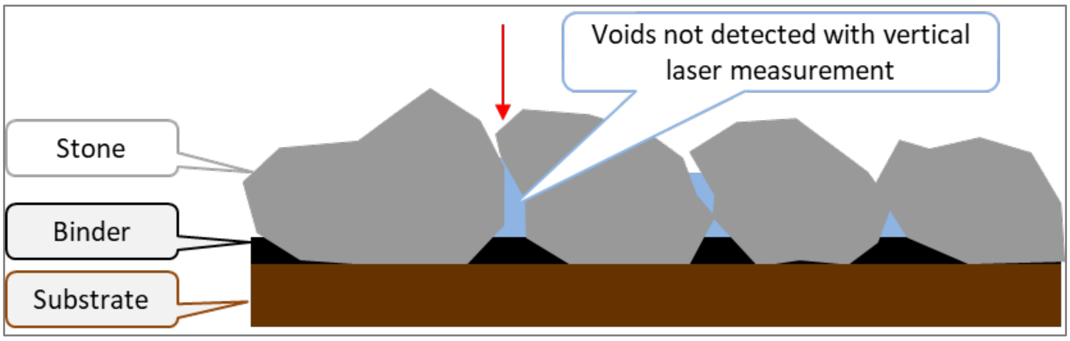


Figure 11 Voids in seal structure not detected with laser measurements

3.1.4 Loss of macro texture

3.1.4.1 Background to the theory (Graphs in old TRH3) and formulae in Manual 40.

The minimum line on the design graphs of TRH3 (2005) to hold the stone, is considered the most accurate – originated from Provincial manuals and verified with time.

The lines for the target textures are still based on work done by Marais 50 years ago, with the stated assumption that:

- Half of the embedment occurs during construction with the rest over a period of 10 years

Therefore, in this theory, if a target texture of 0,7mm is selected, this will only occur after a 10-year period

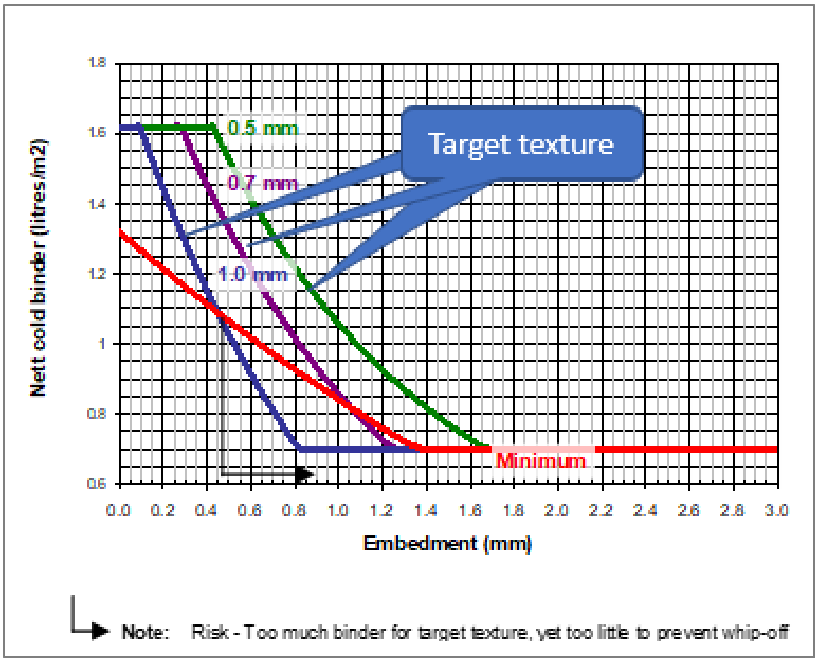


Figure 12 Target texture lines in TRH3 2005

From research over the past ten years, it is concluded that the assumption is not correct:

- Both embedment and stone orientation play a role in texture loss
- Double seals perform significantly different from single seals with regards to the rate of texture loss
- The type of binder has a major influence on the rate of stone orientation
- As the binder ages, the rate of orientation and embedment reduces

Figure 9, Figure 10 and Figure 11 provide some idea of data collected and the influence of binders, seal type and embedment on texture loss.

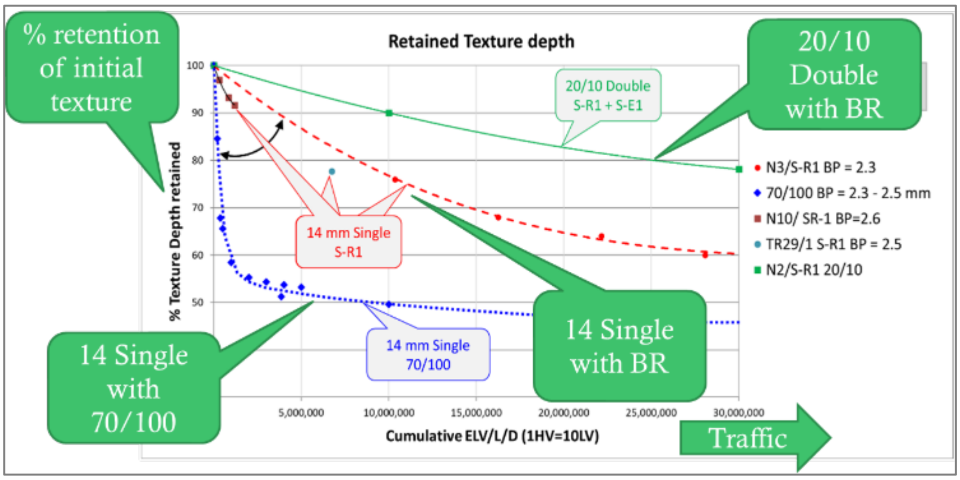


Figure 13 Difference in rate of texture loss

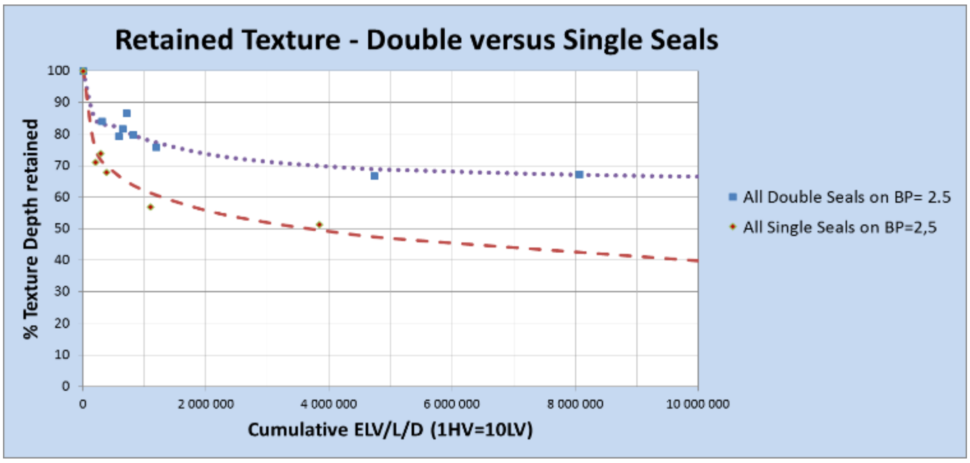


Figure 14 texxture retention between single and double seals

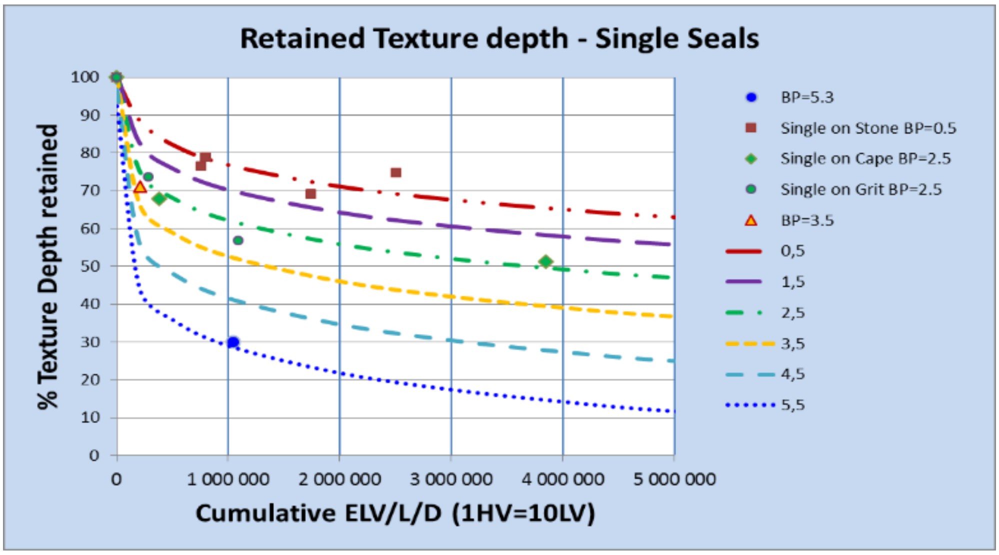


Figure 15 Impact of embedment on texture loss

The above confirms the need to improve on the target texture lines (old graphs) and the formulae for application rates for target texture with time. As is visible from the graphs the binder type, seal type, ageing characteristics, and other factors such as rolling practices should be incorporated.

This issue is addressed to the extent that several master students have investigated the orientation under the MMLS. A major SANRAL Research project to allow linking the rheological properties to the rate of orientation, was already approved in January 2021 but due to the contractual and other issues this project has not started.

In summary:

- Why are the existing target texture formulae still in Manual 40, well knowing that they are not accurate (very conservative)? The answer is that it is still a rough indication of risk of bleeding
- Can we design for a target texture of 0,7 mm for single seals or even 0,5 mm for double seals with 7mm in the second layer. Yes, specifically if the binder selected is modified and the corrected ball penetrations < 3mm

3.1.5 Recommended design philosophy:

- For longevity in terms of skid resistance, design for the minimum plus contractor's tolerance
- Increase towards the target texture lines to assist with crack reflection prevention. The maximum application rate is calculated through the selection of the target texture with the following as guidelines
    - Low speed less than 80 km/h – 0.5 mm
    - Speed 80 – 100 km/h – 0.8 mm
    - Speed 100 – 120 km/h – 1.0 mm
    - High risk areas – 1.2 mm

3.2 Conversion factors for modified binders

3.2.1 Background

Net Cold Conventional Binder (NCCB) refers to the residual binder (non-modified) at 25°C after evaporation of any volatiles such as water or solvents. A 70-100 Penetration grade bitumen is a conventional binder and at 25°C a NCCB. The typical 65% Cationic rapid setting emulsion and the 60% Anionic slow setting emulsion are conventional binders. After evaporation of the water in the emulsion, the residue at 25°C is then the NCCB

The volumetric design of chip seals in Manual 40 starts with the determination of the residual binder required to hold the stone in place (minimum) and to ensure that there is still sufficient macro texture to displace water in front of vehicle tyres (maximum). The design takes into account the loss of voids due to embedment and aggregate wear (estimated over ten years).

Modification of the conventional binder e.g. addition of synthetic polymers of rubber crumbs changes the characteristic of the conventional binder, requiring more binder to hold the stone in place during early life. Slower orientation of the stone with modified binders, mainly due to stiffness and elasticity, initially results in lower aggregate surface area in contact with the binder with typica; aggregate shape and spread rates. Therefore, more binder is required to obtain sufficient initial bond strength.

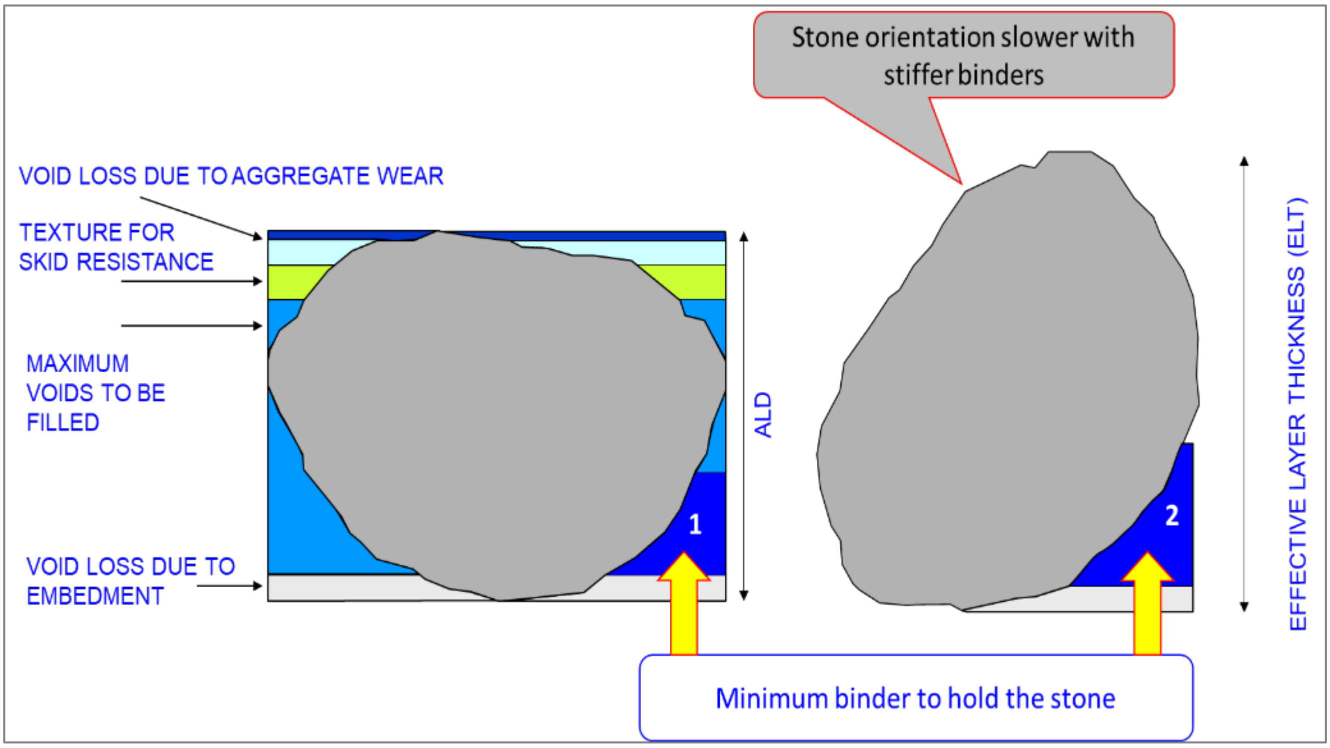


Figure 16 Additional binder required when using modified binders

Data collected on single seals emphasised the slower orientation when using modified binders (referFigure 17)

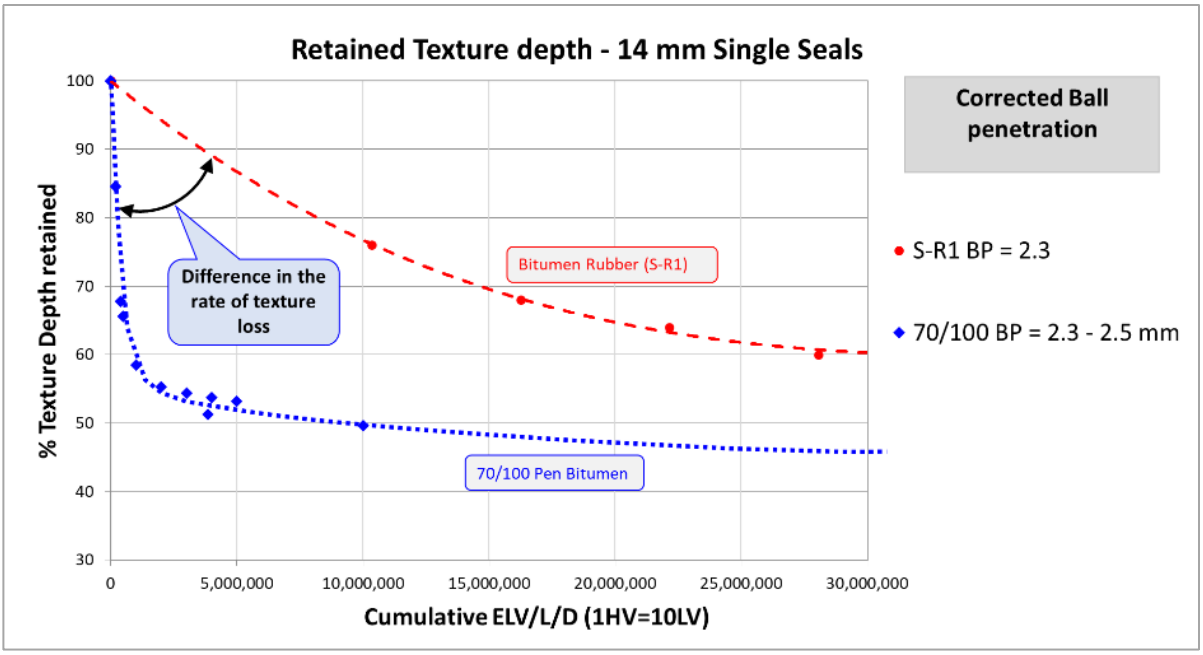


Figure 17 High texture retention on bitumen rubber seals due to slow stone oreintation

The tabled conversion factors in Manual 40 for hot modified binders were derived from trial and error to obtain good performing seals.

Notes:

- We still do not have a very good understanding of the difference in rate of orientation between the S-R1 and S-R2 binders. The S-R2 is definitely softer and allows quicker orientation during construction and first 5000 vehicle passes. The current conversion factor in Manual 40 of 1,7 is considered too high and must still be accurately determined.
- Current research is focussed on correlating the rate of orientation to rheological properties of the binder.

3.2.2 Conversion factors for polymer modified emulsions

TRH3 (2005) did not recommend conversion for polymer modified emulsions. The reasoning behind this was that the viscosity of the emulsion during construction is low, resulting in rapid orientation of the stone.

However, due to observations and sensitivity of stripping reported, it was realised that the stone does not necessarily orientate rapidly as expected. The following factors of importance:

- Any emulsion is allowed to be sprayed at road surface temperatures of 10°C (and rising)

- Although the single sized stone is directly applied into the emulsion, PTRs cannot be used until the emulsion starts to break (stones easily turn resulting in the binder adhering to the tyres)
- When the water evaporates from a SC-E1 polymer modified emulsion (breaking of the emulsion), the viscosity increases rapidly similar to the viscosity of the related hot polymer modified binder (S-E1) at the prevailing road surface temperature
- At this stage the road surface temperature might still be far below the temperature conducive to allow stone orientation (typically above 20°C

The above resulted in the recommendation in Manual 40 for converting Net Cold Conventional Binder (NCCB) to Net Cold Modified Binder (NCMB) as below:

E.4.3.1.3 Homogenous cold modified binders

The provisional recommendation is that the conversion for polymer modified emulsion is 50% less than for the hot polymer modified binder. Therefore:

- Conversion for SC-E1 = 50% of the conversion for S-E1 and;
- Conversion for SC-E2 = 50% of the conversion for S-E2.

As an example, using Table E 9, the conversion factor for SC-E2 for a single seal with ELV < 5000 = 1.2.

The explanation is not clear with the result that the conversions are now presented in Table 10 and Table 11.

Table 10 Adjustment for SC-E1 binder application

SC-E1 ADJUSTMENT (Conventional to modified binder)				
Traffic (ELV)		Single seal	Double Seal	*Split application double seal*
Min	Max			
0	5000	1,15	1,05	*1,1*
5001	20000	1,1	1	*1,05*
20001	*80000*	*1,05*	*1*	*1*

Table 11 Adjustment for SC-E2 binder application

SC-E2 ADJUSTMENT (Conventional to modified binder)				
Traffic (ELV)		Single seal	Double Seal	*Split application double seal*
0	5000	1,2	1,1	*1,15*
5001	20000	1,15	1,05	*1,1*
20001	*80000*	*1,1*	*1*	*1,05*

4. Guidelines for specific seal types

4.1 7 mm Single seal design

The changes made from the TRH3 (2005) resulted from too little binder and stripping when applying the volumetric design for single seals.

Figure 18 Result of volumetric design after construction and stripping within a week

This resulted in revisiting the Western Cape design process as highlighted below (Materials manual, Volume 6).

Table 6-30: Emulsion spray rates for a 6,7 mm seal

ALD mm	SPRAY RATE (HOT) litre/m^2
<3,5	1,00
3,5 - 4,0	1,20
>4,0	1,40
OTHER CONDITIONS	1. If the existing surface is dry and cracked, the spray rate shall be increased by 0,2 ℓ/m^2 2. If cubical chips are used, i.e., a Flakiness Index <15, the spray rates shall be in-creased by 0,1 ℓ/m^2. 3. If the total spray rate is less than 1,2 ℓ/m^2 the use of a single spray of emulsion should be considered 4. If the total spray is >1,2 ℓ/m^2 a split application shall be applied. The top spray shall be an emulsion diluted 1:1 with water and sprayed at 0,8 ℓ/m^2

Using these recommendations, the basic application rate could be calculated as follows:

$$NCCB = 0.52\ x\ ALD - 1.17$$

What is missing to the formulae in Manual 40 is that is **only applicable in the range between the typical values ALD 3.5 mm and 4.3 mm**.

Applying the Western Cape rule sets for 65% emulsion and converting to NCCB and typical binders used for this seal results in recommended hot application rates for stone with FI >15 and FI <15 as shown in Table 6 and Table 7.

Table 12 Hot application rates for different binders with Flakiness Index more than 15

Flakiness Index > 15									
				65% Emulsion			70% Emulsion		
ALD	NCCB	70/100 hot	S-E1 hot	Total	Tack coat	Cover spray (50/50)	Total	Tack coat	Cover spray (50/50)
3,5	0,65	0,71	0,70	1	1		0,93	0,93	
3,6	0,702	0,77	0,76	1,08	1,08		1,00	1,00	
3,7	0,754	0,82	0,81	1,16	1,16		1,08	1,08	
3,8	0,806	0,88	0,87	1,24	0,84	0,8	1,15	1,15	
3,9	0,858	0,94	0,93	1,32	0,92	0,8	1,23	0,83	0,8
4	0,91	0,99	0,98	1,4	1	0,8	1,30	0,90	0,8
4,1	0,962	1,05	1,04	1,48	1,08	0,8	1,37	0,97	0,8
4,2	1,014	1,11	1,10	1,56	1,16	0,8	1,45	1,05	0,8
4,3	1,066	1,16	1,15	1,64	1,24	0,8	1,52	1,12	0,8

Table 13 Hot application rates for different binders with Flakiness Index less than 15

Cubical stone (Flakiness Index < 15)									
				65% Emulsion			70% Emulsion		
ALD	NCCB	70/100 hot	S-E1 hot	Total	Tack coat	Cover spray (50/50)	Total	Tack coat	Cover spray (50/50)
3,5	0,72	0,78	0,77	1,1	1,1		1,02	1,02	
3,6	0,77	0,84	0,83	1,18	1,18		1,10	1,10	
3,7	0,82	0,89	0,88	1,26	0,86	0,8	1,17	1,17	
3,8	0,87	0,95	0,94	1,34	0,94	0,8	1,24	0,84	0,8
3,9	0,92	1,01	1,00	1,42	1,02	0,8	1,32	0,92	0,8
4	0,98	1,06	1,05	1,5	1,1	0,8	1,39	0,99	0,8
4,1	1,03	1,12	1,11	1,58	1,18	0,8	1,47	1,07	0,8
4,2	1,08	1,18	1,17	1,66	1,16	1	1,54	1,14	0,8
4,3	1,13	1,23	1,22	1,74	1,19	1,1	1,62	1,17	0,9

Notes:

1) Area shaded in pink. Application rates for S-E1 should preferably not be less than 1.0 l/m^2 due to sensitivity of tramlining

2) Run-off could easily occur due to the low viscosity of emulsions. When the tack coat application is more than 1.2 l/m^2, the cover spray application could be increased to more than 0.8 l/m^2

3) ***No adjustments should be made for the existing macro texture or for embedment potential***

4) The **conversion for modified binder should not be applied** as this relates to the rate of large stone orientation to prevent aggregate loss during the initial phase (bedding-in phase)

5) Until more performance data becom available it is recommended that this seal type only be used for ELVs less than 4000

<u>Testing the design</u>

During a road noise experiment, the recommended Western Cape design was applied.

- Cationic spray grade emulsion was applied at 1.2 l/m^2 and precoated aggregate (ALD=4.2) spread at 180 m^2/m^3

Figure 19 7 mm seal before cover spray of diluted 60% Anionic emulsion (50/50) at 1.0 l/m2

- Rolling:
  - First two passes with a light steel wheel roller (3 ton) followed by four passes with a heavy pneumatic-tyred roller. The road surface temperature decreased rapidly due to cold winds resulting in a decision to continue with PTR rolling the next day
  - Four passes with a heavy pneumatic rolling the next day when road surface temperatures increased to above 25°C

- Brooming off excess stone
- Cover spray (Cat 65 50/50) applied at 1.0 l/m^2
- Opened to traffic

The visual appearance of the seal after three weeks is shown in Figure 20.

Figure 20 Visual appearance of the 7mm seal after 3 weeks

4.2 20/7 Double seal

The 20/7 double seal is considered a low-risk seal with the 7 mm wedging the 20 mm stone and allowing more aggregate particles in touch with the vehicle tyres to minimise the risk of aggregate loss.

From experience, good performing 20/7 double seals have been designed and constructed. The following recommendations apply:

1) Use the sum of ALDs of the two aggregate layers as the design ALD

2) Although any binder could be used for the tack coat, low viscosity emulsions should **not** be used for the penetration coat. Hot homogenous polymer modified binder e.g. S-E1 recommended for this purpose

3) Both aggregate layers should be precoated

4) A cover spray using a cationic emulsion, diluted 50/50, 60/40 or 70/30, is recommended

5) Recommended distribution of the total NCCB between the tack coat and penetration coat (first and second binder application), after subtracting 50% of the cover spray NCCB, is 50/50 or 45/55

6) The 20 mm aggregate should be spread to obtain a shoulder-to-shoulder matrix after rolling.

7) Using a light (2 – 4 ton) steel wheel roller on the 7 mm layer in addition to PTR rolling, before brooming results in a finer texture and lower noise levels. Refer Figure 21

Figure 21 Different spread rates of 7 mm resulting in different macro textures

4.3 20/7/7 Split-application double seals

4.3.1 History

The 20/7/7 seal developed as a result of non-availability of 14 mm and 10 mm aggregate due to high demands for reseal. A series of experiments was conducted by H van Vreeden, in the now Mpumalanga Province, on high coal traffic routes using 20 mm and 7 mm combinations. The 20/7/7 with the first 7 mm layer applied without a binder layer proved to be the best combination.

4.3.2 Design and construction guidelines

This seal type does not fit into the volumetric design approach as voids are created within the structure. However, with numerous 20/7/7 seals constructed with excellent performance the following lessons learnt:

1) Use the sum of ALDs of the two aggregate sizes as the design ALD (ALD 1 + ALD2)

2) Although any binder could be used for the tack coat, low viscosity emulsions should **not** be used for the penetration coat. Hot homogenous polymer modified binder e.g. S-E1 recommended for this purpose

3) Always design with a cover spray (1,0 l/m^2 min to 1.2 l/m^2 maximum cationic 65% emulsion, diluted 70/30 or 60/40)

4) Distribute the remaining NCCB between the tack coat and penetration coat in a ratio of 50/50 to 45/55 %

5) Typical hot application rates for S-E1, 1.1 l/m^2 minimum to 1,5 l/m^2 maximum for each layer. For S-R1 or S-R2 in tack coat 1,9 – 2,3 l/m^2. The above dependent on the embedment potential, traffic and stone properties

6) The first aggregate layer (20 mm) and final aggregate layer (7 mm) must be precoated. Although the dry layer has been precoated in cases, the lighter colour of the non-precoated 7mm stone helps significantly to ensure the right spread of the dry layer.

Figure 22 "Salt and pepper look" with the non-precoated 7 mm dry layer

7) Over spreading of the dry 7 mm layer prevents good adhesion of the penetration coat to the 20mm stone. Rather a bit too low application of the dry layer than too much. The surface with slightly low application will initially have a "egg shell/ orange peel "look with small holes visible. However, this will disappear with time

8) Provision has been made in the design of the 20/7/7 double seal design for an additional binder layer (emulsion/diluted emulsion) before the first 7mm (therefore not a dry layer). If this option is selected a diluted cationic emulsion (70/30 or 60/40) at 0.8l/m^2 is recommended

9) The spread rate of the 20 mm aggregate should such that a shoulder-to-shoulder matrix is achieved after rolling with a PTR. A "too open" matrix results in the dry 7 mm aggregate falling into the voids and forcing the binder upwards

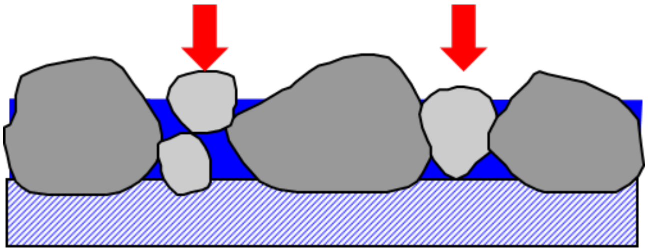


Figure 23 Open 20 mm structure allows 7 mm aggregate to force binder upwards

Figure 24 Bleeding in the wheel tracks as a result of a "too open" 20 mm spread

Orientation of the first aggregate layer during construction is highly dependent of the softness of the substrate, the binder type selected, the spread rate of the aggregate, as well as the roller type, mass and repetitions. The aim with this seal type is to create voids in the structure. Using a steel wheel roller on the 20 mm layer could result in significant orientation, low spread rate of the dry 7mm layer and low voids. Figure 25 shows the effect of only PTR rolling (left) and a combination of PTR and steel wheel rolling (right).

Figure 25 Difference in aggregate orientation with only PTR rolling versus PTR and steel wheel

10) If the dry layer is not spread uniformly, a drag broom will assist in a more uniform cover.

11) Although different rolling options could be applied, good results are obtained with:

   a) 8 Passes with a heavy PTR on the 20 mm layer

   b) 2 passes with a steel wheel roller on the dry layer

   c) A combination of 8 passes with a heavy PTR and 2 passes with a light steel wheel roller on the final 7 mm layer

4.4 20/10 Double seal

The 20/10 double seal is considered the most difficult seal to construct properly. Several reasons have been identified by experience practitioners namely:

1) Shape and size of the 10 mm aggregate. Sensitivities recorded are:

   a) If the ALD of the 10 mm aggregate is more than 50% of the ALD of the 20 mm aggregate and/or the 10 mm is round/cubical (Low Flakiness Index), it does not fit properly into the voids of the 20 mm matrix

   Note:

   b) The above has led to some practitioners specifying a minimum FI to allow the 10 mm to wedge in or reducing the spread rate of the 20 mm aggregate (more open structure) to create a more stable structure. The problem with the latter approach is “How open” should the 20 mm structure be and how does it influence the design of the binder application rate ?

2) Reluctancy of contractors to use steel wheel rollers

3) General opinion that the total binder application rate for the 1 ½ configuration is too low

The schematic diagram in Manual 40 for a full double seal (refer Figure 26) is considered idealistic as it is almost impossible to create a structure without some of the 20 mm aggregate visible at the surface. Using different aggregate spread rates and roller combinations (refer Figure 25) more stone orientation and embedment could be achieved to obtain a relative “flat/smooth” surface on which a single 10 mm aggregate can be applied.

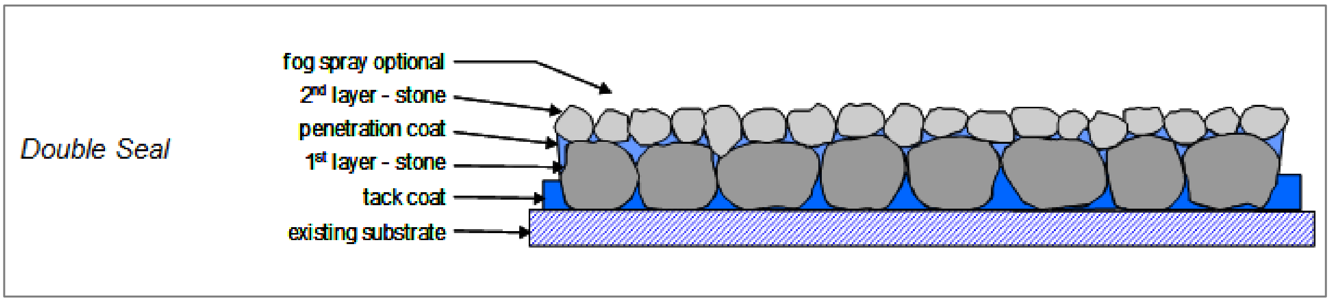


Figure 26 Idealistic view of the full double seal

Recommendations to reduce risks of poor performance as follows:

1) Design for a full double seal i.e. using ALD1 + ALD2 as the design ALD

2) Always apply a cover spray on this seal type. Recommended to apply a 65% cationic rapid setting emulsion (spray grade), diluted 60/40 or 70/30 with water and applied at 1.0 to 1.2 l/m2.

3) After subtracting 50% of the NCCB of the cover spray from the total NCCB, distribute the remaining binder for the tack coat and penetration coat in the ratio 50/50 to 45/55 ensuring a minimum of 1.0 l/m^2 NCCB in the tack coat

4) Use a combination of PTRs and light steel wheel rollers on both aggregate layers

5) Only open to traffic when road surface temperatures increase above 25^oC

Figure 27 shows the final surface of a full 20/10 double seal designed and constructed in accordance with the above recommendations. As can be observed, there are still 20 mm aggregate visible in the matrix.

Figure 27 Full 20/10 double seal

4.5 Cape seals

4.5.1 Background

The Cape seal is considered the most robust and low risk initial seal in both the urban and rural environment. However, poor performance due to early cracking has been recorded on several Cape seals in recent years. Forensic investigations identified one of the main causes of failure a "too low binder content" in the slurry.

Although this issue was identified and addressed in Manual 40, designers still tend to specify the minimum binder as determined from the Wet Track Abrasion Tests (WTAT).

4.5.2 Information towards recommendations

1) The main reason for bleeding of Cape seals is migration of a "too soft binder" in the tack coat, forced upward due to traffic compaction of the slurry. Application of the slurry reduces the rate of oxidative hardening in the tack coat. Therefore, the softening point could remain low for a long time. With road surface temperatures increasing far above the softening point, the tack coat binder becomes liquid with very little resistance to upward displacement. Slurry typically compacts to approximately 80% of the wet volume and in a Cape seal first slurry down 2 mm to 3 mm below the top of the large seal aggregate.

2) Slurry binder contents according to the Western Cape Materials Manual are 14 to 20 parts of stable grade emulsion by mass of the dry aggregate and 20 parts for the second slurry layer. For a 60% anionic stable grade emulsion, this converts to 8.4% to 12% bitumen for the first layer and 12% for the second layer. To note that the specification for permeability of less than 1.0 l/h on the final layer, when measured by means of method SANS 3001-BT12 (Marvil test), is based on the above binder contents. Lower binder contents would result in higher permeability

3) Aggregate loss with increasing conventional binder content in the WTAT typically stabilises at 6.5 % to 7.5 % bitumen with slurry aggregate gradings within specification. However, the mix at such binder contents is still hard and brittle.

4) Introducing the Indirect Tensile Strength (ITS) indicates higher optimum binder contents than the minimum from the WTAT to stabilise aggregate loss. Figure 28 shows the test results of the WTAT and ITS on a fine slurry (Medium grading). Although 7% bitumen would satisfy the aggregate loss requirement, the maximum ITS for the same mix was achieved at 9% bitumen.

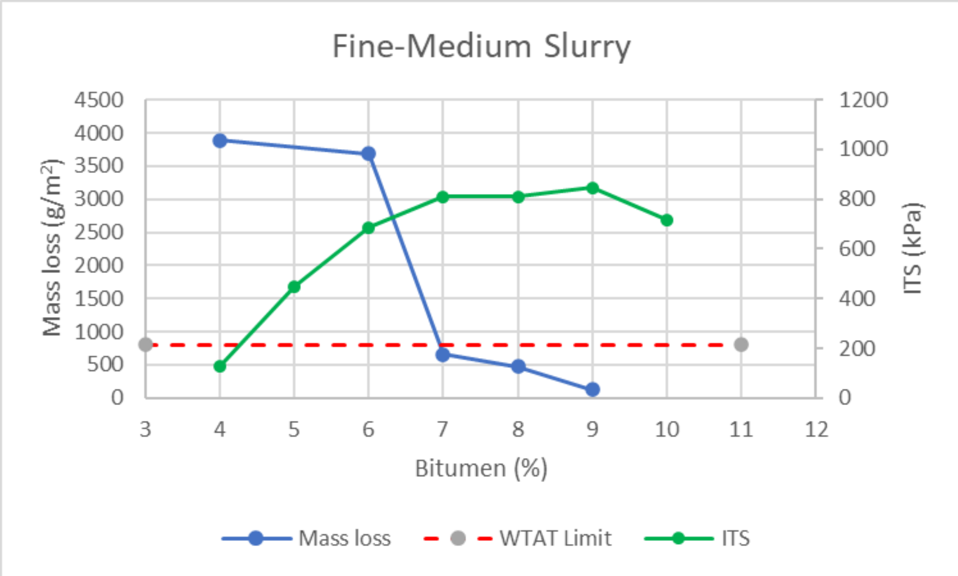


Figure 28 Mass loss and ITS results

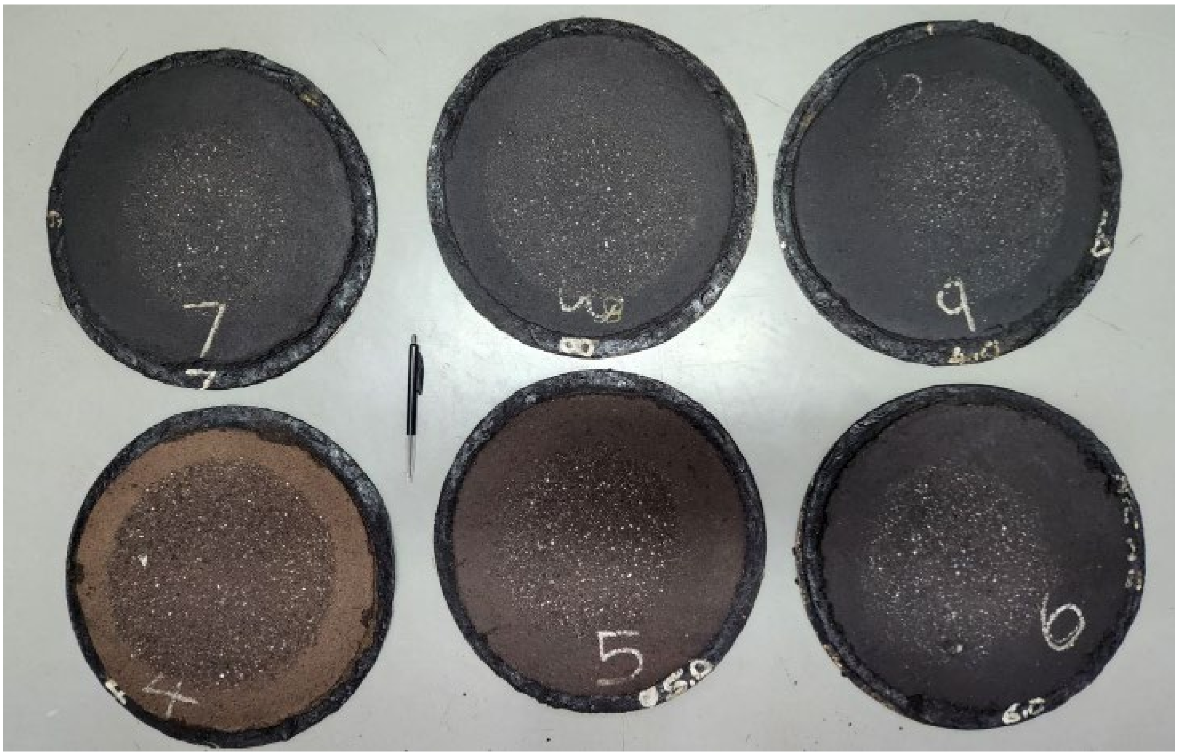


Figure 29 Fine slurry (Medium grading) - Specimens after WTAT

Figure 30 Fine slurry (Medium grading) - Specimens after ITS test

5) Different to a slurry overlay, the Cape seal slurry, after the initial compaction is protected by the large aggregate. Therefore, a higher binder content than obtained with the maximum ITS (increased film thickness), will be beneficial to reduce permeability and to prolong crack reflection

4.5.3 Recommendation

The minimum binder contents for Cape seal slurry are:

- First layer at binder content at the maximum ITS or 8.5 %
- Second layer with minimum binder content 1.0 % above the maximum ITS or 9.5%

4.5.4 Slurry application rates

There is a discrepancy in terms of Cape seal slurry applications (Manual 40 versus COTO 2020) for the 2 different layers. Table A10.1.3-7 in COTO 2020 provides nominal spread rates for tender purposes

Table 14 COTO 2020 Nominal spread rate of slurry

The following spread rate of slurry (saturated aggregate volume) shall apply for tender purposes only:

Table A10.1.3-7 Nominal spread rate of slurry for Cape seals

Nominal size of aggregate (mm)	First layer of slurry (m^2 per m^3)	Second layer of slurry (m^2 per m^3)
20	140	185
14	150	
1	180	

Notes:

1) **The nominal spread rates are incorrect (refer discussion below)**

2) The nominal size of 1 mm in the third row should be 10 mm

Appropriate slurry spread rates are highly dependent on:

- Spread rate of the 20 mm aggregate
- Orientation and final matrix of the aggregate after construction, influenced by:
  - The tack coat binder and road surface temperature
  - Roller types and passes
  - Softness of the substrate
  - Existing base texture
- Grading of both slurry layers
- Time of compaction of the first slurry layer before applying the final layer
- End result aimed for i.e. coarse, medium or, fine

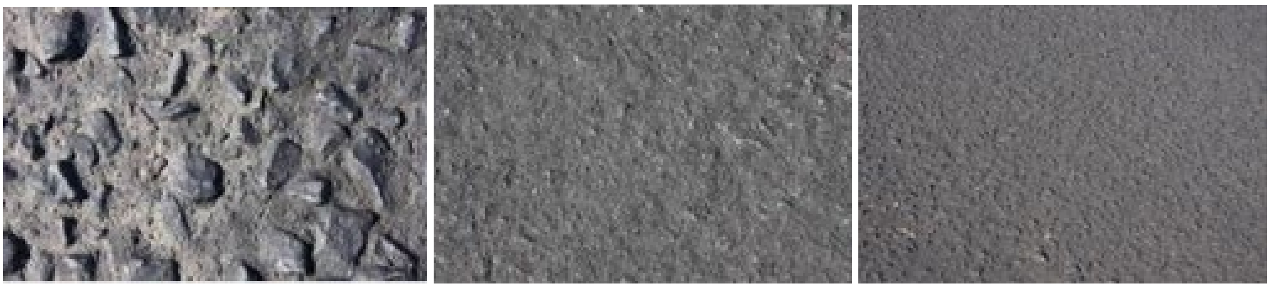


Figure 31 Macro textures of cape seals

The Manual 40 recommendations were aimed at a total of 125 m^2/m^3 for both layers as per Colto 98, with distribution approximating recommendations from experienced Western Cape engineers. Typically, the spread is approximately 6.5 kg/m^2 for the first layer and 3 kg/m^2 for the second layer.

There is not a specific right or wrong and the ideal would be to specify a total as per Colto 98. However, if the fine-medium is specified for the first layer and fine-fine for the second layer there must be two nominal rates and two payment items.

Table 16 provides a range of spread rates documented, recommended and actuals recorded.

Table 17 shows the current Manual 40 recommended 20 mm Cape seal slurry spread rates

Table 15 Documented and actual spread rates for Cape seal slurries

	TRH3 2007	W Cape manual	Manual 40	Colto 98	COTO 2020 (Error)	COTO 2023 recommended	Range recommended by Experienced practitioners		Site checks - Actual recorded							
				Both 125												
1st layer	Not provided	Not provided	190		**140**	190	170	185	120	167	137	151	170	181	193	190
2nd layer	Not provided	Not provided	365		**185**	365	475	390	420	385	380	145	434	390	340	385
												Box applied 2nd layer				
1st layer (m^3/m^2)			0,0053		0,0071	0,0053	0,0059	0,0054	0,0083	0,0060	0,0073	0,0066	0,0059	0,0055	0,0052	0,0053
2nd layer (m^3/m^2)			0,0027		0,0054	0,0027	0,0021	0,0026	0,0024	0,0026	0,0026	0,0069	0,0023	0,0026	0,0029	0,0026
Total (m^3/m^2)			0,0080		0,0125	0,0080	0,0080	0,0080	0,0107	0,0086	0,0099	0,0135	0,0082	0,0081	0,0081	0,0079
Total (m^2/m^3)			125	125	80	125	125	125	93	116	101	74	122	124	123	127

Table 17 provides the recommended spread rates documented in Manual 40. The values are considered appropriate and the averages should be used to update COTO 2020.

Table 16 Existing Manual 40 recommended spread rates

Single seal size (mm)	**1st Layer (m^2/m^3)**	**2nd Layer (m^2/m^3)**
20	185 - 195	360 - 370
14	195 - 205	
10	330 - 340	

4.6 Sealing delay after rain

4.6.1 Binder rise

Entrapment of moisture in the substrate before sealing could result in different mechanisms of failure. The effect of high moisture contents in a granular layer is well described in Manual 40 - PART B (Performance), highlighting the reduction in the Radius of Curvature and rapid fatigue of the seal layer with repeated loads.

When sealing on an existing bituminous surfacing or base with entrapped moisture, the risk exists that binder rise could occur with high road surface temperatures.

Pressure build-up occurs when moisture in the substrate below the seal expands due to increased temperature. If the new seal layer is impervious and the viscosity of the binder in the seal at the prevailing temperature is low enough, bubbles form on the surface with a bitumen skin and water vapour inside. Increased temperature and time at elevated temperatures result in increased pressure and eventually in bursting of the bubbles, leaving small holes through which the moisture escapes. Bubbles typically occur over the full road width and smearing of the excess binder by traffic results in tackiness and pickup in the wheel tracks.

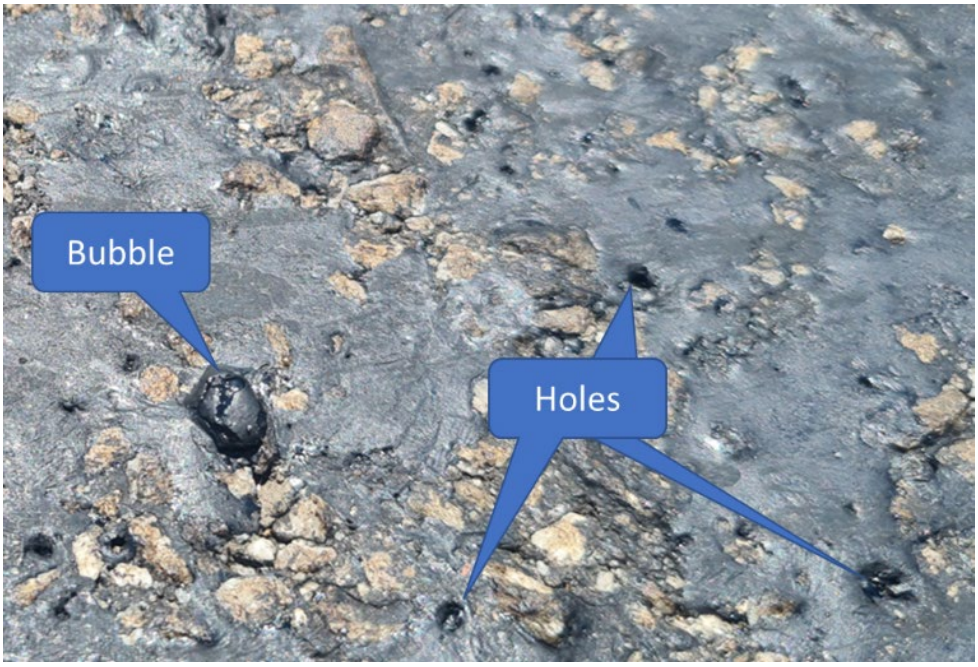


Figure 32 Effect of binder rise

Bleeding as shown in Figure 32 occurred regardless of specifications met.

4.6.2 Existing recommendations and specifications

Weather limitations in COTO 2020 and Manual 40 are similar as below.

A10.1.3.2 Weather limitations

The following general limitations shall apply:

- Whenever the temperature of the road surface falls below the specified temperature for the binder to be applied or will probably fall below the required temperature before spraying the binder, no binder shall be sprayed;
- No bituminous work shall be done during foggy or rainy weather and, when a cold wind is blowing, the above temperatures as specified in the sub-sections below, shall be increased by 3°C to 6°C.
- When strong winds (more than 30 km/h) are blowing which are likely to interfere with the proper execution of the work, no sealing, especially spraying of binder, shall be done;
- No sealing shall be done when rain or cold temperature is imminent;
- No sealing shall be done when the surface of the layer is visibly wet, i.e. more than damp;
- No sealing shall be done after sunset

Western Cape Materials Manual (Volume 6) states:

If a reseal is likely to trap moisture below the cracked surface a delay in the resealing process of at least 48 hours is recommended after prolonged rainfall, or 12 hours after light showers. If in doubt remove a portion of the old seal and determine the moisture content for the top 50 mm. The moisture content should not exceed four percent.

4.6.3 Binder rise case study

A case study on National Route N2 near Kareedouw confirmed binder rise as the cause of severe bleeding. Resealing was done in-between rainy spells in both directions but at different times. It was confirmed through sampling and testing that the existing surfacing was porous resulting in moisture ingress to a maximum of 4% by mass. Bubbles and bleeding occurred after a few months in service only during an extremely hot spell.

N Mazibuko (2022) studied the failure mechanism and simulated the binder rise phenomenon using samples from both the good and poor performing sections. It is concluded that binder rise will only occur if:

- Moisture is present in the substrate before sealing – Even 1% moisture could result in binder rise
- Road surface temperatures increase to a high level for sufficient time to cause vaporisation

- The binder at the prevailing road surface temperature reduce to a viscosity not able to resist the pressure of the vapor

  Note: People often state that the old seals with conventional binders can breathe, but not the modified binders. The opinion now is that that the vapor pressure easily fracture the softer binders (maybe very, very small bubbles within the seal structure with a very thin soft skin, breaking even before a bubble is pushed to the surface). Stiffer binders with more elasticity can take much more pressure resulting in these bubbles appearing on the surface. The analogue is blowing soap bubbles with diluted and higher concentration liquid soap.

The only difference in the performance in the two directions as shown in Figure 33, was that more favourable conditions for evaporation occurred on the good performing sections.

Rain	Avg 48 hrs before sealing		Rain before	Avg 48 hrs before sealing	
48 hrs before	Temp °C	Humidity %	48 hrs	Temp °C	Humidity %
11mm	11,5	68,3	1 mm	21,5	55,6

Figure 33 Difference in performance due to evaporation of moisture before sealing

4.6.4 Discussion towards new specifications

4.6.4.1 Different situations

The question to be answered, is “how long should we wait before sealing after rain?” (with current specifications and guidelines not being sufficient in all cases). Different situations require different specifications e.g.:

1) If no water penetrated the old surfacing, then we can seal immediately when the surface is dry (not visibly wet)

2) If water penetrated the old surfacing, then we have to wait until the water has evaporated before we seal. The sensitivity for binder rise is also a function of the new binder characteristics e.g. a modified binder might be more prone to bubbles forming on the surface than a 70/100 pen bitumen (rheological properties to be defined at a later stage)

3) The risk of bubbles forming is a function of the expected road surface temperatures and time at elevated temperatures. From two studies (Mazibuko,2022) and (Herington, it appears that road surface temperatures above 40°C study could initiate binder rise, even with 1% moisture in the substrate. More research required to quantify the risk.

4.6.4.2 Moisture content in the substrate (existing surfacing) or sensitivity to retain moisture

Possible methods for testing moisture/moisture sensitivity:

1) Nuclear measurements. Due to hydrocarbons in the bitumen, nuclear measurements on any bituminous layer are not accurate

2) Sampling and gravimetrical moisture determination. Considered too time consuming

3) Drill thin cores, weigh, saturate, seal on side and determine mass loss at different temperatures and humidity. This could certainly assist to define the risk, but considered too time consuming

4) Drill cores and test High Pressure Permeability (HPP). Considered too time consuming

5) Marvil permeability test. Although at a low water head, this test could be done on site and could provide useful results

Evaporation potential

The main factors causing evaporation of water are air and water temperature, relative humidity, wind velocity, surface area, atmospheric pressure and salinity of the water.

The need exists to research evaporation from existing road surfaces taking temperature, time and humidity into account. However, until properly quantified, provisional guidelines are required.

The Western Cape Materials Manual specifies temperature/time to allow evaporation of water from emulsion before further action is allowed (refer Figure 34).

- ❑ When spray grade emulsion is used for the first coat of the Cape Seal, the second application of binder, diluted emulsion fog spray, shall be applied at least 2000°C.hours later.

- ❑ Following the application of the diluted emulsion fog spray, the first slurry coat shall be applied at least 1000°C. hours later.

The °C.hours shall be calculated for intervals of 24 hours, taking the product of 24 hours and half the sum of the maximum and minimum ambient temperatures for the 24 hour interval. The product shall be accumulated until the specified value of °C.hours has been achieved.

Figure 34 Western Cape guidelines for evaporation

Applying the same principle to the Kareedouw sections, multiplying time and temperature before reseal revealed the following:

- Failed section = 552 °C.hours
- Good section = 1032 °C.hours

4.6.5 Recommended new interim specification

Although humidity should be taken into account, setting a limit of 1000 °C.hours could serve as an interim specification for existing moisture sensitive surfacings.

The moisture sensitivity (potential for moisture retention) could be defined using the Marvil test (SANS 3001-BT12). Three levels of permeability are defined low, medium and high. Although a conservative approach would be to allow no water ingress (very often encountered), it is proposed to set a provisional limitation as defined for low permeability. Defined in the test method as follows:

> *a) When the water level has not reached the 50 mL mark within 3 min stop the test and record that the water level failed to reach the 50 mL mark within 3 min.*

If low permeability is recorded, the existing specification for sealing after rain could be applied i.e.:

- No sealing shall be done when the surface of the layer is visibly wet, i.e. more than damp;

If the permeability is higher, regardless whether the water flows horizontally through the surfacing and pops out next to the apparatus, any seal work should be delayed after rain until 1000 °C.hours

5. When does labour intensive sealing become a risk?

5.1 General

Manual 40, Section D.10 (Surface treatments for labour enhanced construction) provides guidelines to reduce the risk of poor performance. Key aspects discussed are safety, base quality and seal constructability with risk levels also assigned to seal type and binder type. However, requests from industry demand a quick answer in terms of limiting traffic volumes.

5.2 Principles towards setting guidelines for maximum traffic volumes

The most critical component of a seal is an appropriate binder application rate to prevent aggregate loss on the one hand and to ensure sufficient macro texture for skid resistance on the other hand. Of importance as stated in (DOT 2011):

- *Although projects must be designed to maximise labour-based techniques and the use of local materials, the use of labour-based construction methods must not compromise national and provincial road standards.*

From volumetric design principles, as shown in Figure 35, a degree of variation in binder application rates could be tolerated with low traffic volumes. However, with high traffic volumes the margin of allowed variation becomes very low and nil where the minimum binder application to hold the stone will result in the binder covering the stone (bleeding and low skid resistance).

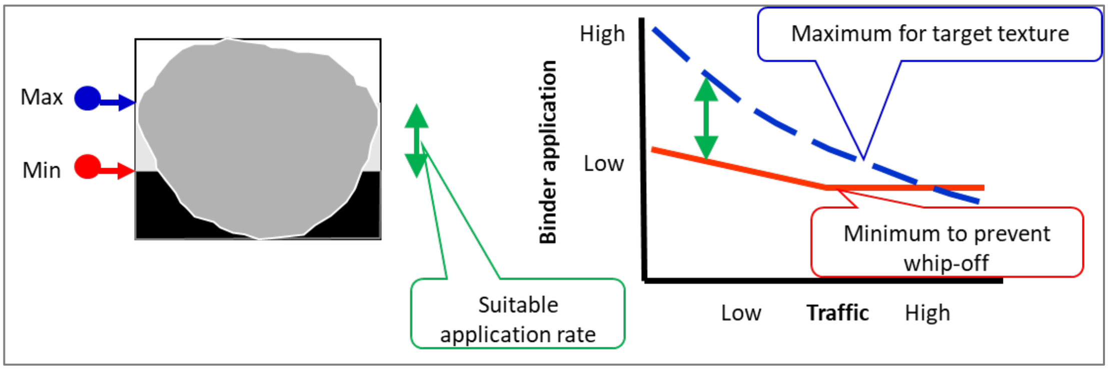


Figure 35 Risk of poor performance increasing with increasing traffic volumes

The point at which the risk becomes very high is also highly dependent on the softness (embedment potential) of the substrate and the aggregate size of the seal.

Calculating the range of suitable application rates for Corrected Ball Penetration less than 4 mm for different single and double seals, indicated a recommended maximum traffic volume of 2000 Equivalent Light Vehicles per lane per day to accommodate a variation in binder application rates of 10%. Figure 36 shows an example of determining traffic a traffic limit to allow 10% variation in application rates.

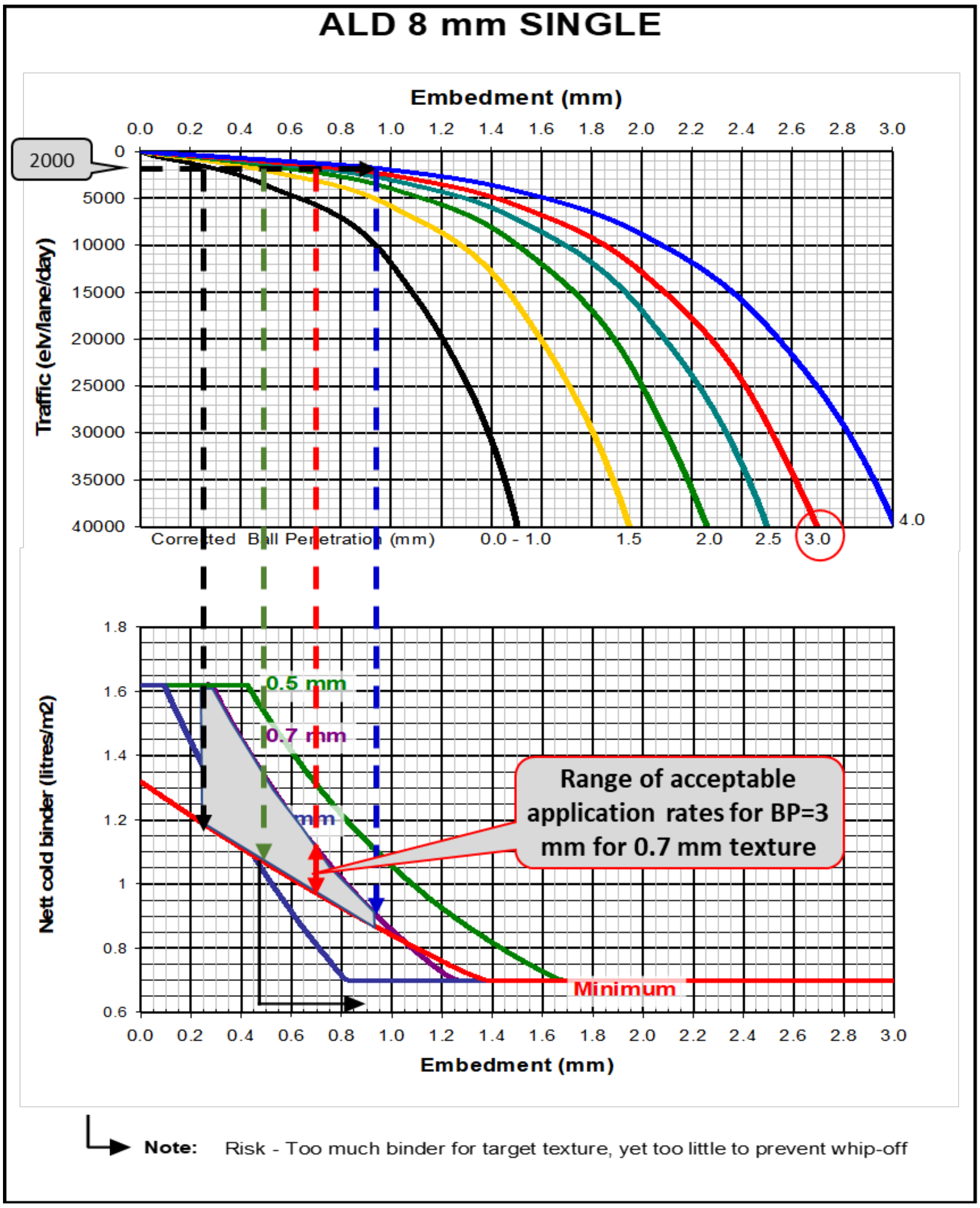


Figure 36 Example of exercise to evaluate traffic impacts on binder application

ELV of 2000 with 10% heavy vehicles roughly equates to an AADT of 800 vehicles per day in both directions on a two-lane road. Should no centre line be provided e.g. on narrow roads then a maximum of 400 vehicles per day is recommended for labour intensive seal work.

6. Cost and life expectancy

The cost and life expectancy are prerequisites for life-cycle cost analysis. Table 18 provides the unit cost ratios of surface treatments. The 14 mm single seal with a 70/100 Pen bitumen is used as the reference with a 2022 cost of R45/m^2. This does not include:

- Overheads including P&Gs, safety and environmental requirements, traffic accommodation and risks;
- Consultant costs including investigation, design, quality assurance and contract administration;
- Laboratory costs;
- Cost of pre-treatment (e.g. pavement repairs), and
- Line marking.

Table 17 Seal costs (Ratio to 14 mm single seal)

Seal Code	Description	Binder	Cost ratio to 14mm single seal	Average estimated life	Labour enhanced construction	Comments
S3 (S <10)	Graded aggregate seals - Single application (<10mm) (6 mm sand seal)	MC3000	0,69			Not recommended for initial construction seal
		Cat 65%	0,73			Not recommended for initial construction seal
S3D (S <10)	Graded aggregate seals - Double application of single sand seal (10-12 mm)	MC3000	1,24	8	Medium	Binder application only with distributor. Risk at intersections and tight curves
		Cat 65%	1,31	8	Good	Not suitable on steep grades > 6%[1]. Risk at intersections and tight curves
S3 (S 10+)	Graded aggregate seals - Single application (10mm or more) (10mm)	MC3000	1,16	8	Medium	Binder application only with distributor
S3 (D 10+)	Graded aggregate seals - Double application (16-20mm covered with sand seal)	MC3000	1,80	12	Medium	Binder application only with distributor
	Double Otta seal (Local natural aggregate)	MC3000	2,00	14	Medium	Binder application only with distributor
S7 (<10mm)	Thin Microsurfacing or Slurry seal (3 mm texture slurry)		0,87			Not recommended for initial construction seal
	Thin Microsurfacing or Slurry seal (6 mm coarse slurry)		1,32			Not recommended for initial construction seal
S7 (>10mm)	Thick Microsurfacing or Coarse slurry seal (10 mm microsurfacing)		2,10	8	Not suitable	Application only with continuous slurry machine
	Thick Microsurfacing or Coarse slurry seal (15 mm microsurfacing)		2,50	10	Not suitable	Application only with continuous slurry machine
S1 (7)	Single seal with 7 mm aggregate	70/100	0,60			Not recommended for initial construction seal
		Cat 65%	0,87			Not recommended for initial construction seal
S1(10)	Single seal with 10 mm aggregate	70/100	0,92			Not recommended for initial construction seal
		Cat 65%	1,08			Not recommended for initial construction seal
		S-E1	1,01			Not recommended for initial construction seal
S1(14)	Single seal with 14 mm aggregate	70/100	1,00			Not recommended for initial construction seal
		Cat 65%	1,11			Not recommended for initial construction seal
		S-E1	1,25			Not recommended for initial construction seal
		S-R1	1,49			Not recommended for initial construction seal
S1(20)	Single seal with 20 mm aggregate (16 mm)	S-R1	1,63			Not recommended for initial construction seal
S2(10)	Double seal with 10 mm aggregate and sand	Cat 65%	1,24	8	Good	Not suitable on steep grades > 6% [1]
		SC-E1	1,41	10	Good	Not suitable on steep grades > 6% [1]
S2(14)	Double seal with 14 mm aggregate and sand	Cat 65%	1,52	10	Good	Not suitable on steep grades > 6% [1]
		SC-E1	1,61	12	Good	Not suitable on steep grades > 6% [1]
S4(10)	Cape Seal with 10 mm aggregate and one layer of slurry	SC-E1 (t)	1,59			Not recommended for initial construction seal
S4(14)	Cape Seal with 14 mm aggregate and one layer of slurry	Cat 65% (t)	1,75	12	Good	Not suitable on steep grades > 6% [1]
		SC-E1 (t)	1,79	14	Good	Not suitable on steep grades > 6% [1]
S4(20)	Cape Seal with 20 mm aggregate and two layers of slurry	70/100	2,25	15	Medium	Binder application only with distributor
		Cat 65%(t)	2,41	15	Good	Not suitable on steep grades > 6% [1]
		S-E1	2,40	16	Medium	Binder application only with distributor
S2(14/7)	Double seal with 14 mm aggregate and a layer of 7 mm aggregate	70/100	1,70	10	Medium	Binder application only with distributor
		S-E1	1,82	12	Medium	Binder application only with distributor
S2(14/5)	Double seal with 14 mm aggregate and a layer of 5 mm aggregate	70/100	1,65	11	Good	Binder application only with distributor
S2(20/10)	Double seal with 20 mm aggregate and a layer of 10 mm aggregate	70/100	1,98	13	Very Low - High risk	Binder application only with distributor
		S-E1	2,10	15	Very Low - High risk	Binder application only with distributor
		S-R1 or S-R2	2,30			Not used for LVRs as initial seals
S2(20/7)	Double seal with 20 mm aggregate and a layer of 7 mm aggregate	S-E1	1,94	14	Medium	Binder application only with distributor
S2(20/7/7)	Double seal with 20 mm aggregate and two layers of 7 mm aggregate	S-E1	2,10			Not used for LVRs as initial seals
S8(14)	Slurry-bound Macadam seal with 14 mm aggregate (20 - 25 mm)	60% Anionic	2,55	14	Very Good	
S8(20)	Slurry-bound Macadam seal with 20 mm aggregate (30 -40 mm)	60% Anionic	3,20	16	Very Good	
AC[2]	Asphalt layer with suitable grading and thickness (Continuous 15mm) within 50km of plant		2,55	14		Refer note (2)
	Asphalt layer with suitable grading and thickness (Continuous 30mm) within 50km of plant		3,32	16		Refer note (2)
	Asphalt layer with suitable grading and thickness (Continuous 40mm) within 50km of plant		3,90	18		Refer note (2)

7. Precoating of quarzitic stone

The minerology of quarzitic stone could vary significantly resulting in the many cases in poor adhesion to the binder. Sensitivities recorded are:

- Fine micro texture (glassy appearance)
- High porosity
- Dusty

The recommendation is that all quarzitic stone should be precoated with suitable precoating fluids, even if emulsions are used.

Figure 37 shows poor adhesion of quarzitic stone with a polymer modified emulsion. To note that the dust content was within specification.

Figure 37 Poor adhesion of quazitic stone to polymer modified emulsion

8. References

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APPENDIX A

- Testing, reporting and interpretation of Ball penetration and Texture depth – Highlight typical testing errors and recommend standard format for reporting
- More detail on labour intensive seal work – When does it become a risk ?
- Cape seal and slurry design – Causes of failures. Elaborate with additional design and construction guidelines
- More detail and examples of 7mm single seal and 20/7 double seal required
- Modified binder conversion factors for emulsions – Provide a table as for hot modified binders
- Prime coats and precoating fluids – How, which, when and where ?
- Moisture in substrate before sealing – Testing and evaluation procedure required
- Aggregate spread rates for different seal types – Discuss implications of too low and too high application
- Pre-treatment/ Repairing of bleeding surfaces – Address appropriateness of different methods under different circumstances
- Importance of resealing at the right time - Elaborate on effect of oxidative hardening
- Update of costs and life expectancies – for budget purposes and life-cycle cost analyses
- QA
- Finalise and incorporate SANS 3001 BT25 – Spray flair test
- Reporting Design (D4 form) and As-built – standardisation
- Incorporate latest research/findings of forensic investigations
- Stone orientation
- Limiting macro texture depths for different seal types
- Additional binder required for bridging of stone on coarse surfaces
- Limiting risks for climate change e.g. binder rise (sealing after rain)
- Reducing permeability (High Pressure Permeability research results) and benchmarking
- Dealing with new proprietary products
    - New Modified Emulsions
    - Adhesion agents