Table 57 Approximate residual conventional binder for Cape seals

LVRs < 2000 ELVs										
Cape seal size		20mm			14 mm			10 mm		
HV Speed	Macro texture (mm)	Hard <1mm	1 - 3mm	Soft 3-4 mm	Hard <1mm	1 - 3mm	Soft 3-4 mm	Hard <1mm	1 - 3mm	Soft 3-4 mm
>40km/h	Coarse (>1.3)									0.55
	Med (0.8)									0.55
	Fine (0.3)								0.65	0.55
< 40km/h	Coarse (>1.3)						0.65		0.65	0.45
	Med (0.8)						0.65		0.60	0.45
	Fine (0.3)						0.65	0.65	0.55	0.45

Conversions for the use of modified binders and from cold to hot application should be done according to the recommended conversion factors provided in SABITA Manual 40.

Notes:

- Good practice suggests always applying a diluted emulsion cover spray, regardless of whether the aggregate is precoated. In this case, different from single seals, the full residual (net cold) binder component from the cover spray should be deducted from the total binder volume to obtain the tack coat application rate; The stable mix-grade emulsion used in the slurry seal may also be used for the cover spray. If available, this may be the most desirable. A mixture of equal parts of 60 per cent stable grade emulsion and water applied at a rate of 0.8 to 1.2 litre/m2 is recommended; Compatibility of the water to be used with the emulsion for the cover spray should be checked. Water which is fit for drinking is usually suitable for the dilution of cationic (spray grade and stable mix) and anionic stable mix emulsions. In all cases the water should be added gradually to the emulsion; Where emulsion is used for the tack coat, the calculated spray rate may exceed the maximum permissible spray rate of 1.5 litres/m2 (to prevent run-off). In such cases, the first spray should be reduced to 1.5 litres/m2 and the rest of the binder should be sprayed in the second spray in a ratio of emulsion to water not exceeding 1.2 litres/m2;
- The maximum emulsion spray rate should be reduced with steep gradients, smooth surface textures (< 0.5 mm) and very coarse surface textures (>1.5 mm), and
- In exceptional cases, where diluted emulsion cannot be used for the cover spray, the undiluted emulsion may be used.

b. Slurry component

For low-volume roads and aggregates within the COTO specifications, a mix consisting of 100 parts aggregate to 20 parts stable grade emulsion (60 per cent) by mass is recommended. The cement/lime content should be between 1 and 1.5 parts. The water content may be varied, but it will normally be about 15 parts to give a flow of 30 to 40 mm using ASTM test method D 3910.

Approximate slurry spread rates for the different Cape seal types are provided in Table 58. This could vary based on the true shape and spread of the single-sized aggregate, the softness of the substrate and the construction process. During construction, the first layer of slurry is levelled off with the top of the stone. Trafficking this layer will result in compaction of the slurry and reduce the volume to approximately 80 to 85 per cent. In the case of an open spread 20 mm aggregate, this will result in a coarse macro texture and high road noise. A final layer of finely graded slurry is then applied, again level to the top of the stone.

Table 58 Slurry Spread Rates

Single seal size (mm)	1st Layer (m2/m3)	2nd Layer (m2/m3)
20	185 to 195	360to370
14	195 to 205	
10	330 to 340	

The use of a MC-NME slurry as part of the Cape seal (Chapter 7.7.6) can add additional benefits in terms of flexibility, permeability and adhesion to the stone.

7.7.8 Sand seals

Generally, single sand seals are not recommended as initial seals for roads on which the traffic exceeds 750 ELV per lane per day.

Should a sand seal be selected as the initial seal, it is recommended that a double sand seal be constructed or that provision be made to reseal the road within three years. Timeous reseal, even with another sand seal, could result in a service life of the second seal above ten years.

- There is no specific design method for sand seals. A nominal bituminous binder application rate of 1.0 litre/m2 residual binder is recommended;
- As a rule of thumb, the hot binder is applied at the following rates:
    - o Penetration grade bitumen 1.1 to 1.3 litres/m2;
    - o Cut-back bitumen 1.2 to 1.4 litres/m2, and
    - o Emulsion 1.4 to 1.6 litres/m2.

The selected application is a function of the purpose of the seal, the porosity and texture of the existing seal, the grading of the sand, the prevailing temperature and the expected traffic.

Thereafter the sand is applied at a rate of between 200 and 100 m2/m3 and rolled for one to two weeks, depending on the traffic. The excess sand is swept back towards the wheel tracks to prevent fattiness and pick-up until no further sand is retained by the binder.

7.7.9 Graded aggregate seals (Otta seals)

The seal consists of graded aggregates (natural gravel or crushed rock) in combination with soft (low-viscosity) binders. From experience, three different aggregate gradings have been defined, namely “Open”, “medium” or “dense”.

Depending on the circumstances, a single or double layer of aggregate is constructed after which a sand cover seal is generally applied. The total thickness of a single Otta seal is approximately 16 mm. A single Otta seal with a sand cover layer is normally used with AADT < 100 vpd.

Key aspects for a successful Otta seal are:

- Using a soft binder that can work itself up into the aggregate layer;
- Maximum particle size (Preferred 16 mm - Maximum 19 mm);
- Dust content (<0.075 mm) (Preferred <10 per cent - Maximum 15 per cent), and
- After-care in the form of brooming material back into the wheel tracks during the first hot season.

From experience, suitable binder application rates have been determined and provided in Table 59.

Table 59 Binder Application Rates for Otta Seals

Hot bitumen spray rates for an un-primed base course (litre/m2)						
Type of Otta Seal		Grading				
		Open	Medium	Dense		
				AADT<100	AADT>100	
Double	1st layer 2nd layer	1.6	1.7	1.8	1.7	
	1st layer	1.5	1.6	2	1.9	
Single with sand cover seal	Fine sand	1.6	1.7	2	1.9	
	Crusher	0.7	0.7		0.6	
	dust or coarse river sand	0.9	0.8		0.7	
Single		1.7	1.8	2	1.9	
Maintenance reseal (single)		1.5	1.6	1.8	1.7	

Notes:

Reduce application rate by 0.2 litre/m2 for the first layer on a primed base course

Increase application rate by 0.3 litre/m2 if the aggregate water absorption is more than 2 per cent

Recommended aggregate spread rates are provided in Table 60.

Table 60 Aggregate Spread Rates for Otta Seals

Type of seal	Aggregate spread rates (m2/m3)		
	Open grading	Medium grading	Dense grading
Otta seals	77 to 63	77to63	63to50
Sand cover seals	100 to 83		

7.7.10 Asphalt design

a. Hot mix asphalt

i. Rural areas

SABITA Manual 35 provides guidelines for the design of hot-mix asphalt. For low-volume roads with primarily light traffic, the manual recommends a Level 1 design.

Cognisance should be taken that road sections where asphalt is considered more appropriate and cost-effective than surface treatments are normally subjected to high external stresses e.g., heavy vehicle turning actions, clearing of landslides, etc.

Warm-mix asphalt provides several benefits when working in remote areas with longhaul distances. SABITA Manual 32 provides guidelines for the design of these mixes.

ii. Urban areas

SABITA Manual 27 provides guidelines for thin (20 to 30 mm) asphalt layers, suitable for LVRs in the urban environment.

The key design objectives should ensure that the functional requirements associated with relatively light traffic in residential or other low-speed environments are met. These are:

- Low permeability, through limited and dispersed voids, to protect underlying layers – often granular bases – from the ingress of water;
- Compactability, given the rapid cooling of thin layers and, hence the limited compaction windows. Two compositional aspects that would require attention are appropriate maximum aggregate sizes and binder grades;
- A surface texture to provide sufficient skid resistance associated with low speeds (< 80 kph). Because of the generally low prevailing speeds to be accommodated, the skid resistance would be derived from the micro-texture of the asphalt, and
- A compliant consistency, being sufficiently flexible and durable to accommodate the transient deflections associated with light, mainly granular, pavement structures rather than meeting structural requirements e.g., stiffness (i.e., load-spreading capacity) and resistance to permanent deformation.

b. Cold mix asphalt

i. Introduction

Cold Mix Asphalt for surfacing is a cold-laid mixture of continuously graded aggregates and bitumen emulsion.

Specifications for the design of cold mix asphalt have not yet been formalised and documented in South Africa for reference purposes. However, international guidelines have been adapted for South African conditions with the assistance of experienced practitioners.

ii. Binder selection

Different emulsion formulations could be used for this purpose. Binders suitable for cold mix asphalt are shown in Table 61.

Table 61 Binders suitable for cold mix asphalt

Emulsion type	Comments
Slow setting 60% anionic emulsion	Due to slow-setting characteristics, the mix can take a long time to cure. During this period, it will be susceptible to washout by rain.
Slow setting 65% - 70% cationic emulsion	Works well with most aggregates and gives adequate working time before setting.
Micro-surfacing grade emulsion (Rapid setting polymer modified cationic emulsion)	Continuously graded premixes prepared with MS grade emulsions must be mixed with aggregate that is heated to 100 to 110 °C in either a drum, continuous type mixer or a concrete mixer fitted with a heating device such as a gas burner. The water component of the emulsion evaporates during the mixing process. The mix should ideally be stockpiled for about 10 days before use, to ensure that any residual water evaporates. Due to the hydrophobic characteristic of mixes, the permeability of mixes reduces dramatically. Properties of nano polymers from different suppliers could vary significantly, leading to new proposed end-result specifications
New (Nano) Modified Emulsions (MC-NME);	

iii. Aggregate requirements

The grading requirements for crushed aggregate are shown in Table 62 and Table 63 and the strength requirements in Table 64.

From a practical perspective: The reactivity of the aggregate with the emulsion varies between different parent rock types. Thus, trial mixes must be made up to ensure that no "balling" of the emulsion with the fines in the aggregates occurs (cationic emulsions are particularly sensitive with mostly negatively charged aggregate in South Africa) as this would prevent proper coating of the coarse aggregates. If "balling" occurs, the fines content must be reduced towards the lower boundary of the recommended grading envelope.

Table 62 Grading requirements for slow-setting emulsion mixes

Sieve size (mm)	Percentage by weight passing
14	100
10	80 to 95
7.1	58 to 85
5	40 to 68
2	19 to 40
1.18	12 to 28
0.425	6 to 16
0.3	4 to 13
0.15	2 to 9
0.075	1 to 7
Sand equivalent min. 40	
Flakiness Index Max 30%	

Table 63 Grading requirements for medium-setting emulsion mixes

Sieve size (mm)	Medium grading	Fine grading
14	100	-
10	82 to 100	100
5	54 to 75	64 to 88
1	25 to 42	35 to 54
0.3	11 to 23	16 to 28
0.15	7 to 16	8 to 18
0.075	4 to 10	4 to 12
Typical compacted thickness (mm)	25 to 50	20 to 40

Table 64 Aggregate strength requirements

Aggregate strength requirements	AADT at the time of construction	
	<100	>100
Min Dry 10% FACT	90 kN	110 kN
Min Wet/Dry strength ratio	0.60	0.75

iv. Design requirements

Design requirements as published in ILO 2013 for cold mixes are provided in Table 65. The degree of compaction during construction is assessed using the permeability of the layers as determined by the modified Marvil permeability test described in Sabita Manual 27. The permeability shall be ≤ 2 litres/hour.

Following research and performance testing of material treated with MC-NME, provisional end-result specifications have been developed as shown in Table 66.

Table 65 Properties of Compacted Cold Mixes

Test	Requirement
Modified Marshall Stability at 50 blows, 24 hr oven cure at 40oC and 1 hr soak (kN)	Min 3.0
Voids in Total Mix (%)	3 to 8
Flow (mm)	2 to 5
Stability loss after immersion (%)	Max 50
Aggregate Coating (%)	Min 50

Table 66 Proposed specifications for MC-NME-treated material

Test or Indicator	Materi al1	Material classification			
		NME1	NME2	NME3	NME4
Material specifications after treatment					
UCSwet (kPa) (rapid curing + 4 h in water)	**150 mm Φ Sample**	>3200	>1750	> 1100	> 750
UCSdry (kPa) (rapid curing)	**150 mm Φ Sample**	>4000	>2500	> 1 600	> 1200
Retained Compressive Strength: UCSwet/UCSdry (RCS) (%)		> 85	> 75	> 70	> 65
ITSwet (kPa)(rapid curing + 4 h in water)	**150 mm Φ Sample**	> 240	> 180	> 120	> 100
ITSdry (kPa) (rapid curing)	**150 mm Φ Sample All**	> 280	> 220	> 160	> 130
Retained Cohesion: ITSwet/ITSdry (%)		> 85	> 75	> 70	> 65
Typical vertical Effective Elastic Moduli (MPa)*		600 - 300	400 - 200	300 - 100	200 - 80
UCSdry; ITSdry = testing after rapid curing;					
UCSwet; ITSwet = testing after rapid curing and 4 hours in water;					
UCSsoaked; ITSsoaked = testing after rapid curing and 24 hours in water					

For LVRs, the requirements for MC-NME4 should suffice.

7.7.11 Proprietary products

Proprietary products for cold mixes could be used if they meet the Agremént specifications (SABITA CMA, 2020).

The dense graded, cold-laid bituminous paving mixtures shall consist of:

- A uniform mixture of coarse and fine aggregates, having approximately the same bulk density, with or without mineral filler. The maximum aggregate size shall not exceed 14 mm, and
- A bituminous binder of undisclosed composition, the base bitumen of which complies with SATS 3208 or its replacement as a national standard.

Requirements for specific properties are shown in Table 67.

Table 67 Performance criteria for proprietary cold mixes

Property	Test method/procedure	Requirements
Resistance to permanent deformation	Sabita Manual 39 – ASP 4.	Min. number of passes to 12 mm rut depth: 15 000
Permeability		
Air voids:	Sabita Manual 39 – ASP8	≤4 %

Air permeability:	Sabita Manual 39 – ASP5	Fundamental air permeability ≤1 X 10-8 cm2
Durability		
Binder film thickness:	Sabita Manual 35, Section 5	≥5 µm
Tensile Strength Ratio (TSR)	ASTM D 4867	≥0.70
Surface texture		
Coarse aggregate Polished Stone Value (PSV)	SANS 3001–AG11	≥45

7.8 Non bituminous surfacing options

7.8.1 Block or Paving Stone

Paving stones (blocks or cobbles) can be produced by cutting or breaking large natural boulders. Each stone should be a strong, homogenous, isotropic rock, free from significant discontinuities such as cavities, joints, faults and bedding planes. Rocks such as fresh granite, basalt and crystalline limestone have proven to be suitable materials. Quartzite rock is not suitable, nor is any rock that polishes or develops a slippery surface or abrades under traffic.

The material infilling the spaces between the cobblestones should be a loose, dry, natural or crushed stone material with a particle size distribution equivalent to well-graded coarse sand to fine gravel. It must be clean and free from clay coating, organic debris and other deleterious materials.

7.8.2 Clay bricks and cement blocks

Burnt clay bricks and concrete blocks are potentially useful surfacing materials. Both of these can provide good riding quality and sufficient skid resistance and are highly labour-intensive in their construction. Problems due to poor construction or insufficient support can be easily maintained with only the localised areas showing distress requiring removal and resetting, after correcting the causes of the problems. The blocks/bricks must have adequate strength and be durable.

7.8.3 Aggregates for Concrete

Concrete aggregate comprises two components – a coarse fraction and a fine fraction. The fine aggregate is usually naturally occurring sand, with particles up to about 2 mm in size. The coarse aggregate can be natural gravel or, more commonly, crushed or hand-broken stone with a range of sizes from about 5 mm to 20 mm (or sometimes larger).

Aggregates must be entirely free from soil or organic materials such as grass and leaves, as well as fine particles such as silt and clay; otherwise, the resulting concrete will be of poor quality. Some aggregates, particularly those from salty environments, may need to be washed to make them suitable for use.

Both the coarse and fine aggregates need to contain a range of particle sizes and are mixed in such a way that the fine aggregates fill the space between the coarse aggregate particles. A ratio by volume of one- part fine aggregate to two parts coarse aggregate is generally used. Aggregates can be crushed and screened by hand or by machine.

8. Required Maintenance Actions

8.1 Introduction

All roads require regular maintenance to ensure that their basic function is fulfilled for the duration of their design life. Achieving this will depend on the implementation of suitable maintenance strategies, with operations selected and carried out in a planned manner.

Important maintenance concepts are discussed in Appendix H.

8.2 Definitions

Maintenance comprises a range of activities necessary to keep a road and associated structures at the required level of service as intended during the design and phase as constructed.

Road maintenance could be categorised as follows:

Routine maintenance also referred to as "reactive" maintenance, comprises ad-hoc treatments that are applied to a pavement, structures and the road reserve to keep the assets functioning properly. Routine maintenance is carried out on roads when specific signs of deterioration are observed. Routine maintenance works are divided into the following categories:

- Non-Pavement: Include day-to-day activities that are undertaken outside of the road surface such as cleaning drains and culverts, vegetation control, line marking, guardrail repair, road sign repair, etc., and Pavement: Include day-to-day activities responding to minor pavement defects caused by a
- combination of traffic and environmental effects, for example, crack sealing, patching, edge repair, shoulder regravelling and blading.

The need for routine maintenance could be identified through formalised regular inspections and public incident reporting through a Maintenance Management System (MMS).

Periodic maintenance also referred to as preventative or corrective maintenance, comprising periodically scheduled activities that are aimed at restoring the level of service provided by a road before major repair to the road formation or structure is required. The need for periodic maintenance is generally identified through formalised annual inspections, analysis and prioritisation as part of a Pavement Management System (PMS), Gravel Road Management System (GRMS) and a Bridge Management System (BMS).

Emergency maintenance is limited to the immediate work required to reopen a road after it has been damaged by an unexpected event, making it safe for use by the road user and preventing further damage to the road. This includes the removal of debris, undertaking temporary repairs, providing a detour or bypass or similar works. Repairs carried out under Emergency maintenance are generally temporary and will require permanent works to be included from within the existing budget or programmed in future periodic or upgrading programs. Emergency maintenance is considered the most critical component of maintenance and therefore an allowance must be made each year to cover these works.

Note: Proper and responsible designs, good quality of construction, continuous routine maintenance and specifically timeous periodic maintenance, drastically reduce the need for emergency maintenance

Rehabilitation of a road, in the context of Low Volume Sealed Roads, means activities that are aimed at restoring a surfaced road that has deteriorated beyond the point at which periodic maintenance can restore it to effectively function, generally requiring major repair to the structure of the road formation and the pavement and road surfacing. These activities can include recycling existing layers and/orreplacing worn or deteriorated layers with layers of equivalent strength and structure as the original road.

8.3 Maintenance planning

8.3.1 Introduction

Maintenance planning aims to identify the need for maintenance works and potential improvements of the network to achieve or maintain standards. In conjunction with road planning, appraisal and design processes, it attempts to optimise the overall performance of the road network over time. At a practical level, it aims to ensure that the correct activities are performed on the network at the right time, and to the desired quality. The process comprises a series of management functions and relates to both short-term and long-term decisions, and concerns both the whole network and individual lengths of road. Key elements in the planning process are:

- Road network inventory and location referencing;
- Data collection (Condition assessment);
- Condition description and performance monitoring;
- Treatment (remedial measure) selection;
- Activity prioritisation;
- Budgeting and resource requirements;
- Work scheduling, and
- Contracting.

8.3.2 Condition assessment and activity prioritisation

a. General

To apply the correct maintenance treatment at the appropriate time, it is necessary to assess the condition of the road and to identify those defects that need to be corrected.

The information and detail gathered for routine maintenance and periodic maintenance activities and prioritisation thereof could differ significantly and are also different for network-level planning, and project-level investigations.

At the network level, condition assessments are undertaken visually and through instrumental measurements of riding quality, rutting and texture depth for higher-order roads. The recommended frequency for visual assessment is one to two years and for instrumental surveys three to five years.

b. Assessments for periodic maintenance and rehabilitation purposes

Knowledge of the condition of roads (assets) and their performance is essential as all management decisions regarding maintenance, rehabilitation and renewal revolve around these two aspects.

Condition data elements selected must be appropriate to describe the current condition, to apply selected performance prediction models and to select appropriate remedial measures.

The processes and recommended methodologies are described in:

- TMH 22: Road asset management manual;
- TMH 13: Automated road condition assessments;
- TMH 9: Manual for visual assessment of road pavements:
  - o Part A: General;
  - o Part B: Flexible pavements;

- o Part C: Concrete pavements;
- o Part D: Block pavements, and
- Part E: Unpaved roads;
- TRH12: Flexible pavement rehabilitation investigations and design,
- and SABITA Manual 40, Part 2: Seal type and binder selection.

8.3.3 Assessments for routine maintenance purposes

Routine maintenance embraces a wide variety of different activities that are employed in response to the appearance of different defects. They are normally planned on the following basis:

- A reactive (i.e., condition responsive) basis in response to a defect exceeding a certain condition state, and
- A cyclic (i.e., programmed) basis where work is undertaken at a set frequency or a particular time of the year, the interval often varying because of environmental as opposed to traffic responses.

Assessments for routine maintenance purposes are relatively quick, executed by drive-over, occasional stops and recording whether standards are met or not and allocating a priority or urgency to the selected relevant activity. A practical way to allocate an “urgency” rating for low-volume roads is to evaluate these roads in terms of functionality criteria such as accessibility, safety, mobility and impact on pavement performance as presented in Table 68 and where applicable, estimate quantities.

Table 68 Urgency rating for routine maintenance

	Unacceptable		Requires attention	Acceptable
Urgency	**A**	**B**	**C**	
Accessibility	No Access	Difficult access with normal saloon car	Possibility of getting stuck	
Safety/ Risks	Risk of life loss or serious accidents	High risk of accidents	Risk of vehicle damage	
Mobility		Unacceptable slow movement or damage to sensitive agricultural produce due to poor surface condition	Uncomfortable driving, potential damage to sensitive agricultural produce and time loss e.g. due to poor road signs	
Performance Impact		Seriously impacts the performance of the road	Impacts on the performance of the road	

Depending on the type and structure of routine maintenance contracts, the different activities could be separated e.g., for a small community-based project where skill levels are low, and equipment limited, only specific activities could be selected. This would mean that only the relevant defects are assessed on a high frequency (e.g., one-week intervals).

In the case of large area-based routine maintenance contracts, all elements that might trigger routine maintenance activities should be assessed.

Assessment items could be grouped as follows:

- Road reserve maintenance (Table 69);
- Paved roadway maintenance (Table 70);
- Unpaved roadway maintenance (Table 71);
- Drainage facility maintenance (Table 72);
- Bridge structure maintenance (Table 73);
- Miscellaneous structure maintenance (Table 74), and
- Maintenance of road furniture, signs and markings (Table 75).

The priority/urgency is marked by the assessor.

Table 69 Road reserve maintenance

Road Reserve	Vegetation Control	Grass Cutting		Creeper Grass		Bush Clearing		Trees Trimming		Trees Removal				Other Vegetation	
		Routine	Periodic	Routine	Periodic	Routine	Periodic	Routine	Periodic	Routine	Periodic			Routine	Periodic
	Animal Control	Fence Repair		Gate Repair		Cattle Grid Repair								Other Animal	
		Routine	Periodic	Routine	Periodic	Routine	Periodic							Routine	Periodic
	Litter and Obstacles	Litter		Obstacles		Dead animals		Abandoned vehicles/scrap		Anthills		Signs/encroachments		Other Obstacles	
		Routine	Periodic	Routine	Periodic	Routine	Periodic	Routine	Periodic	Routine	Periodic	Routine	Periodic	Routine	Periodic
	Slope Maintenance	Erosion prevention		Erosion Repair										Other Slope	
		Routine	Periodic	Routine	Periodic									Routine	Periodic

Table 70 Paved roadway maintenance

Paved Road Way	Routine	Rut & Depressions		Pothole/Edge		Unpave shoulder		Crack sealing		Bleeding				Other Paved routine	
		Routine	Periodic	Routine	Periodic	Routine	Periodic	Routine	Periodic	Routine	Periodic			Routine	Periodic
	Periodic	Fog Spray		Reseal		Overlay		Shoulde regravel		Shoulder reshape				Other periodic	
		Routine	Periodic	Routine	Periodic	Routine	Periodic	Routine	Periodic	Routine	Periodic			Routine	Periodic

Table 71 Unpaved roadway maintenance

Unpaved Road Way	Routine	Dragging		Sand cushion Maintenance		Dry grading/ Light blading		Pothole Patching		Erosion Runnels Repair		Dust prevention		Other routine	
		Routine	Periodic	Routine	Periodic	Routine	Periodic	Routine	Periodic	Routine	Periodic	Routine	Periodic	Routine	Periodic
	Periodic	Wet Grading		Reshaping		Regravelling		Sand Cushioning							
		Routine	Periodic	Routine	Periodic	Routine	Periodic	Routine	Periodic					Routine	Periodic

Table 72 Drainage facility maintenance

Drainage Facilities	Culvert Maintenance	Culvert cleaning		Culvert In/Outlet		Culvert Repair		Marker post		Post Reflector				Other culvert	
		Routine	Periodic	Routine	Periodic	Routine	Periodic	Routine	Periodic	Routine	Periodic			Routine	Periodic
	Drainage maintenance	Drain cleaning		Unlined Erosion		Unlined reshape		Drain lining repair		Lining Repair				Other drainage	
		Routine	Periodic	Routine	Periodic	Routine	Periodic	Routine	Periodic	Routine	Periodic			Routine	Periodic
	Erosion Protection Works Maintenance	Stone Pitching Repair		Concrete Repair		Gabion Repair		Scour and Chutes Repair		Berm Repairs				Other protection works repair	
		Routine	Periodic	Routine	Periodic	Routine	Periodic	Routine	Periodic	Routine	Periodic			Routine	Periodic

Table 73 Bridge structure maintenance

Bridge Structures	Bridge Routine Maintenance	Deck cleaning		Weep hole cleaing		Wearing course		Rails/parapets						Other routine	
		Routine	Periodic	Routine	Periodic	Routine	Periodic	Routine	Periodic					Routine	Periodic
	Bridge Periodic Maintenance	Rust & Paint		Bearings clean		Bearings replace		Steel replace/repair		Erosion repair		Concrete repair		Other drainage	
		Routine	Periodic	Routine	Periodic	Routine	Periodic	Routine	Periodic	Routine	Periodic	Routine	Periodic	Routine	Periodic
	Waterway Maintenance	Debris/ Obstacles		Waterway erosion		Waterway desilting								Other waterway	
		Routine	Periodic	Routine	Periodic	Routine	Periodic							Routine	Periodic

Table 74 Miscellaneous structure maintenance

Miscelaneous Structures	Drift & Causeway Maintenance	Structure damage		Waterway		Drift reshaping		Marker post		Post Reflector		Stone pitching repair		Other drift	
		Routine	Periodic	Routine	Periodic	Routine	Periodic	Routine	Periodic	Routine	Periodic	Routine	Periodic	Routine	Periodic
	Retaining Wall Maintenance	Minor repairs		Weep hole		Vegetation clearing								Other retaining wall	
		Routine	Periodic	Routine	Periodic	Routine	Periodic							Routine	Periodic
	Railway Crossing Maintenance	General repairs												Other Railway	
		Routine	Periodic											Routine	Periodic

Table 75 Maintenance of road furniture, signs and markings

Furniture, Signs and Markings	Road Furinture Maintenance	Guardrails		Kerbstone		Kerb maintenance		Distance marker						Other furniture	
		Routine	Periodic	Routine	Periodic	Routine	Periodic	Routine	Periodic					Routine	Periodic
	Road Sign Maintenance	Sign cleaning		Repainting		Sign repair		Sign replace						Other signs	
		Routine	Periodic	Routine	Periodic	Routine	Periodic	Routine	Periodic					Routine	Periodic
	Road Marking Maintenance	Repainting		Reflective studs										Other marking	
		Routine	Periodic	Routine	Periodic									Routine	Periodic
	Rumble Strips and Speed Humps	Rumble strips		Speed humps										Other speed	
		Routine	Periodic	Routine	Periodic									Routine	Periodic

8.4 Maintenance Delivery Models

Labour-based maintenance has proved to be cost-effective globally for several years. Guidelines are readily available (Johannessen, 1999; PIARC 2001; Donnges et al 2007). Cook et al. (2013) described several general options for the actual delivery of the maintenance, including:

- Direct public works (Force Account);
- Large contractor;
- Small local contractor or SME;
- Contracted local groups;
- Village Groups, and
- Single contracts (Length-men).

Each of the above has its advantages and disadvantages depending on the physical, climatic and financial environment (Johannessen, 1999). Overarching some of the above is a decision on the contracting model to be used; traditional BoQ based or some form of a performance-based contract. This latter option is being increasingly favoured by donors (Salomonsen and Diachok 2015; Silva et al, 2011).

The contractor in an output or Performance-Based Contract (PBC) for road maintenance is paid on a monthly or quarterly basis for maintaining the road at a specified service standard. The resulting condition of the road is defined by performance criteria rather than on an input basis as occurs under traditional maintenance contracts where payment is based on the volume of work (Bull et. al 2014). These performance criteria are basic and easily measurable, targeting the principal defects to be addressed (e.g., maximum number, size and depth of potholes; maximum height of vegetation; maximum allowable degree of blockage of the drainage system). This is in contrast to the BoQ-based approach where the contractor is paid strictly in terms of the time and resources used as per a submitted list of costed items.

Whilst there are undoubted advantages for the performance-based approach, there remain significant challenges for its implementation at the LVR level in terms of Client/Contractor experience, particularly in terms of appreciation of risk, for example from climate impacts. To be effective a PBC-based LVR initiative is only applicable for “maintainable roads”; that is roads that are generally fit for purpose and have only minor defects which can be rectified using routine or periodic maintenance, without significant rehabilitation.

8.5 Implementation of New Technologies

8.5.1 General

The goals and objectives of rural road development include the implementation of new technologies to "do more for less".

The international market is flooded with proprietary products claiming huge benefits. Although true in many cases, procurement rules prevent authorities from utilising such products unless they adhere to either generic material specifications, Agrément certification or, end-product specifications.

The development of Nano Modified Emulsions (NME) both with a Bitumen Emulsion (BE) basis or a Nano Polymer Nano Silane (NPNS), opened new possibilities to the cost-effective maintenance of surfaced roads as well as to gravel preservation of the shoulder materials (or, for that matter on unsurfaced roads). These options includes:

- MC-NME precoating of stone (chips) used in single or double seals;
- Alternatives to fog sprays, i.e., "clear seals" consisting of a 1 to 10 mixture of a Nano Polymer Nano Silane (NPNS) with water applied to existing surfaced pavement;
- MC-NME mixtures to mix locally at ambient temperatures for pothole repairs, and
- MC-NME mixtures for surfacing slurries, also as part of a Cape seal.

8.5.2 MC-NME precoating of stone (chips) used for single or double seals

Limited trail sections have been done since 2018, replacing traditional precoating mixes with a MC-NME pre-coating on actual reseal projects in a comparative study. The use of the MC-NME resulted in zero stone loss, compared to a 2 per cent to 4 per cent stone loss using traditional precoating additives.

These results are in expectation with the chemical bond created between the aggregate and the binder when using the MC-NME precoating agent. With traditional precoating agents, adhesion is established through a bit of binder absorption and the filling of crevasse in the stone (ships). The selection of a suitable MC-NME pre-coating agent should be done similar to the selection of a suitable NME stabilising agent as discussed in Chapter 6.

8.5.3 NME (NPNS) "clear seals" as alternative to diluted bitumen emulsion fog sprays

The development of a "clear seal" consisting of an NME – NPNS have been shown to potentially be a game - changing technology (Jordaan and Steyn, 2022; Jordaan and Steyn, 2023; Horak, et al, 2024) for cost-effective preventative maintenance, protecting existing surfacings through waterproofing in cases where

- Existing surfacing exhibiting micro cracking's where water-proofing will prevent water ingress and accelerated deterioration of pavement layers;
- Existing pavement structures showing distress in terms of pothole forming and deformation due to water ingress, where immediate interim intervention is urgent required to limit distress in preparation for a more permanent solution in terms of, for example, an NME slurry with a zero HPP, restoring some irregularities and providing a surface with no water penetration, and
- Protection of gravel shoulders (and surfacings against erosion and the effect of rolling wheel abrasion.

The clear seal normally consists of the dilution of 1 litre of NPNS in 10 litres of water where some minor distress (micro cracking may be evident and can be adjusted to a 1 to 20 litre dilation where only porous surface void filling may be done. When little or no surfacing distress is evident, the NPNS can be dissolved in a water truck with the required water and distributed or applied by hand in cases where significant differences in surface condition are present. Application rates depend on the conditionof the existing surfacing and applied until saturation is achieved. Figure 84 shows application of a NPNS“clear seal” by hand to saturation, ensuring waterproofing of the surfacing layer (a), as measured using the Marvil apparatus (b)

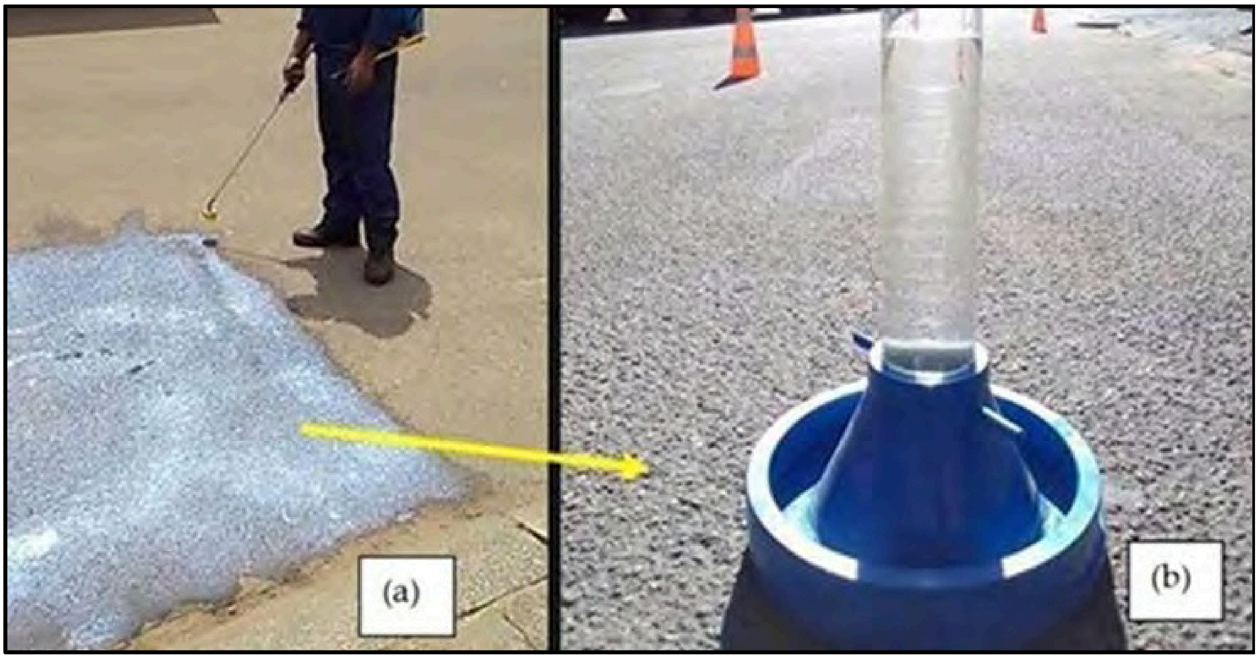

Figure 84 Hand application of a NPNS “clear seal and permeability measurement

Figure 85 Application of a NPNS clear seal from a flow-bin on the back of a trailer

TheapplicationofaNPNSclearsealofferssseveraladvantagesincomparisontoalternativeenrichment usingdilutedbitumenemulsions.TheparticlesizesofagoodNanoPolymervariesbetween40and80nm withanassociatedparticlesizeofahigh-qualityNanoSilaneoflessthan1nm,whileabitumenemulsion particleisbetween1and5µminsize.Aparticlesizesofarejuvenatingagentwillresultinatemporary surfacesealantwithbenefitsrangingfrom1to2years.TheconsiderablysmallerparticlesizesofaNPNS clearsealpenetratesmicrocracksindepth,renderingitwaterproofforeffectivesealinglastingconsiderably longer.DuetothesmallparticlesizesoftheNME-NPNSclearsealnochangeintheskidresistancehas beenshown.Theclearsealapplicationwilldrywithin1hour,withnoneedfortherepaintingofroadtraffic markings.

Qualitycontrolonsitecaneasilybedonewitheachbatchofclearsealdelivered,bytestingtheproduct usingaMarshalmouldfilledwithbuildingsand(finesand).Theapplicationofacomparativeapplication rateonthetopofthebuildingsandintheMarshallmouldshouldresultinthepenetrationoftheNPNSclear

sealtothefulldepthoftheMarshallmould.After48hoursinanovenat40–45C,thebottomofbuilding sandatthefull-depthoftheMarshallmouldshouldbeboundtogetherandwaterappliedtothebottomof thematerialshouldshowdropletsformingasanindicationofthewaterproofingachievedthroughoutthe depthof the Marshall mouldwiththebuildingsand.

At thisstage,nocomparativedatacomparingconventionalrejuvenators(fogsprays)againstNPNSclear sealsareavailable.However,theprovenwaterrepellentcharacteristicsoftheNanoSilanestogetherwith the considerablysmallerparticlesizesofthenanopolymerbinder(25to125timessmallerthanatypical bitumenparticle)makesthisanalternativethatwarrantsmorecomprehensiveconsiderationfor implementation.

8.5.4 MC-NME pot-hole mixes using locally available granular materials

Pothole mixes using MC-NME liquid to mix with locally available granular materials, considerably reduces costs, can be used at ambient temperatures, provide a waterproof solution and is labour intensive. The same principles contained in Chapter 6 for the development of a MC-NME stabilising agent for the stabilisation of NAGM, are also applicable to MC-NME pothole mixes. The End Product Specification for a pothole mix is also a function of the traffic loading (refer Table 41).

8.5.5 Protection of gravel shoulders against erosion and gravel preservation

The NME (NPNS) technology has shown great promise to penetrate gravel to a depth of at least 60 mm (using a standard Marshall mould of 60 mm in thickness as discussed in Appendix E, Item F1014. This aspect has also been demonstrated in practice, where flood waters have caused no damage to compacted NME layers subjected to high flood conditions (Jordaan and Steyn, 2022b).

The potential impact and cost implications of this technology require more thorough investigation in terms of potential use for gravel preservation on shoulder materials and on unpaved roads.

8.5.6 MC-NME slurries as a maintenance option

The use of NME slurries have already been discussed as a surfacing option in Chapter 7.7.6, including preliminary End Product Specifications. The relatively high flexibility achieved without any cement additive, together with a zero HPP water test makes this an attractive option for use as a preventative maintenance option, especially on highly flexible rural roads or even within urban environments faced with severe pavement surfacing deterioration and vehicle turning actions. This option is also labour intensive, working at ambient temperatures, presenting authorities with relatively cost-effective option to address immediate problem areas along road networks, while creating numerous labour-intensive work opportunities and opportunities for the development of SMME's. In such cases it is advisable that local authorities go out on tender directly to available suppliers using the recommended "End Product Specifications. Successful suppliers meeting the minimum required engineering properties will supply the MC-NME liquid directly to the authority for distribution within its jurisdiction to labourers and/or SMME's.

The application of NME slurries as a maintenance option using a continuous slurry machine (10 -12 mm), could improve riding quality on roads by eliminating some unevenness (Figure 86).

Figure 86 Application of a 12 mm MC-NME slurry using a continuous slurry machine

Trials were conducted to evaluate the ease of mixing MC-NME slurry with small equipment and application by hand. A uniform thickness with smooth surface was obtained without any difficulty (Figure 87).

Figure 87 Mixing and hand application of a 12 mm MC-NME slurry

8.5.7 Sequence of maintenance actions addressing highly distressed roads

Large portions of rural and urban road networks are exhibiting severe distress. Faced with limited resources, authorities need to address current problems effectively using available technologies within the restriction of funding regimes. Using the above-described technologies, a combination of the action may provide options not previously available as temporarily relief. The sequence of events to improve the severely distressed roads is illustrated in Figure 88 (Jordaan and Steyn, 2023).

Although many of the aspects are still in a test phase, the proven hydrophobic characteristics of a good nano silane together with various actions as shown, makes this option an improvement to the “do nothing” option.

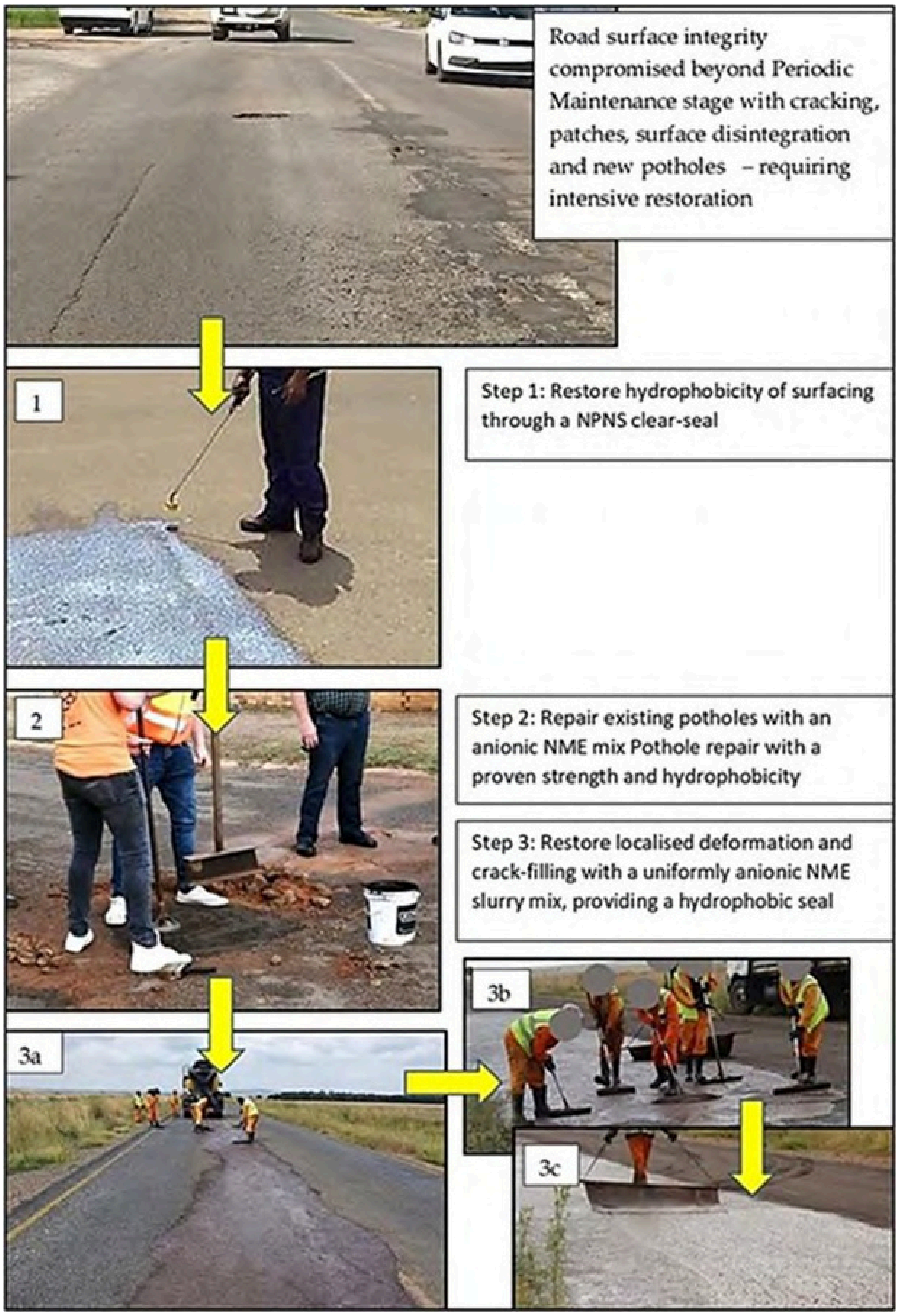

Figure 88 Sequence of events to restore severely distressed roads

8.5.8 Drive towards end-product specifications

To stimulate innovation in the local industry and to allow suppliers to compete on a level playing field it is essential to develop end-product specifications for maintenance treatment products. This requires both fundamental and practical research.

Significant work in the utilisation of nanotechnology has led to end-product specifications for treating local marginal materials for road pavement layers (Jordaan and Steyn, 2020). However, specific research is required to quantify the cost-effectiveness and to develop/finalise end-product specifications for maintenance treatments e.g.:

- Cold mixes for pothole and edge repairs;
- Additives to improve properties of slurry mixes i.e., tensile strength, and permeability;
- Additives for improved binder- aggregate adhesion, and
- Rejuvenators.

Whereas the specifications for MC-NME4 materials (refer Table 41) could be applied to cold mixes, the effect of different additives on the short- and longer-term rheological properties of bituminous binders e.g., ageing or excessive softening, is not properly quantified.

Regarding rejuvenators, the standard practice for decades in South Africa has been to apply a diluted anionic stable-grade emulsion. Performance studies confirmed an increased surfacing life of three to four years. Research by suppliers led to the development of proprietary products, which proved to extend the effective service life of surface treatments by up to four years (Figure 89). Based on the proven performance, generic specifications were developed for invert emulsions that could be used as rejuvenators and were incorporated in COTO 2020.

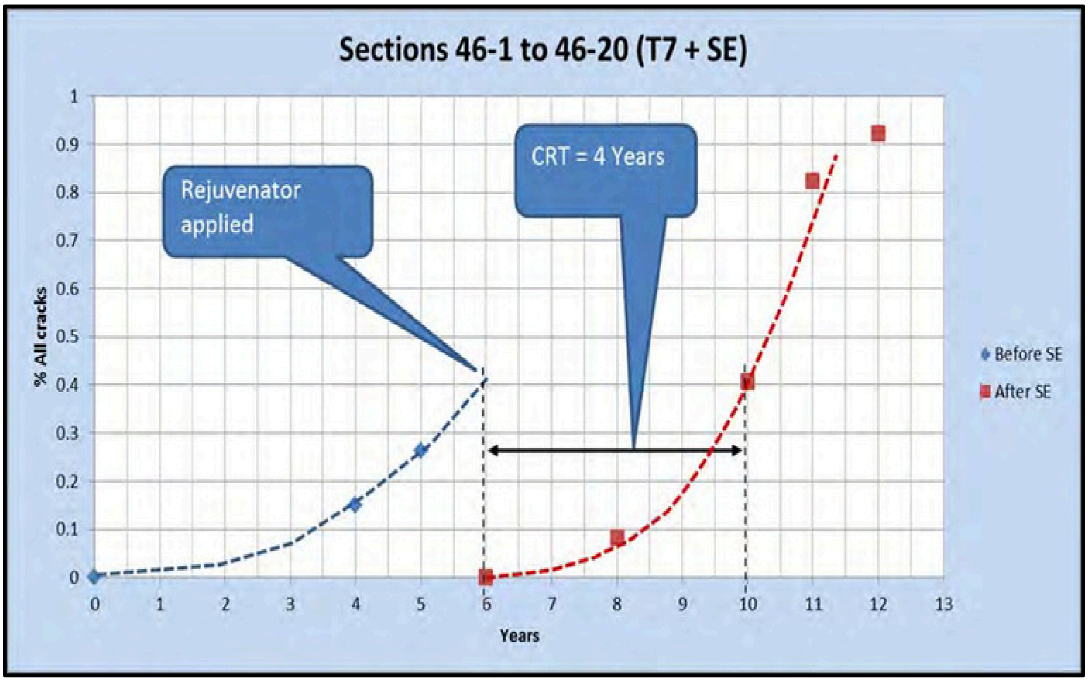

Figure 89 Rejuvenator extending effective service life for four years (SABITA Manual40)

Continuous research with nano silane products has highlighted that additional benefits couldbeobtained to improve the flexibility of aged binders while dramatically reducing the permeability of existing seals (Jordaan, 2021). Due to the different properties and characteristics of products from differentsuppliers, suitable parameters must be identified to measure the effectiveness and to set appropriate specifications.

9. Method of Contract for Upgrading of Unpaved Roads

9.1 Introduction

9.1.1 Purpose

This Chapter is specifically aimed at recommending sound procurement processes to be followed, meeting the objectives to be achieved within the existing legal framework, while ensuring that all specifications are being met in terms of infrastructure development in support of the people of South Africa without compromising quality and durability.

9.1.2 Objectives

The objective is to recommend a contract procurement and project management programme that will enable the objectives of the project to be maximised within the current legal framework, i.e., to:

- Enable the labour content of the works to be performed through the specification of the construction processes aimed at the maximisation of labour-enhanced procedures, and
- Manage projects in such a way as to allow SMMEs to develop and fully participate in all aspects of the road construction works.

Considering the objectives, it is realised that tasks for the execution of normal road construction projects within any specific implementing authority will require adoption that may range from considerable to relatively minor, depending on the original mandate of the authority i.e., from National to Regional to Municipality. All Road authorities will have adopted management procedures and quality control procedures to enable projects to be performed according to strict regulations and standards applicable to the road networks they were mandated to manage in support of the greater well-being of the South African economy as a whole. With the roles hanging considerably in terms of the accommodation of the Upgrading of Unpaved Roads, these specifications, criteria and management procedures may need considerable adaption, depending on the road authority involved.

Nevertheless, all adaptations must be done within the existing legal framework, enabling road authorities to fully adhere to the requirements of the fiscal auditing authorities and meeting the checks and balances required to obtain a clean audit in terms of procurement regulations, expenditure and associated accountability. It follows that the recommendations of the “Type of contract” to be adopted must fully allow any authority to still be able to obtain clean audits as per existing fiscal requirements.

The recommended procurement approach for the Upgrading of Unpaved Roads is aimed at addressing the objectives of the programme, ensuring that all the procurement requirements are met in full. Any recommended procurement process must allow for:

- Optimisation of labour content of projects without compromising the applicable standards and the required integrity of the road pavement structure,
- Opportunities for the development of viable SMMEs, ensuring financial support (e.g., through sessions for the direct payment through sessions of, e.g. equipment and material suppliers) and technology transfer to ensure that the applicable specifications and design criteria are met, and
- Full access for all material suppliers of MC-NME stabilising agents (where required) to compete on an equal basis based on the test procedures and material specifications as provided.

9.2 Recommended procurement procedures

The main components and the main responsibilities of the various role-players in the recommended procurement process are highlighted in Figure 90.

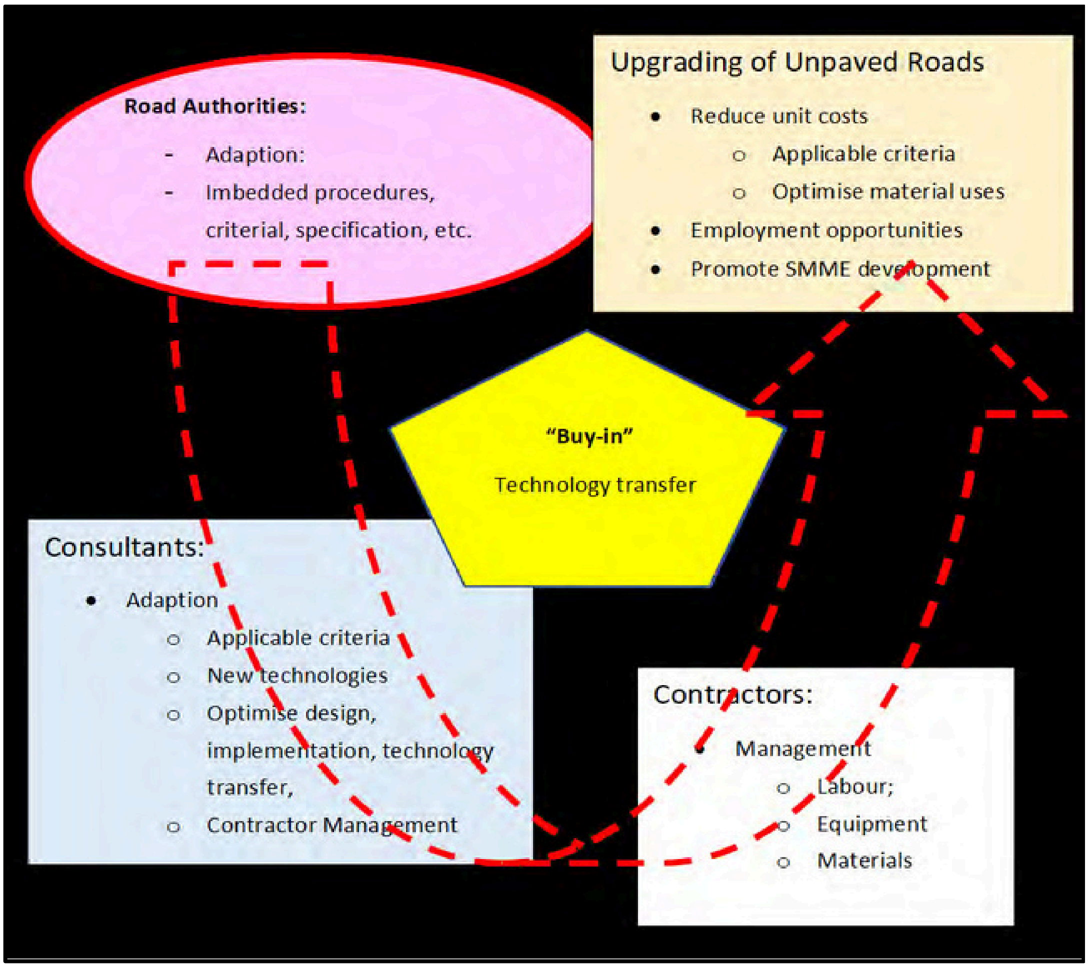

Figure 90 Role-players and their responsibilities in the recommended procurement process

9.2.1 General

The procurement of the Works for road construction and maintenance takes on many forms. Each procurement form is suited to particular circumstances. The various forms of procurement of works are outlined in Table 76.

Conventional wisdom is to allocate risk to the party best placed to manage it. Therefore, it is standard practice to use the contract most suited to the associated risk profile.

There are numerous models developed all over South Africa and the rest of the World aimed at increasing the labour content of road construction projects. Several Provincial and Municipal Road authorities within South Africa have developed their implementation strategies aimed at the development of SMMEs and increasing the labour content of their road infrastructure projects to meet the objectives of their constituencies

In the case of upgrading and maintenance of Low Volume Roads, consideration must be given to:

- Economic situation to secure stable funding;

- Readiness and quality of the industry to take and maintain responsibility;
    - Client: Maturity of Road Asset Management, prioritising needs and development of asset management plans, procuring services timeously, payment for services delivered, and
    - Contractors and small enterprises: Staff skills and quality of equipment to meet specifications, financial standing and stability.

Table 76 General forms of procurement

Procurement type	Description
Conventional Procurement	The contractor is appointed by the client to construct the works as designed by the designer. Normally the designer is a consulting engineer. The consulting engineer also administers the contract and monitors that the contractor constructs the Works as designed and that the works comply with the specified requirements.
Product Performance Guarantee System (PPGS)	The contractor includes a guarantee for one of the final products constructed/used in the works, which is normally a proprietary product or for the result of work utilising a proprietary product. Examples are a specific type of final surfacing, such as a UTFC, a type of bridge joint, or the sealing of joints in concrete pavements utilising a proprietary joint sealant. Therefore, there is a reduced need for monitoring quality during construction on behalf of the client.
Design and Construct	The client specifies the works (facility) required and its intended purpose. The contractor employs a designer and delivers a Turnkey solution that must meet the intended purpose of the facility. Turnkey implies the client literally turns the key and takes over the road.
Design, Build and Operate (DBO)	The client specifies the works (facility) required and its intended purpose, as well as hand-over conditions. The contractor employs a designer and delivers a Turnkey solution that meets the client's requirements. The contractor then operates and maintains the facility for a specified period before handing it over to the client.
Concession	The concessionaire, which is typically a consortium consisting of a contractor, consulting engineer (designer) and financier, provides a complete solution for a section of road for a pre-set period, the concession period. Only the level of service provided to users is audited by the client during the concession period.

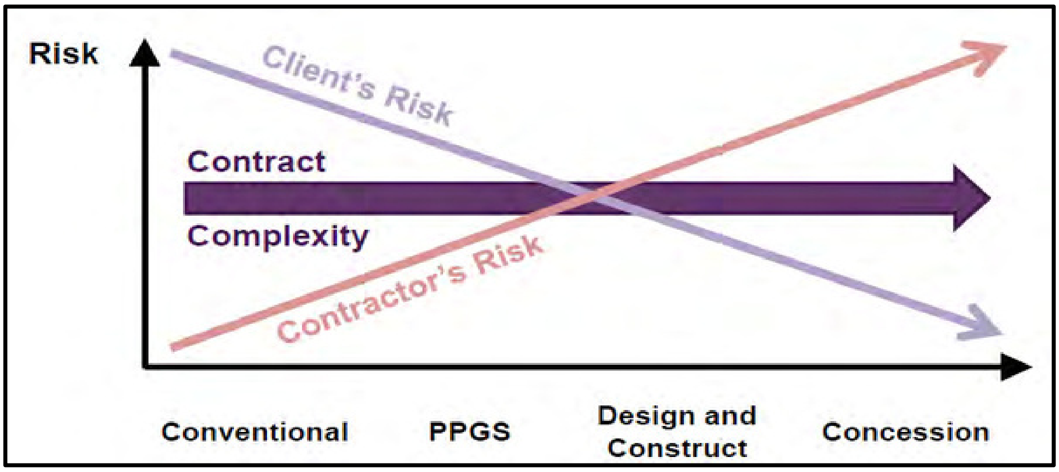

Figure 91 Risk profile in relation to the type of contract adopted

The current situation suggests that the contracting industry is not ready to take high risks. Therefore, most risks should be taken by client bodies.

The conventional/traditional client, consultant and contractor concept can be maintained within a framework where the responsibility and the works are still transferred to a contractor.

a. Conventional contract suitability and procedures

Conventional contracts are suited to projects where the client, or their agent (consulting engineer), knows what is required and can specify this in the tender and contract documentation. The contractor then prices the tender with the knowledge of what is required and how to achieve those requirements. The client has systems and resources, such as consulting engineers, in place to ensure that the contractor achieves these desired requirements during construction, in the knowledge that if these are achieved, the project will be successful.

This form of contract is normally suited to road construction and rehabilitation situations where the clients, consulting engineers and contractors are all knowledgeable and have a good understanding of readily available technologies and materials. It is the most suitable form of contract for roadworks where there is sufficient time for investigation, design and contract documentation. All the possible uses of locally available materials are investigated and all risks can be identified and allowed for in the contract documents. All the items of work are properly quantified and specified in the design, schedule of quantities and related specifications and documentation. The contractor, in turn, prices these items with minimal allowance for extraneous risks. Variation orders are issued during construction to cater for any situations that were not catered for in the bill of quantities. This type of contract, therefore, delivers a fair price for the work involved.

Note: The contractor will still be required to tender for the works, taking limitations into account as to the role required to be performed in the execution of the works. In such a scenario, the Main Contractor will be limited to performing specialised services only, while providing the required skill set for the technology transfer and managerial input to SMMEs to perform non-specialised services. Within such an approach, little change would be affected in many road authorities already implementing similar structures. The appointed contractor will, as usual, provide the entire necessary legal requirement for the execution of the works and deal with the consultant and the Client as per the normal contract.

9.2.2 Recommendations

The main principles of the recommended procurement and execution process to be implemented for the upgrading of unpaved roads are contained in Figure 92.

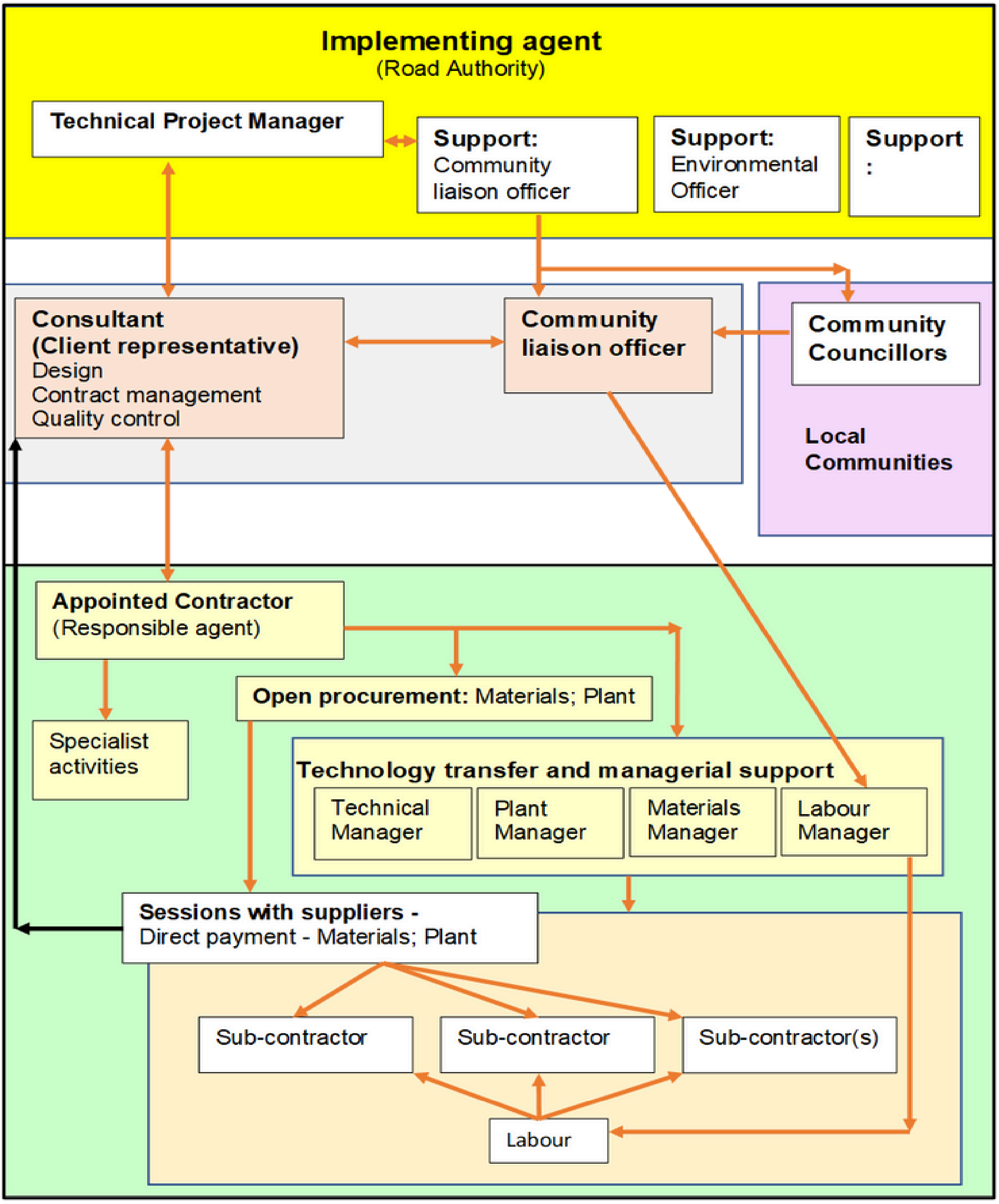

Figure 92 Recommendations towards an applicable method of contract

These recommendations take into consideration that:

- Many road authorities have in place management procedures aimed at the Client, consultant and contractor roles in the provision of road infrastructure;
- Many road authorities already have in place the required structures containing the main elements as shown in Figure 92, with specific reference to in-house labour-relation officers and in-house procedures and requirements for enhanced labour construction projects with all the associated legal requirements;
- Knowledge about construction methods and the practical execution and management of projects is mainly based in the construction sector of the industry and hence, they are the best equipped to give the technical expertise and training to SMMEs, and
- SMMEs will not have the required funds to buy or hire equipment and/or the materials to execute projects and will need assistance, hence it is recommended that Sessions be signed with preferred suppliers and equipment. Direct payment to suppliers of specialised materials such as MC-NME stabilising agents will be done in accordance with the prescribed " End product Specifications" as detailed in Appendix F and, with the risk vested in the Contractor with his supplier to meet the minimum specifications as per the design of the upgrading. During the design stage, the Consultant must do the necessary tests to assure himself that the specifications can be met.

9.3 Procurement of MC-NME solutions for the stabilisation of Naturally Available Granular Materials (NAGMs)

9.3.1 Defining MC-NME stabilising agents

Materials Compatible New (Nano) Modified Emulsion (MC-NME) stabilising agents or similar where an emulsion is defined as any additive in the form of a solution, including any additive added to the construction water, including (but not limited to):

- Bitumen emulsions with/without a modified emulsifying agent (e.g., aggregate adhesive, water-repellent agents (e.g., organo-functional-silanes) and/or with the addition of polymers (micro- and or nano-polymers);
- Material-compatible polymers (micro- and/or nano-polymers) with or without a modifying agent, or
- Any "alternative" rock/aggregate/soil stabilising agent.

In the context of this document, MC-NME may be considered as an abbreviation covering the use of any or all of the above-mentioned stabilising or material improvement additives. However, the engineering requirements in terms of strength criteria, sample preparation and test protocol contained in this document must be met in all cases.

The END PRODUCT SPECIFICATIONS (EPS) require an MC-NME to be verified prior to usage AND GUARANTEED by the contractor through his supplier using a conventional tendering process. It is important to note that the MC-NME stabilising agent (or equivalent) is costed in terms of cubic metre of the material that is being stabilised and NOT by the quantity of the stabilising agent. The cost of a stabilising agent depends on the end result and not on the quantity added to the material.

The principles of a tendering process for the inclusion of a MC-NME stabilising agent could, as an alternative, also be applied during the design phase with the consultant providing materials to interested suppliers to test based on the EPS, in a separate tender for any project. In this case, the quality and performance guarantees of the MC-NME stabilising agent will be vested in the supplier. An implementing agency could also apply the same recommendations in terms of the EPS, to separately procure a MC-NME stabilising agent for a specific project. It follows, that different implementation agencies could apply the EPS in different approaches, all based on the engineering properties contained in the recommended EPS. The general principles contained in the recommended EPS, specifying minimum engineering requirements depending on design requirements, prevents the introduction of inferior technologies into the roads industry on the back of proven scientifically based products.

9.3.2 Principles allowing for open tender

In preparation for the open tender for the provision of an applicable MC-NME stabilising agent for naturally available materials, suppliers need to have access to basic information and materials to submit MC-NME stabilising agents. Potential suppliers are to submit their products for testing and evaluation. The objective is to recommend a contract procurement and project management programme that will enable the objectives of the project to be maximised within the current legal framework, i.e., to:

- Enable the labour content of the works to be performed through the specification of the construction processes aimed at the maximisation of labour-enhanced procedures, and
- Manage projects in such a way as to allow SMMEs to develop and fully participate in all aspects of the road construction works.

The successful implementation of the programme strongly relies on the “Buy-in” of all parties involved, including the clients (road authorities that may require traditionally embedded procedures to be drastically adapted), consultants that will adapt their usual design methods with the emphasis on cost optimisation, especially concerning the traditional use of “Catalogue designs” and contractors that will play a major role in project management.

The appointed Consulting Engineer will be required to do the testing and the structural design of the pavement according to the recommendations contained in this guideline design method. The main aim of the design will be focused on cost reduction, applicable criteria, labour-friendly construction methods and the optimum use of naturally available materials. Only in cases where NAGMs do not meet specifications, more detailed testing will be done. Only the material thicknesses that need to be improved through MC-NME stabilisation will be sampled and tested, determining at least the following material properties:

- Maximum Dry Density (MDD);
- Optimum Moisture Content (OMC);
- Grading of the materials, and
- XRD scans analyses of the NAGMs as per recommended protocol (Jordaan and Steyn, 2019), determining the mineralogy of the **total sample** as well as of the **fraction passing the 0.075 mm sieve size**.

It is important to note that ONLY the material earmarked for improvement must be sampled. Samples should be taken at points that coincide as close as possible with the specific design percentile values applicable to the Category of the road as recommended in Table 77. All identified surface geological or soil structures that are identified for possible use, should be sampled.

Potential suppliers will be given coordinates of materials collection points should they wish (at their own cost) to sample and optimise their MC-NME solutions for submission for independent evaluation if the procurement process requires such an approach.

Table 77 Recommended design reliability and risk profile for the various category of roads

Category of Road	Design Reliability (Percentile level)	Percentage Confidence Interval	Network level	Project level
			Accuracy: (± error)	Accuracy: (± error)
A	95	95	40	10
B	90	95	40	10
C	80	95	40	10
D	65	95	40	20
E	45	95	40	20

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Appendices

Appendix A. Key Data for Economic Prioritisation

Population data

The population data applied for the current simulation was provided by the CSIR (2021) and reflects the population demand scenarios generated as part of an exercise to estimate infrastructure investment needs for achieving the United Nations Sustainable Development Goals in South Africa. This is likely the most detailed population data publicly available. Alternative population data sources include most recent available Census data at the enumeration area level from Statistics South Africa, or the 2016 mesozone population distribution by the CSIR (available at: http://stepsatest.csir.co.za).

Land use data

Urban roads were identified and subsequently removed from the road network under review using the South African functional town typical developed by the CSIR (2018) (available at: http://stepsatest.csir.co.za). This typology was developed to provide a fine grained, but nationally comparable overview of regional scale settlement patterns and trends. Another useful, albeit less accurate, method to isolate rural roads is to filter urban road categories under the Naming classification (e.g., avenues, lanes, streets).

Basic service facilities data

The Department of Basic Education publishes quarterly key characteristics, including the GPS location, of all publicly registered primary and secondary schools (available at: https://www.education.gov.za/Programmes/EMIS/EMISDownloads.aspx).

The National Department of Health have shared, in response to a special request, the GPS locations for 5 389 healthcare facilities. Unfortunately, this information is not published, in addition to being subject to change as some healthcare facilities are mobile clinics that relocate from time to time. Going forward, road departments must therefore request updated data from their respective provincial Department of Health in order to factor healthcare access, where it differs from basic education access, into the analysis.

Gross Value-Added data

The CSIR (2023) applies the concept of Gross Geographic Value Added (GVA) to estimate regional economic activity (available at: http://stepsatest.csir.co.za). GVA is broadly similar to Gross Geographic Product (GGP): GVA (factor cost) is equal to the Compensation of Employees plus the Gross Operating Surplus. The GVA data for all economic sectors are produced on a local municipal level by Quantec. The CSIR then assigns the municipal level data to mesozones using dasymetric mapping principles, according to which secondary data representing the potential points where production occurs are used to re-assign the economic production data to the mesozones. The result is an indicator of economic production per sector (excluding construction) expressed in Rands per mesozone. Because the data have been transformed through the dasymetric process, they represent normalised rather than real GVA values. The result is a system of ratios that can be used to compare all mesozones across space ('spatial comparison'), as well as to compare a mesozone with itself over time ('temporal comparison').

Basic Access and Multi-functional Road Networks

The procedure to identify the access networks that connect clusters of households with basic service facilities is to geospatially locate all communities in a region of analysis and map which roads link communities to public primary and secondary school and healthcare facilities. Two exclusionary conditions apply to Basic Access Roads and are factored into the simulated potential Basic Access Road Network shown in Figure A 1. First, Basic Access Roads must fall outside the minimum prescribed level of access to constitutionally protected basic education and healthcare facilities. The gazetted access norms and standards prescribe a feeder zone with a radius of 5.0 km for public primary and secondary schools (Government Gazette 33283, 2010). This standard reflects a deemed acceptable walking distance to schools, creating buffers within which road departments are not constitutionally required to provide access roads. Road departments may include specific direct access routes as part of the Basic Access Road Network given the importance of direct and all-weather road access to schools. No such access standard exists for healthcare facilities, which is sensible as it is unreasonable to expect people requiring medical care to walk non-trivial distances. Secondary, urban roads are excluded from consideration as Basic Access Roads due to the availability of alternative routes to service centres in these areas.

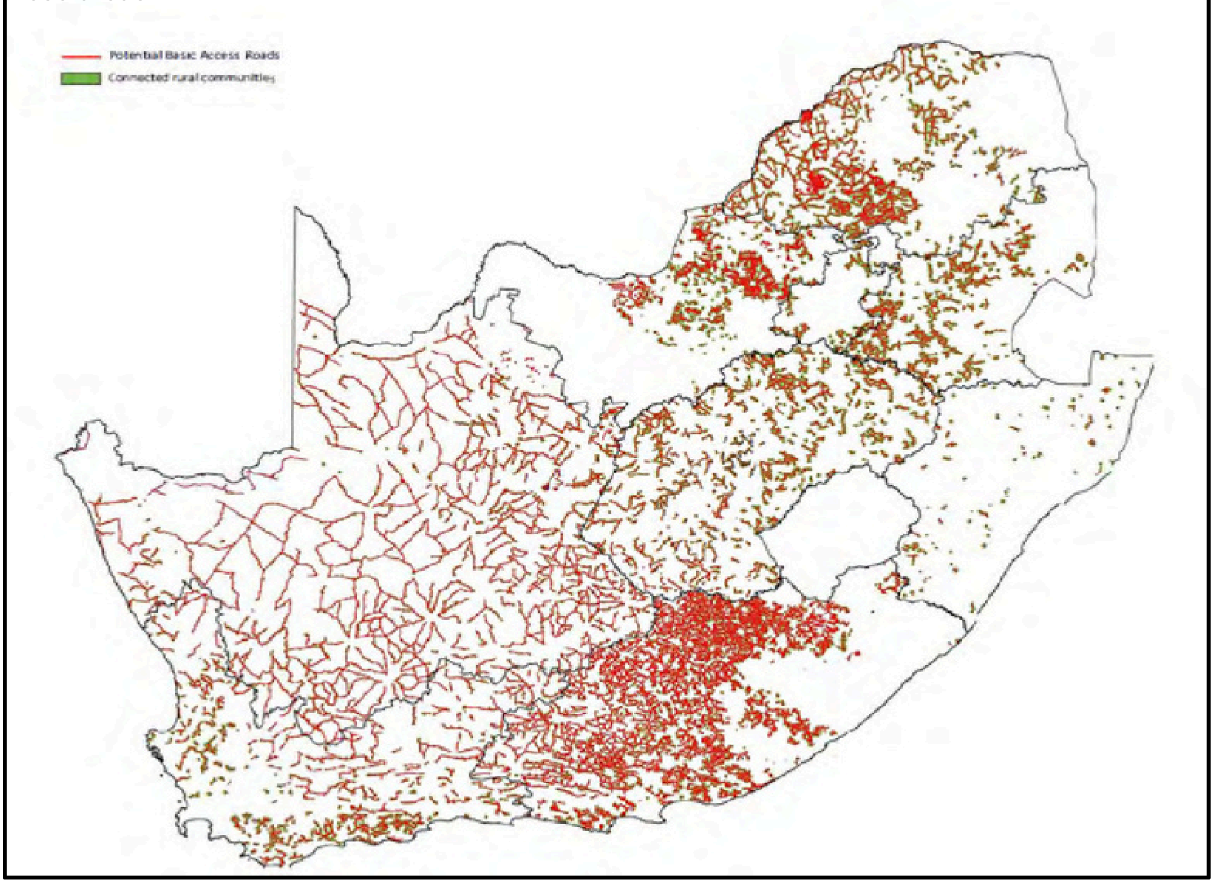


Figure A 1 Potential basic access road network

As noted, some roads that provide a basic access function also contribute to economic growth. These multi-functional roads are efficient as they allow road departments to address access needs at the same time as promoting economic growth, and hence are the highest priority for upgrade to LVSR. While multi-functional roads can be found in any rural or peri-urban setting where there is isolated economic activity, these roads are typically concentrated in areas with relatively higher economic activity. Using the CSIR's GVA data, shows the likely distribution of multi-functional roads disaggregated according to productivity quintiles. Comprehensive traffic data, covering heavy vehicle traffic, were not available for this version of the network level classification. However, road departments should include these data in analyses going forward.

Relocation of basic service centres presents authorities with a means through which to cost-effectively create significant redundancies amongst the Basic Access Roads in the lower GVA quintiles, specifically GVA quintile 1 and some areas in quintile 2. The process entails reclassifying Basic Access Roads as

Surplus Roads by optimally locating schools and healthcare facilities relative to communities they service. In almost all cases, the saved road maintenance costs from this exercise will more than offset the costs to either relocate or build new basic service centres. Townshend (2020) identifies approximately 45,757 km of Basic Access Roads that authorities could convert into Surplus Roads by rationalising network functionality in this way. It is important that authorities address this process of road network optimisation prior to upgrading any Basic Access Roads to LVSR. It therefore makes a virtue of necessity that budget constraints will confine upgrades of unpaved roads to LVSR to multi-functional roads over the medium- to long-term. This provides authorities with time to undertake the complex community consultation processes without which optimisation of the rural road network cannot be achieved.

Strategic Road Network

Strategic Roads include high value transport routes, which are generally within or between key regions and locations such as cities, major towns, international and local trade corridors, and high-volume freight and passenger terminals. While the concept of a Strategic Road Network is often used to refer to national roads, this network should extend to all roads that are core enablers of economic activity. SANRAL's (2015) Road Network Study identified a 9 200 km Core Strategic Network, a 9 600 km Secondary Strategic Network, and a 14 000 km Primary Road Network. The Secondary Strategic Network provides alternative routes to the Core Strategic Network, which are required in areas where low road density makes the Core Strategic Network difficult to reach. The Primary Road Network feeds the two strategic road networks. The Core Strategic Network and Secondary Strategic Network are designated as national roads, while the Primary Road Network is a combination of provincial and national roads. Importantly, user demand for Strategic Roads must be inelastic with respect to fluctuations in business cycles. Adding this criterion to the designation of Strategic Roads ensures that no investment in them that respects best-practice engineering design principles and specifications can ever be economically irrational. Numerous studies from around the world, over many years, show that roads with inelastic demand from commercial users are the least risky focus for investment among all the elements of standard development infrastructure.

Urban roads, which have similarly inelastic demand to the Core and Secondary Strategic Networks and Primary Road Network, should also be classified as Strategic Roads. Urban roads combine to form integrated networks that support important daily mobility and access functions, including the transportation of goods consumed within urban boundaries and the movement of residents between homes, public facilities, and places of work. Incorporating urban roads into the Strategic Road Network aligns maintenance schedules with population density and trends in urban sprawl.

Given these characteristics of Strategic Roads, none occur as part of the network of unpaved roads being considered for upgrades to LVSR. Road departments can thus move directly from prioritised upgrades to Basic Access Roads on to consideration of Tactical Roads.

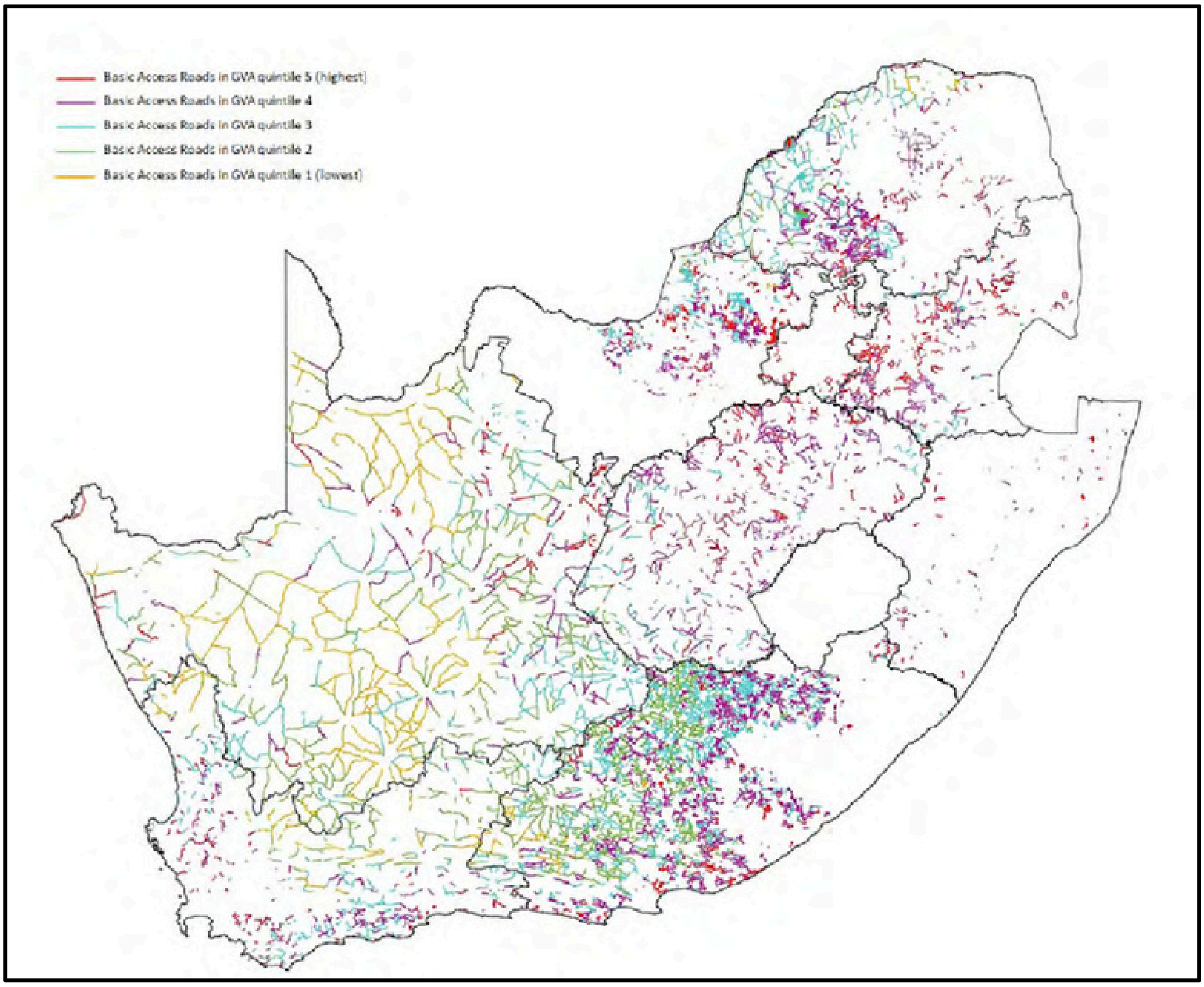


Figure A 2 Potential Basic Access Road Network and GVA, 2020

Tactical Road Network

Tactical Roads are identified as rural and peri-urban roads that support economic growth, at least outside of business cycle recessions, conditional on achievement of macroeconomic policy targets. The NDOT (2006) stress the importance of an effective Tactical Road Network for economic growth as the origin, transport route, and destination for many economic activities are located along secondary and tertiary roads that are not part of the Strategic Road Network.

Having attended to multi-functional roads and then Basic Access Roads, road departments can systematically prioritise the Tactical Roads in descending order of their net expected contribution to GDP. Again, this GDP contribution is approximated through mesozone level GVA. In the event that budgets are insufficient to cover the full network of Tactical roads, which is likely to be a long-term reality given South Africa's current economic outlook, departments are at least assured that unmaintained roads do not leave citizens with neglected basic access rights or support lower levels of economic activity relative to properly maintained roads. The relatively low length of Tactical Roads within GVA quintiles 1 and 2 is due to the fact that most of these roads are classified as Basic Access Roads, with many of these set to fall within the envelope of Basic Access Roads earmarked for rationalisation in the model (Townshend, 2020).

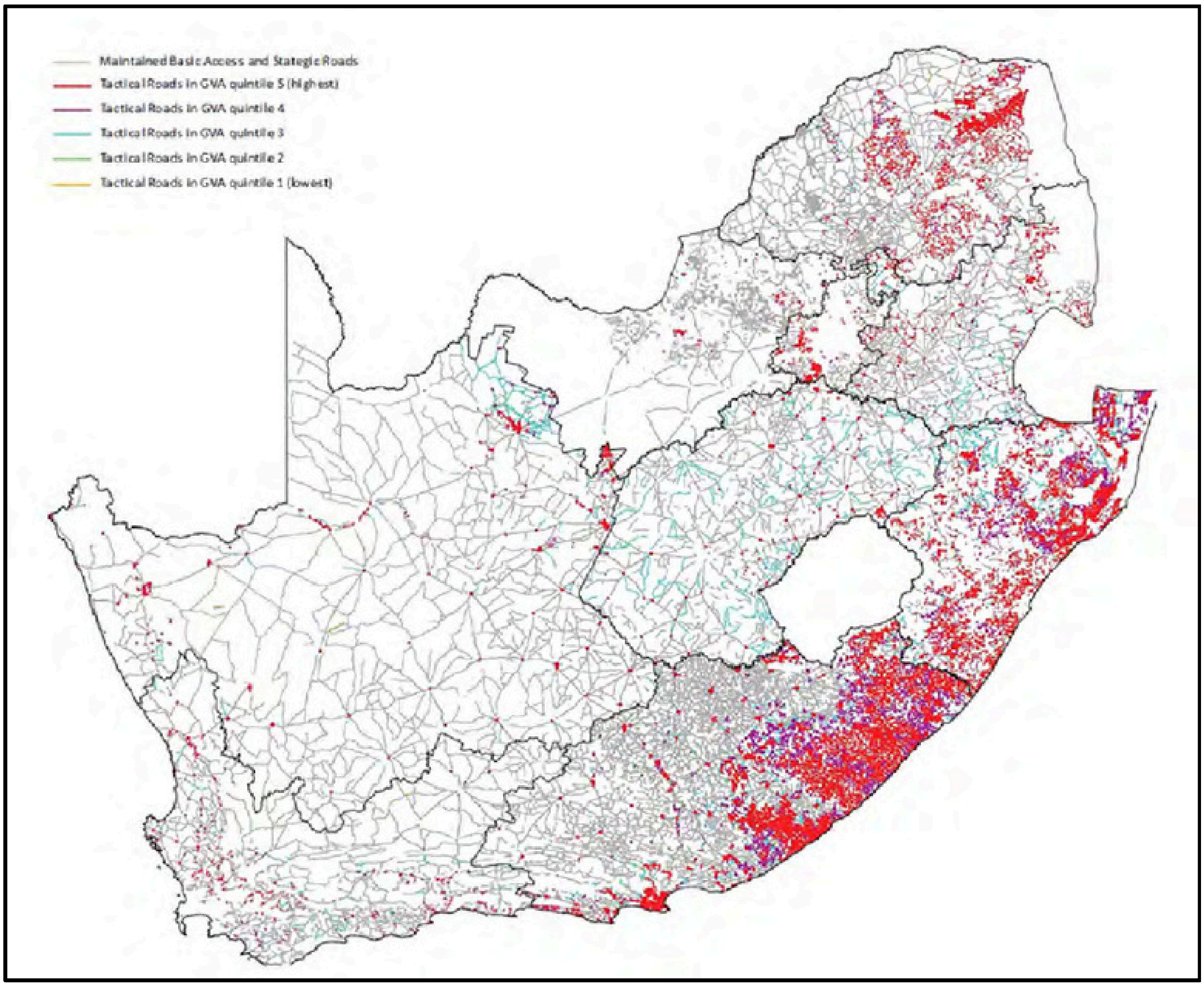


Figure A 3 Potential Tactical Road Network and GVA, 2020

Case study application of the CEA-Based Road Classification System

It is useful to guide road departments about case study applications of the CEA-based road classification. Case study application may be a common requirement given that socio-economic studies are almost always undertaken within but not before a project, and also in light of the somewhat haphazard processes by which LVSR projects are still being identified or passed between departments (e.g. SANRAL taking ownership of certain LVSR projects on provincial roads). The result of these circumstances is that road departments often need to undertake a rapid exercise to confirm that the unpaved road set to be upgraded to a LVSR is in indeed a suitable candidate for such enhancement.

In order to demonstrate a case study application of the CEA-based road classification system we will draw on the pilot projects attached to the development of this manual and rollout of the LVSR programme SANRAL was appointed to manage the upgrade of P133, P143, and D182 in Lidgetton West to a LVSR, shown in Figure A 4. These roads are in the uMngeni Local Municipality in uMgungdunglovo District Municipality in Kwa-Zulu Natal. This project was notably identified by the NDOT as a priority, with no traffic data or socio-economic studies available prior to the award of the contract.

The first classification step is to determine whether the road provides any basic access functions. The road provides access for the communities along its length to Chrystal Springs School. This project satisfies the two necessary criteria (along with not being an urban road) for classification as a Basic Access Road.

Firstly, it is the only transport connection between the communities and the school and secondly, it connects students to the nearest school from a distance beyond 5.0 km. It follows that the road is a required link as per the Access Norms and Standards.

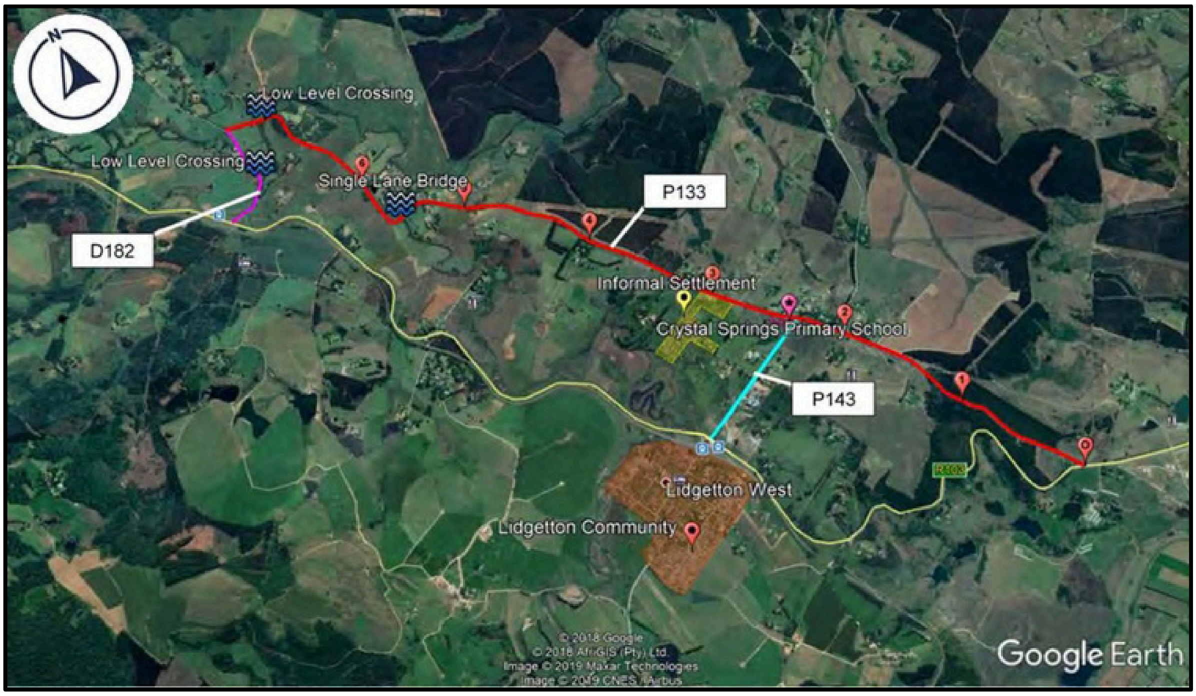


Figure A4 Projectto upgrade P133, P134, and D182to aLVSR

Thenextstepistodeterminewhetherthisroadadditionallysupportseconomicgrowthbyfacilitatingthe transportationofcontributionstoexports.ThisfindingwilldeterminewhetherthisroadisaBasicAccess RoadorisinfactaTacticalRoadwithamulti-functionalrole.IfthisroadisaBasicAccessRoad,thenit shouldnotformpartofthesetofimmediateupgradepriorities.However,analysisoftheGVAconfirmsthat thisroadfallswithinanareathatliesinthe4thGVAquintile,meaningthattheareaproducesarelatively highlevelofoutput.Intheabsenceoftrafficdata,itisimportanttoanalysethesectoralcompositionofGVA to ascertainthelikelyproportionofoutputthatistransportableviaroad.Inthisregard,17.3percentoftotal GVAiscontributedbythemanufacturingsectorand15.5percentbytheagriculture,forestryandfishing sector.Atleastone-thirdofoutput(32.8percent)mustthereforebetransported,whichisabovethenational averageofone-fifth(19.3ercent)(includingtheminingandquarryingsectorwhichadditionallycontributes to GVAinotherareas).

TheemploymentdataforWard4inuMngeniLocalMunicipalityfromthe2011Censusconfirmsthatthere aresignificantlevelsofeconomicactivityinthearea,withanemploymentrateof67.4percent-morethan doubletheemploymentrateof31.5percentinKwaZulu-NatalProvinceasawhole.Thereisalsoanecdotal evidencefromtheavailableprojectdocumentsthattheobservedroadtrafficincludesfarmvehicles, tractors,andheavyvehiclesfortimberplantations.Theareaisalsoapopulartouristattraction,labelled the“MidlandsMeander”withmanydifferentresorts,restaurantsandartistandcraftpractitioners, particularlyoverweekendsandduringschoolholidays.Assuch,thisroadshouldbeclassifiedasaTactical Roadwithamulti-functionalprofileandearmarkedforupgradetoaLVSRaspartofthefirstlevelofupgrade priorities.Moreover,theGVAprofileindicatesthatthisroadlikelyhasrelativelyhighpriorityforupgradeto aLVSR within the Tactical Road network.

Appendix B. Guidelines for pre- and post-project assessment

Introduction

The prioritisation of LVSR projects is driven by consideration of improved economic outcomes, in the broad sense, for South Africa. These include shadow-priced welfare improvements and additional employment opportunities in local communities. Consequently, an integral part of a road upgrade project should be to assess expected community benefits *ex ante* and compare these with achieved benefits *ex post*.

This appendix explains the importance of pre-project and post-project assessments for LVSR projects, as well as the processes that administrators and practitioners should follow to implement them successfully. For the purposes of this Manual, we offer guidance on the form and process to conduct appropriate economic assessments of LVSR projects. This guidance is based on good practice with due consideration given to the South African context, highlighting critical existing process and resource deficiencies that were identified when undertaking economic assessments of the pilot projects linked to the development of this Manual.

The importance of project assessments

The programme to upgrade many unpaved roads across South Africa to LVSR will require very large public budget allocations and a long-term investment timeframe. As such, this programme should include comprehensive economic project assessments. Against the backdrop of severely limited resources and a pressing need for economic development, the economic viability and priority of LVSR projects hinges on a nuanced understanding of their potential impact. Pre-project and post-project assessments are indispensable tools in measuring the relative importance and expected impacts of road upgrade initiatives across South Africa, so that priorities can be set for limited budgets.

The importance of comprehensive pre-project assessments lies in aligning infrastructure development with economic development objectives. As South Africa continues to strive for inclusive growth, these assessments are essential for specifying project parameters, estimating costs, and identifying potential economic gains. Principles of economic welfare efficiency emphasise the necessity of deploying resources judiciously, making pre-project assessments a crucial step to try to ensure that LVSR projects yield positive net returns, with opportunity costs fully accounted, in terms of improved accessibility, reduced transport costs, and enhanced economic opportunities for local communities.

The economic situation of South Africa, with its unique socio-economic history and the consequent spatial distribution of its population relative to economic opportunities, demands a customised approach to infrastructure investment optimisation – we cannot simply apply an abstract general model. Where roads are specifically concerned, robust project assessment must incorporate three main special features of the country:

1. South Africa's rural road network was built to serve a well-developed agricultural sector as well as to connect multiple villages in rural settlements. A consequence is that, unlike most other developing countries, SA has a large network of rural roads adhering to the basic right of access as written in its constitution.
2. Notwithstanding (1) above, some rural communities lack adequate road access, mainly due to several years of neglected maintenance and poor planning and resource allocations.

3. Because of the high rural unemployment rate, which is structural rather than cyclical, the shadow price of unskilled labour outside the major metropoles is close to zero – every unskilled person employed for infrastructure work is a person whose consumption must otherwise be directly or indirectly supported by social grants. Furthermore, human capital development opportunities are extremely large.

Post-project assessments allow us to estimate the actual impact of LVSR projects. Not only can this information serve to ratify investment projects, but it also promises vital feedback for the refinement of strategies and the optimisation of ongoing and future projects. By quantifying economic gains, identifying instances of greatest improvement, and identifying unanticipated challenges, post-project assessments contribute to the overarching goal of maximising the economic impact of available budget envelopes.

These assessments will provide evidence to identify economic benefits that result from expenditures, which can then be added to the LCCA to motivate dynamic prioritisation metrics. Depending on assessment results, especially employment and skills development benefits from surfacing unpaved roads, findings could be used to advocate for additional public funds for this programme as part of ongoing national efforts to boost employment, reduce poverty, and build the country's capital base. Moreover, the individual project assessments (based on before-after comparisons) should provide road departments with important insights into community responses to surfacing unpaved roads, thereby enabling them to optimise project impacts as the LVSR programme matures. The imperative of comparative pre-project and post-project assessments for LVSR projects thus extend beyond provision of technical knowledge and must be considered a core element of all LVSR projects.

Guidelines for effective economic assessment of LVSR projects

The methods to achieve the project objectives include pre- and post-pilot project economic analysis, to be conducted through a combination of desktop research, community discussions organised following principles of focus group design, and surveys.

Desktop studies Economicanalysesofinfrastructureprovision in South Africa have often been based on desktop work that manipulatesnationalaveragestoestimate key variables such as the cost of labour. However, several shortfallsareassociatedwithsuchdesktop assessments. First, averages based on large-scale dashboards discardmassiveamountsofinformation that can be obtained by more granular scrutiny. Where the economicimpactofruralroadsisconcerned, this discarded information is typically what is most important. Consider,forexample,effortstoestimate the extent of Basic Access Roads. The key determinant of this is householdgeographicaldispersal,since this drives the proportion of people who continue to live outside feeder zonesforbasicservicesasroads are progressively upgraded to surfaced standards. Because of historicalsettlementpatterns,thisdensity is far lower in rural KZN Province than in other parts of rural SA. EstimatesofthetotalkilometresofBasic Access Roads based on the national average rural household dispersionwouldthereforehugelyunderestimate the extent of that high-priority part of the network in KZN. But thisstillonlyscratchesthesurface of the issue. In relatively flat parts of the country, feeder zone boundariescanbereadilyadjustedaseffective access routes change through network upgrades. In areas characterisedbygorgesandwetlandareas – again, most of KZN Province, and the southern zone of the EasternCape–feederzoneboundaries are relatively inflexible, because (for example) children cannot climb cliffstowalktoschool.Aperson's house might be 2 km from her job, but 8 km by shortest road distanceiftheroadmustgoaroundasteep kopje. In addition, it is not enough for the analyst to know the averageincomeinacommunitywhere a project is planned; the distribution of household income strata relativetothegeographyofthetargetroad must also be known.

Calculation of impacts of road upgrades that are insensitive to local variations can lead to community rejection of plans when desktop-derived models meet reality at ground level. Sound economic assessment of projects requires site-level data gathering and parameter adjustment. While desktop research is a useful starting point to gather preliminary data and project insights, it must therefore be supplemented in the project assessments with data gathered through fieldwork.

Pre- and post-project assessments Pre-project assessments establish pre-project baselines for key variables. These data provide baseline reference points against which a road project's impacts can be measured in the post-project evaluation. Pre-project assessments must therefore be conducted before the implementation of a LVSR project to establish the situation or conditions in the project area. It is critical that pre-project assessment be conducted prior to any roadworks beginning, as this work and its expected impacts might distort road user activity and stakeholders' perceptions regarding some survey questions. The project objectives and variables inform the design of the assessment tool and its implementation, ensuring it is sensitive to issues in the community and addresses all relevant project impacts.

Post-project assessments must establish post-project levels of the same key variables tracked in pre-project assessments, which are then compared to the pre-project baselines to estimate and analyse project impacts. The post-project assessment should be conducted at least 6 months after the project completion to allow road use patterns to adapt to the presence of the upgraded LVSR.

Size and composition of the research team Assessment fieldwork should be undertaken by a team of 3 researchers, comprising a qualified project leader and two postgraduate research assistants with tertiary-level training in survey administration and interpretation. This recommended size of fieldwork teams is based on direct experience of practical and safety considerations.

In general, rural South Africa lacks corporate infrastructure for professional-quality design and implementation of socio-economic surveys that combine quantitative and qualitative aspects. Consequently, fieldwork personnel need to be recruited from outside project areas, transported to project sites, and maintained there during fieldwork. This generates a further set of costs in managing acceptance of fieldworkers' expertise and good faith: rural populations in South Africa have ample historical basis for wariness of 'outside' experts, rooted in a long-standing tendency in South Africa to promote overly generic strategies that are oblivious to special local conditions and histories. Such wariness can be successfully mitigated, but this requires experienced fieldwork leaders. It is typically not possible to exactly anticipate in advance how many meetings with community representatives an assessment exercise will require.

Some LVSR project sites are in relatively remote areas where prevalent languages require scarce linguistic competence on the part of field researchers. Field researchers must consequently be engaged from a variety of backgrounds that are representative of South Africa's rural population.

Fieldwork protocols When visiting communities at project sites, fieldworkers should be accompanied by local representatives, such as the Ward Councillor. Teams of fieldworkers should be well briefed and experienced in good-sense personal security management, which includes both avoiding providing temptations to opportunistic theft, but also signalling confidence that most community members are well-intentioned consultants in good faith. Fieldwork must be undertaken with the knowledge and guidance from the road authority and following full notification of relevant local officials.

In order to avoid ad hoc interference with representativeness of data by more relatively influential community members, fieldworkshould be conducted in the presence of community officials with objectively legitimated leadership responsibilities. Some of these roles may arise through the LSVR project itself, in connection with Public Liaison Committees (PLCs) (see below for further detail). In addition, there may be labour bodies that need to be consulted prior to, and involved in, fieldwork, as some questions that focus groups must address will relate to job status and employment opportunities.

Variables of interest
The following variables should be covered by the assessment, comparing pre- and post-project differences where relevant:

- 7-day road traffic counts, in line with TMH 14
  - Pedestrian data;
  - Vehicle data (refer **Table B 1**);
- Road accident statistics;
  - Vehicle accident (damage only);
  - Vehicle accident (damage only and injuries);
  - Vehicle accident (damage only and injuries/fatalities);
  - Number of vehicle occupant fatalities;
  - Number of pedestrian fatalities;

Table B 1 Vehicle types

Vehicle class	**Day**							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**Total**
Motor-Bikes								
Cars								
Number of passengers								
Bakkie								
Number of passengers								
Taxi								
Private Kombi								
Kombi Taxi								
C Kombi								
Short Bus								
Long Bus								
Truck-L								
Truck- Med								
Truck-Heavy								
Tractor								
Livestock								
Other								

- Employment opportunities during the road construction phase;
  - Number of full-time equivalent work opportunities for skilled workers;
  - Number of full-time equivalent work opportunities for semi-skilled workers;
  - Number of full-time equivalent work opportunities for low-skilled workers;

- Employment opportunities from routine road maintenance activities following the completion of the road construction phase;
  - Number of full-time equivalent work opportunities for skilled workers per annum;
  - Number of full-time equivalent work opportunities for semi-skilled workers per annum;
  - Number of full-time equivalent work opportunities for low-skilled workers per annum;
- Small contractor training during the road construction phase;
  - Number of SMMEs engaged in the project;
  - Contract value (Rands) directed to SMMEs;
  - Number of staff provided with NQF/SAQA accredited training;
    - Principals;
    - Supervisors;
    - General workers;
  - Number of NQF/SAQA accredited unit standards completed;
    - Principals;
    - Supervisors;
    - General workers;
- Roadside trading and community-service activities;
  - Number of vendors situated alongside the roadway;
  - Extent and size distribution of businesses using the road for access by customers and suppliers, and
  - Schools and health clinics that depend on the road for learner or patient access

Data and information collection process

Pre-project assessmentsentailwidestakeholderengagement to identify all potential impacts of the road project and to elicit therequireddata.Thepolicyofmost road authorities is to employ a Public Liaison Committee (PLC) as partofitsprojectstakeholderengagement process. The PLC acts as a communication mediator between theroadauthorityandthestakeholders, facilitating dialogue, transparency, and collaboration throughouttheproject'slife-cycle.ThePLC aims to create a forum for stakeholders to express their concerns, provideinput,andreceiveupdatesonthe project's progress. It also serves as a platform to address any issues orconflictsthatmayariseduringproject implementation. Beyond this, the PLC performs an executive functionbecauseitoverseestheadvertisement for and appointment of a Project Manager. This engagement processiscriticalintheSouthAfrican context as community concerns can and often do lead to project delaysandevencancellations.Asinmany other countries, levels of community trust in distant authorities andexpertsistypicallynothighin South Africa, and successful engagement with community informantsrequiresappreciationofthereasons for this.

The PLC is establishedatthebeginningofaroadproject by the road authority. It comprises representatives from the road authority,relevantgovernmentdepartments, local municipalities, community organizations, and other stakeholdersimpactedbytheproject.Thespecific composition of the PLC may vary depending on projects, but for evaluationpurposesitisrecommended that the following groups of project beneficiaries and interested partiesareatleastincluded:

- A representativegroupofcommunitymembers;
  - A spokespersonfromalocalschool;
  - A spokespersonfromalocalhealthcarefacility;

- A representative group of local business owners and managers;
- A relevant official from the contractor;
- Political officials;
  - o Government officials if appropriate (such as a representative from the District Municipality office);
  - o Ward Councillor(s), and
  - o Trade and labour union representatives if appropriate.

The composition of PLCs will vary depending on the project. Some LVSR projects will have a simpler PLC structure if they are located within very small and evidently quiet and cohesive communities, typically comprising one elected councillor who understands the issues and who enjoys the respect of other members of the PLC. However, LVSR projects that traverse several municipal wards or traditional authorities, as well as diverse interest groups, will require larger PLCs in order to be representative. It is important to stress, based on experience, that the composition of a PLC must include representatives from the main economic interests in the area. Principal economic sectors are usually organised, and representatives can usually be included in PLC subcommittees (see below) through direct engagement with the research team.

The PLC holds regular meetings, typically monthly or quarterly, to discuss project-related matters. These meetings provide a structured platform for stakeholders to voice their opinions, seek clarifications, and receive information from the road authority. The information typically shared by the road authority includes updates on project milestones and plans, socio-economic and environmental assessments, and potential impacts on the affected communities. This wide spectrum of already engaged stakeholders with pre-established and regular meeting times makes the PLC the preferred forum through which to conduct the pre-project and post-project assessments.

Experience strongly indicates, however, that at the scale of the whole PLC (in a complex project area) it is difficult to focus in real time on issues at the level of granularity to which assessments must attend. In order for project assessments to best use the PLC structure to recruit required ranges of informants, the PLC should be asked to create 3 sub-committees based on distinct domains of project impacts:

- Sub-committee 1: Community access;
- Sub-committee 2: Commercial activity, and
- Sub-committee 3: Procurement and training of labour, sub-contractors and service providers.

These sub-committees should each contain some PLC members but should also co-opt other community members based on knowledge and interest. Each sub-committee should meet about 3 times per assessment to investigate their particular areas using the guideline discussion questions as per Section 3.7. The outcomes of these investigation meetings should be reported back to the full PLC and community through ‘Town Hall’ style meetings.

In order to feed into assessments, and particularly to support systematic comparisons between pre- and post- project assessment phases, sub-committee and town hall discussions should be facilitated by a fieldworker trained at tertiary level in qualitative social research. This involves two key elements. First, discussions should be managed following focus group principles. These principles mainly concern ways of ensuring that some classes of participants (e.g. women, or younger people) are not silenced, and techniques for following up remarks to ensure that ambiguous comments are clarified. The latter is directly related to the second element of focus group facilitation expertise. Qualitative information must ultimately feed into quantitative welfare analysis by economists. This requires that it be coded according to a pre-designed metric. Focus groups thus resemble surveys with multiple simultaneous respondents. Agendas are important, and free-form discussions must be led to settle on clear enough alternative conclusions – on which, of course, there may be differences within the group – for these to be coded against the metric. This is a set of skills that requires professional training. Such training is available in all South African university programmes in marketing and organisational psychology. Thus, although the assessment exercises should be led by economists trained in quantitative welfare analysis, fieldwork teams should include post-graduate assistant researchers from disciplines that incorporate training in focus group design and facilitation.

Standard focus group discussion questions

The following set of standard focus group discussion questions has been prepared as guidance for the respective PLC sub-committees. The discussions and data should take place as part of both pre- and post-project assessments in order to effectively evaluate project impacts.

Specific questions for Sub-committee 1: Community access

1. As a community, what do you use the road for?
2. Other than (facilitator to list the uses/purposes/reasons mentioned in question 1) what else does the community use the road for?
3. Does this road currently serve the needs of this community very well? If not, why are you as community members not satisfied with the road?
4. Do all community members have easy access to the road? If some community members struggle to access the road, what are the challenges that limit easy access to this road?
5. Does this road help you as community members to access social services? If so, which social services do you access using this road?
6. Do children in this community depend on this road to go to school? How far must most children in this community walk on this road to get to school?

Specific questions for Sub-committee 2: Commercial activity

1. How important is this road to farmers in this community?
2. How important is this road to other business operators in this community?
3. How does this road help the different commercial operators in this community?
4. What challenges do commercial operators in this community face when using this road?
5. How can an upgrade or improvement of the road benefit commercial operators in this community?
6. Are there any people that sell or trade along the road? If so, what do they sell or trade in?

Specific questions for Sub-committee 3: Community engagement in the project

1. Who maintains thisroad? When it's time to do maintenance work on the road, do community members get employedto do some of the maintenance work?
2. Does the maintenanceof this road skills and tools that are locally available? Or does the maintenance of theroad require specialised skills and expensive tools and are not locally available?
3. How should availablework best be shared among those in the community who are capable of and interested in doing it?

General questions for PLC andTown Hall discussions:

1. What challenges is thecommunity facing when using the road?

2. How are you as community members affected by the current status of the road?
3. What can you say about the condition of the road?
4. What situations have made it difficult for the community to use the road?
5. How long does it take for (facilitator to name the situations given by participants) to be resolved so that the community can easily use the road again?
6. Let's talk about the rainy season (a bit more), what changes happen to the road during the rainy season?
7. How do the changes in the road during the rainy season affect you as members of the community?
8. Are you as community members satisfied with how this road is maintained? If you are not, why are you not satisfied?
9. How has the road affected the quality of life of the people in the community?
    a. How has the road positively affected your quality of life as community members?
    b. How has the road negatively affected your quality of life as community members of?
10. How important is this road to the livelihoods of community members?
11. Who are the people in the community that depend on this road to support their livelihood, and how do these people/groups use the road to support/sustain their livelihoods?
12. Does this road connect this community to other communities, towns, or cities? If so which communities, towns or cities does this road connect this community with?
13. Does this road connect with other transport routes? If so, which other routes are connected to this road?
14. Does this road help with transportation of people in and outside this community? If so, which transport routes depend on this road to move people in and out of this community?
15. As community members and road users, can you comment about travel time and costs related to using this road?
16. What mode of transport do people mainly use on the road?
17. How would you describe the motorised traffic volume and type in this road?
18. Are motorists using this road happy with the quality of the road? If not, what are some of the problems that they face when using this road
19. Can you describe the non-motorised traffic volume and type in this road?
20. Can having bicycles help this community use the road more efficiently and effectively? If yes, elaborate further.
21. Do you as a community consider the road as a good and safe road or bad and dangerous road?
22. Are there areas along this road that are perceived as concerning areas with regards to dangerous turns, blind spots or accident areas? If yes, elaborate on these areas.
23. Which accidents occur more frequently in this road?
24. Are there high rates of accidents that involve pedestrians or domestic animals on this road?

25. What do you think can be done to improve the road?

Details regarding sub-committee meetings and surveys

Project-adjacent business conditions and opportunities should be probed through surveys administered to local businesses. All relevant businesses along the road should be identified by driving the length of the road and mapping business sites. All businesses must then be contacted and presented with a standard description of the project. Those businesses successfully contacted should be given a version of the general survey questions below to complete and be assured that responses will be anonymised prior to analysis. The same companies should be surveyed in the pre- and post- project assessments.

1. What is the nature of your business?
2. In what year was your business established?
3. Is your business regarded as formal or informal business? Is it registered as such with the relevant authority?
4. What is the size of your business in terms of number of employees, floor space of physical premises, number of transactions per month?
5. Where are your main supplies sourced from?
6. What condition are these input supplies when they arrive?
7. Where are your main products delivered to?
8. What condition are these main products when they are delivered?
9. Do you have any comments about the current condition of the road being upgraded?
10. In what way, if any, does the current condition of the road being upgraded have an impact on your business' monthly profits?
11. How does the current road condition affect (positive or negative) trade and investment in the area?
12. How will the proposed road upgrade, when it is finalised and operational, influence trade in this area? What are prospective sectors and areas for trade activities, and trade routes? Why?
13. How will the construction of the proposed road upgrade boost investment in this area? What are the prospective sectors and areas for investment, trade activities? Why?
14. What are the principal barriers to trade and investment in the area?
15. When this road is upgraded, how do you expect it will influence your businesses during the construction/post-construction periods?
16. During road construction, the intention is to hire labour near the site to provide temporary employment.
    a. What types of skilled and unskilled labour are available in this area for temporary employment during construction?
    b. What impacts will the hiring of local labour have on your business, positive or negative?
17. What kind of services can potentially be provided by local businesses during construction?
18. What kind of business, if any, could be initiated in this area after construction, when the road is operational?

19. Sometimes the presence of infrastructural development leads to people setting up temporary businesses nearby the construction site. Would your business be thinking of doing something like this?
20. If other businesses set up trading nearby the construction site, do you think that this will result in increased competition against your business? How and what would be the impact on your business?

Procuring assessment expertise

In many countries (including some developing countries) there are companies that employ professionally trained social and economic researchers to conduct surveys and facilitate focus groups in rural areas. This capacity is not present in South Africa, largely due to the extreme nature of the gap between urban and rural service infrastructure. Most private-sector research companies based in cities lack expertise in work based in poor rural communities (because their business clients do not commission such work). The experience of the pilot studies that inform TRH24 demonstrated that satisfactory pre- and post- project assessments of the kind described here can only be carried out by researchers based in universities.

There is an additional reason for this beyond availability of relevant expertise. Road authorities rightly operate very stringent procurement rules for sub-contracted work. Fieldwork research teams cannot be expected to have the capacity to operate the required procurement protocols for sourcing their logistical provisions (e.g., transport, accommodations, catering, banking arrangements for compensating informants). These require numerous small providers that vary from assessment to assessment. Universities have such capacities. Their procurement rules, though stringent and effective at screening out conflicts of interest and fraud, differ from road authorities in that these rules are tailored to the practical circumstances of fieldwork researchers.

We therefore recommend that road authorities commission project assessments by issuing tender advertisements addressed to South African universities. Bids should be assessed according to the road authority's mandated criteria. Sub-contracting should be devolved to the university administering the project. Since the core of assessment is comparison of pre- and post- project exercises, the university that is awarded a tender should always be required to commit to performing both phases, however separated in time these may turn out to be as a result of unforeseen contingencies in project implementations.

Universities will only be able to bid for assessment contacts if suitably expert researchers in their employ are motivated to do the work. Academics are motivated primarily by opportunities to publish their research. Contracts for project assessments should therefore designate aspects of anticipated data that will be regarded as usable for publication of analyses through recognised peer-reviewed processes. Ethics committee oversight at all South African universities is sufficiently strong and reliable to ensure that all information furnished by community informants would be properly anonymised, and that informants rights to informed consent would be respected. Contracts should exclude use of proprietary data from construction and maintenance contractors in publications.

Publication and peer-review of findings from road project assessment research would enhance the credibility, rigour, and quality of analyses, and would enhance the accumulation over time, and public availability of, knowledge about the social returns on road infrastructure investment programmes.

Assessment cost estimates

Table B 2 and Table B 3 give anindication of general budget estimates for undertaking pre-project and post-project assessments. Theseestimates currently exclude flight and road transport costs, which will vary with project locations but must beappropriately factored into specific budgets. Moreover, budgets may differ depending on the number of jurisdictions covered by the road project, the number of affected communities and businesses, and the complexity of community dynamics.

Table B 2 Budget estimate (2024) for the pre-project assessment

Task	Team member Project leader	Unit Hours	# of units per project	Unit cost	Total cost per project
Regional situation analysis	Research assistant 1 Research	Hours Hours	32	R 950.00	R30 400.00
	assistant 2 Project leader Research	Hours Hours	4	R 800.00	R3 200.00
	assistant 1 Research assistant 2	Hours Hours	4	R 245.00	R 980.00
Pe-project scoping meeting	Project leader Research assistant 1	Hours Hours	24	R 950.00	R22 800.00
	Research assistant 2 Ac c omoda ti	Person nights	24	R 800.00	R19 200.00
	on Road travel Fl i g hts Catering	Kms R e turn	24	R 245.00	R5 880.00
PLC engagement meeting	Translation Project leader Research	Per head	16	R 950.00	R15 200.00
	assistant 1 Research assistant 2 Ac c	Hours Hours	16	R 800.00	R12 800.00
	omoda ti on Road travel Fl i g hts	Hours Hours	16	R 245.00	R3 920.00
	Catering Translation Participant	Person nights	3	R1 500.00	R4 500.00
	remuneration Project leader	Kms R e turn		R 4.00	R 0.00
	Research assistant 1 Research	Per head		R4 500.00	R 0.00
	assistant 2 Snowball by sub-	Hours Hours	15	R 100.00	R1 500.00
	committee members Project leader	Hours Hours	2	R 750.00	R1 500.00
PLC sub-committee meetings & meetings with businesses	Research assistant 1 Research	Hours Hours	40	R 950.00	R38 000.00
	assistant 2 Ac c omoda ti on Road	Hours Hours	40	R 800.00	R32 000.00
	travel Fl i g hts Catering Translation	Hours Person	40	R 245.00	R9 800.00
	Participant remuneration Project	nights Kms R	10	R1 500.00	R15 000.00
	leader Research assistant 1 Research	e turn Per		R 4.00	R 0.00
	assistant 2 Participant remuneration	head Hours		R4 500.00	R 0.00
	Catering Translation	Hours Hours	56	R 100.00	R5 600.00
		Hours Hours	8	R 750.00	R6 000.00
		Hours Per	192	R 35.00	R6 720.00
Survey analysis and report development		head Hours	80	R 950.00	R76 000.00
			8	R 800.00	R6 400.00
			40	R 245.00	R9 800.00
Sub-committee research			384	R 35.00	R13 440.00
PLC finalisation meeting			8	R 950.00	R7 600.00
			8	R 800.00	R6 400.00
			8	R 245.00	R1 960.00
			3	R1 500.00	R4 500.00
				R 4.00	R 0.00
				R4 500.00	R 0.00
			15	R 100.00	R1 500.00
			4	R 750.00	R3 000.00
			60	R 35.00	R2 100.00
				R 950.00	R7 600.00
Town Hall meetings			8	R 800.00	R6 400.00
			8	R 245.00	R1 960.00
			8	R 35.00	R7 000.00
			200	R 100.00	R5 200.00
			52	R 750.00	R3 000.00
			4		**R398 860.00**
Total cost (Excluding VAT)					

Table B 3 Budget estimate (2024) for the post-project assessment

Task	Team member	Unit	# of units per project	Unit cost	Total cost per project
Update and review of regional situation analysis	Project leader	Hours	32	R950.00	R30 400.00
	Research assistant 1	Hours	0	R800.00	R0.00
	Research assistant 2	Hours	0	R245.00	R0.00
PLC sub-committee meetings & meetings with businesses	Project leader	Hours	40	R950.00	R38 000.00
	Research assistant 1	Hours	40	R800.00	R32 000.00
	Research assistant 2	Hours	40	R245.00	R9 800.00
	Accomodation	Person nights	15	R1 500.00	R22 500.00
	Road travel	Kms		R4.00	R0.00
	Flights	Return		R4 500.00	R0.00
	Catering	Per head	56	R100.00	R5 600.00
	Translation	Hours	8	R750.00	R6 000.00
	Participant remuneration	Hours	192	R35.00	R6 720.00
Survey analysis and report development	Project leader	Hours	80	R950.00	R76 000.00
	Research assistant 1	Hours	8	R800.00	R6 400.00
	Research assistant 2	Hours	40	R245.00	R9 800.00
Sub-committee research	Snowball by sub-committee members	Hours	384	R35.00	R13 440.00
PLC finalisation meeting	Hours / Project leader Don Ross		8	R950.00	R7 600.00
	Hours / Research assistant 1		0	R1 450.00	R0.00
	Hours / Research assistant 2		8	R800.00	R6 400.00
	Person nights / Accomodation Road		8	R245.00	R1 960.00
	Kms / travel Flights Catering		3	R1 500.00	R4 500.00
	Return / Translation Participant				R0.00
	Per head / remuneration Project			R4.00	R0.00
	Hours / leader Research assistant			R4 500.00	R1 500.00
	Hours / 1 Research assistant 2		15	R100.00	R3 000.00
	Hours / Participant remuneration		4	R750.00	R2 100.00
	Hours / Catering Translation		60	R35.00	R7 600.00
Town Hall meetings	Hours		8	R950.00	R6 400.00
	Hours		8	R800.00	R1 960.00
	Per head		8	R245.00	R7 000.00
	Hours		200	R35.00	R5 200.00
			52	R100.00	R3 000.00
			4	R750.00	**R314 880.00**
Total cost (Excluding VAT)					

Appendix C. Physical Environment

General

The physical environment of the project site exerts a great influence on the design and performance expected from the upgrading of unpaved roads. It is thus essential to have a comprehensive understanding of the various factors that make up the physical environment of the road in the identification of uniform sections along the length of the road. The composition and nature of the subgrade soils along the alignment of a road, for example, are primary determinants of the requirements of the pavement structure. In addition, drainage design (Chapter 4) is dependent on climatic factors such as rainfall intensity and duration, while binder selection for bituminous surfacings (Chapter 7) is influenced by the prevailing ambient temperatures.

The purpose of this section is to highlight the various features of the physical environment that could affect the structural design of the road. Both the physical features and climate classifications are discussed and their potential impact on the design process is highlighted.

The following physical features are considered in this section:

- Topography;
- Geology;
- Soils, and
- Climatic zones and classification.

Maps applicable to the identification of the physical nature of a project and examples as to the use thereof are given in this appendix.

Topography

South Africa covers a large surface area and thus has a highly variable topography as a result of its long geomorphologic history. Most of South Africa's inland landscape is made up of high, flat plateau areas. These areas are covered with rolling grasslands and tree-dotted plains. To the east, south, and west of the plateau lands is a mountainous region (the Great Escarpment) as shown in simplified form in Figure C 1. The topography plays a major part in the route location and geometric design of the roads, with generally more costly works in the areas with more rugged topography. In addition, construction materials availability is strongly related to topography.

Detailed topographic mapping is available for South Africa at a scale of 1:50 000, which is more useful during design, although Digital Elevation Models (DEMs) allow easier use during design. Google Earth can also be used to identify major topographic features.

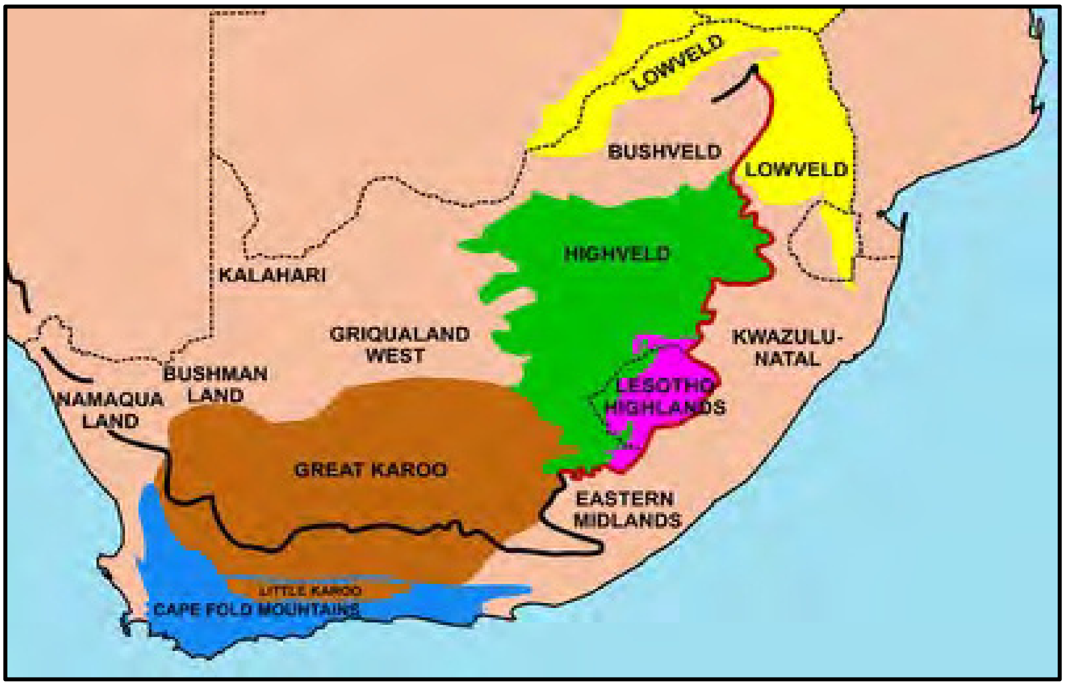


Figure C 1 Topographic regions of South Africa

Note: The thick black line traces the Great Escarpment which is marked by the red line in the area known as the Drakensberg

Source: (https://upload.wikimedia.org/wikipedia/commons/humb/c/cf/Regions_of_South_Africa_1.png/400px-Regions_of_South_Africa_1.png)

Geology

South Africa hassomeoftheoldestrocksintheworldresultinginavariedandcomplexgeology with large

areas of sedimentary,metamorphicandigneousrocksaswellasextensivetractsofrelatively young sands and pedocretes.

Surface geologymapsshowingpetrologyandlithologyaregenerallyavailableontheinternet, containing information aboutthegeneralin-situmaterialsandtheirvariationthatcanbeexpectedalong a road. This information willindicateweatheringpatterns(togetherwithapplicablemapsshowingclimatic factors such as temperatureandrainfallpatterns)andindicatesthemainrocktypes,thechangestotheirproperties that have occurredovertimeandtheexpectedmineralogythatispresentwithinanyspecificarea. Similar to all other data sources,theavailableinformationvariesfromthesuperficial(butuseful)generalised geological features, whichmayindicatetheoriginalprimaryrockformations,tomoredetailed(general country features) to verydetailedsurfacegeologymaps.

The geology alongtheroutealignmentwillaffecttheavailableconstructionmaterials,subgrade conditions, potential subgradeproblemmaterials,etc.andthismustbestudiedearlyintheproject.Figure C 2 shows a simplified geologicalmapofSouthAfricaatasmallscale.Itisrecommended,however, that all road design officeshaveacopyofthemoredetained1:1000000geologicalmapsofSouthAfrica available from the CouncilforGeosciencesinPretoria.Variousdigitalfilesforthismaparealsoavailable at:

https://www.geoscience.org.za/index.php/publication/downloadable-material.

Geological maps at various scales (down to 1: 50 000) are available from the Council for Geosciences in Pretoria.

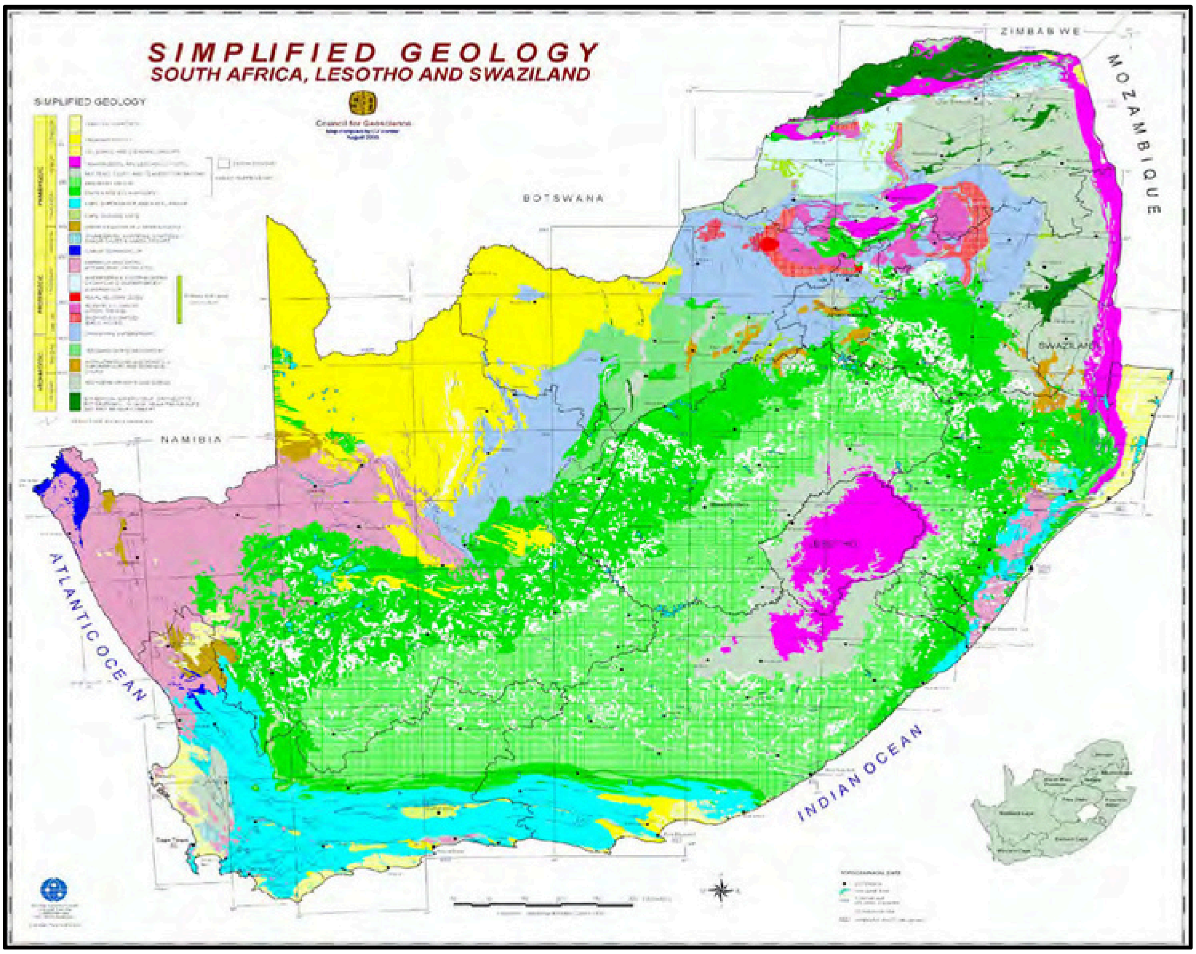


Figure C 2	Simplified geological map of South Africa

Source: (https://www.geoscience.org.za/images/Maps/rsageology.gif)

Detailed geological maps covering the whole of South Africa are available. These maps allow for a specific road under investigation to be scaled to the same level of detail as can be identified using Google Earth. This will enable the main geological features and their variations (if any) over the length of the route to be identified (example shown in Figure C 3).

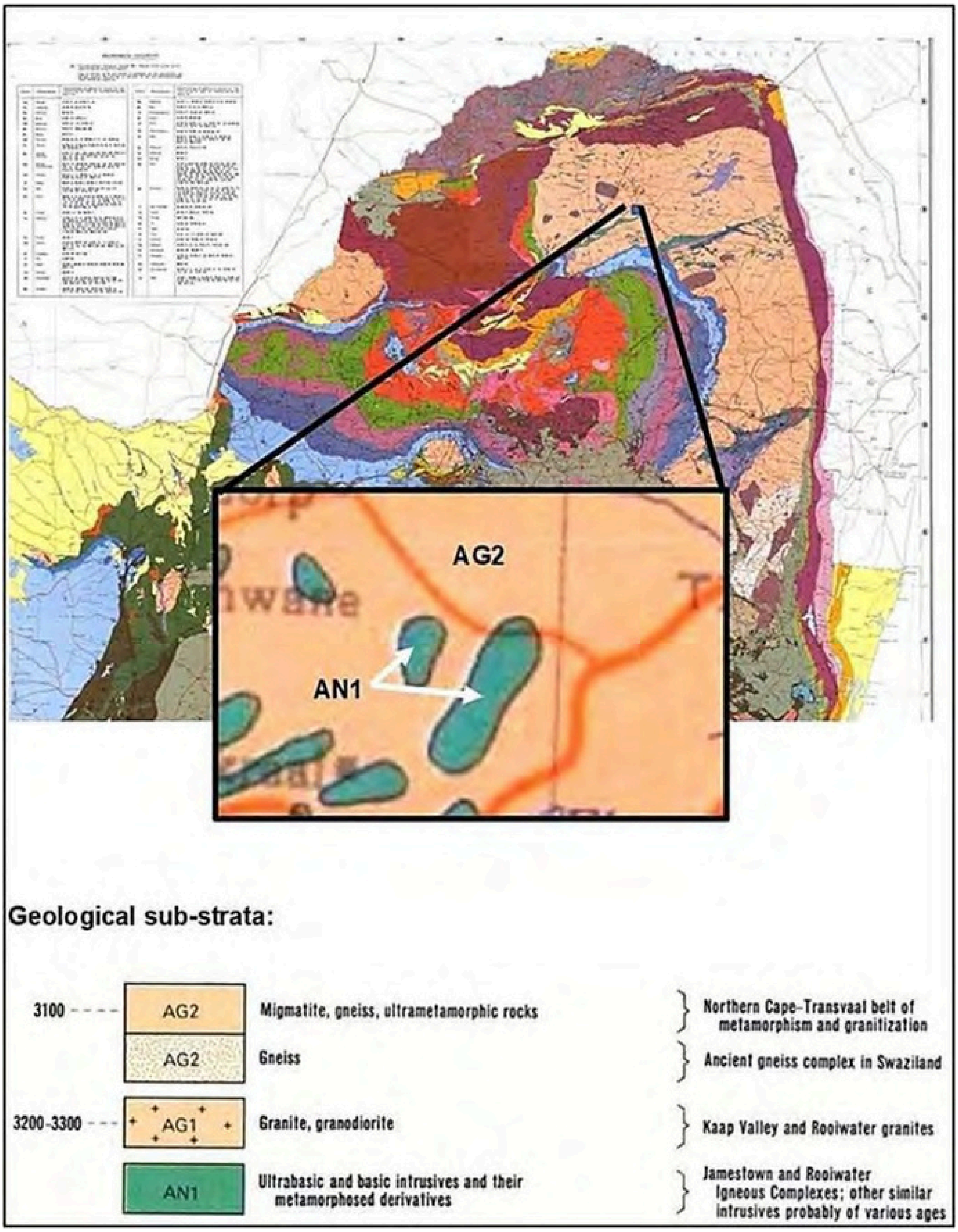


Figure C 3 Detailed geological map of the North of South Africa

Note: The location of the route scaled to the same scale

The rock types (lithologies) beneath the surficial soil cover can be used to get a preliminary indication of the type of residual material andsoils that would form from weathering and alteration of the underlying rock.

Large areas of South Africa, however, are covered by transported soils, and the underlying geology thus plays only a minor part in the overlying materials. The materials in areas covered by residual soils (derived from weathering of the in-situ material beneath them, are a direct function of the original material type as well as the type of weathering (decomposition or chemical weathering under wet environments and disintegration or physical weathering, where the materials break down with little change in their mineral composition).

The geology along the route alignment will affect the available construction materials, subgrade conditions, potential subgrade problem materials, etc. and this must be studied early in the project.

Knowledge of geology will provide the basic information necessary regarding the expected material types and properties in the area.

Soils

Soils comprise at least the upper metre of the land surface in most parts of South Africa and will affect the support and founding conditions of most roads. Like the geological maps, the soil maps of South Africa can provide important information regarding the underlying conditions along proposed road alignments. Figure C 4 shows the wide distribution and variety of broad soil patterns occurring in South Africa including coastal sands, swelling clays, plinthic soils, duplex soils, rocky soils, wetlands and many others (No legend is shown on the map in Figure C 4 due to a large number of soils present). This map has been developed from the 1: 250 000 soil maps covering the whole of South Africa that, together with their accompanying Memoirs are available from the Agricultural Research Council.

(https://www.arc.agric.za/arc-iscw/Product%20Catalogue%20Library/Land%20Type%20Maps%20and%20Memoirs.pdf).

Many different types of soil occur in South Africa, each the result of weathering through a combination of the climate and the source rock material as affected by the local drainage and geomorphology of the area during the formation of the soils over long periods (hundreds of thousands to millions of years). These parameters may be very different to those prevailing at present. However, it is important to understand the nature and type of minerals in these soils, especially when considering material improvement using chemicals.

Similar to surface geology maps, soil maps can easily be accessed to obtain knowledge about the expected materials and the variation thereof in the area through which the road is earmarked for upgrading traverses. Details on soils may vary from superficial to very detailed. The available detail will depend on the extent of detailed investigations that have previously been done in the area of interest.

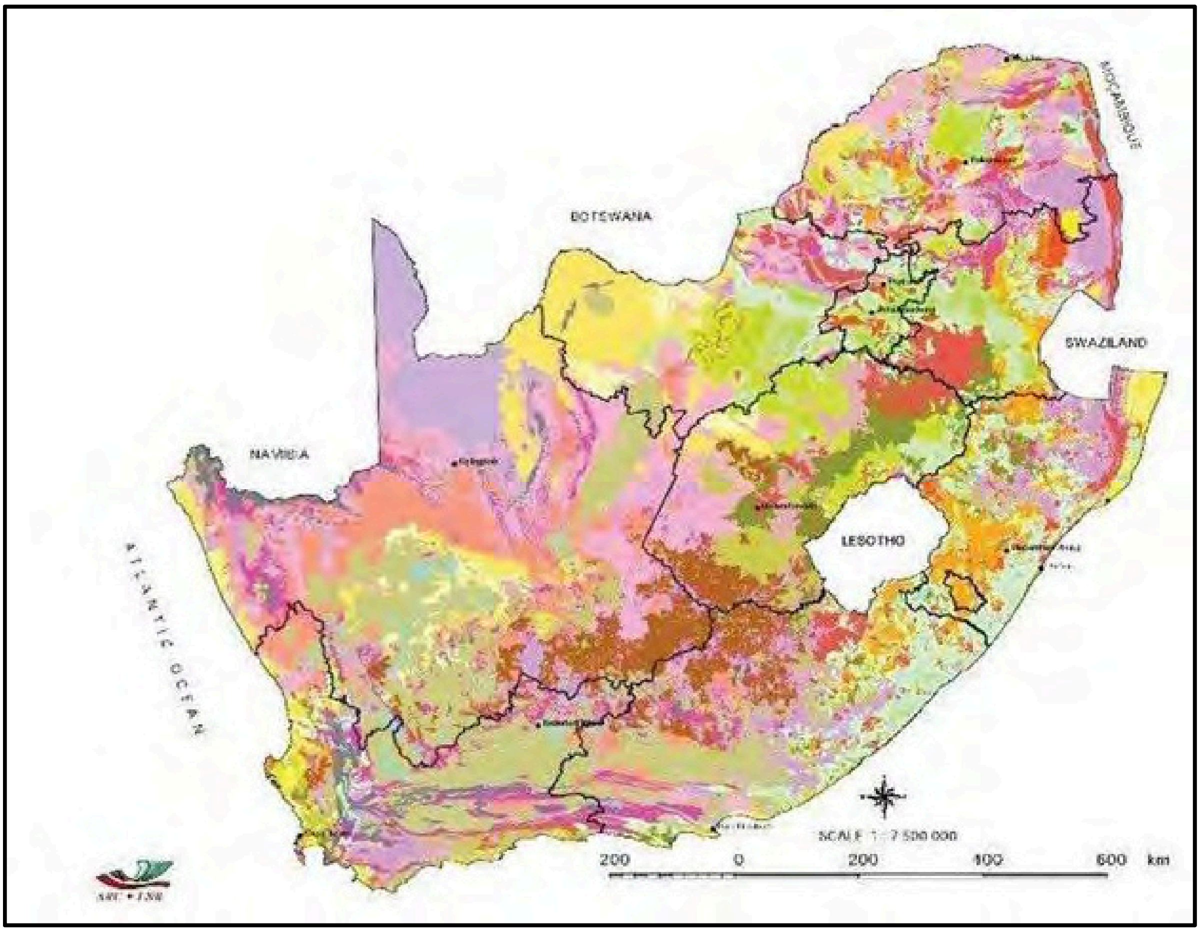


Figure C 4 Broad soil pattern map of South Africa

Source: (https://www.grainsa.co.za/natural-resource-assessments-for-agricultural-planning-and-development)

Similar to the other identified available data maps, considerable information may also be available on the soils covering the area of interest in which the identified route to be upgraded is situated. A detailed soil map covering the area of interest (as an example) of the unpaved route to be upgraded is shown in Figure C 5.

Referring to the major soil Classification systems, the following valuable information is readily available.

Three major soil regions can be identified within the borders of South Africa. East of approximately longitude 25°E, recent soils have formed under wet summer and dry winter conditions. The most important soil types in this region are Laterite (also called Ferricretes) (brown-red, leached, iron-bearing soils), un-leached sub-tropical soils and greyish (i.e., blue-grey, sticky, and compact) Podzolic soils (highly leached soils that are low in iron and lime). The example route used in the previous maps of reference is situated within this region.

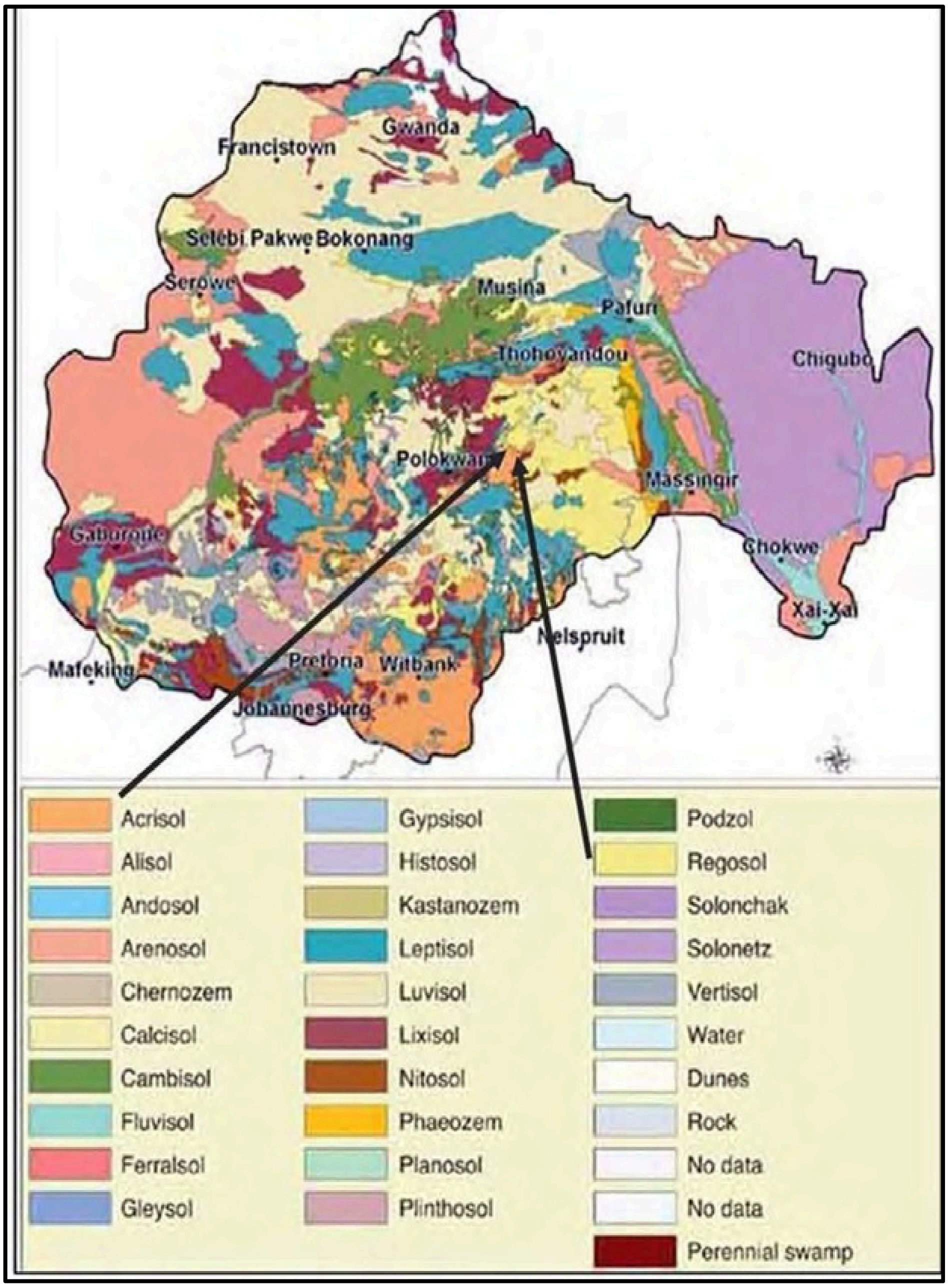


Figure C 5 Detailed soil-map of the area of the Gravel Road to beupgraded

The winter-rainfall coastal regions of the Western Cape and EasternCapecanbeidentified as a second major soil-region. Soil types within this region generally contain grey-sandyandsandy-loam soils. The rest of the country can mainly be classified as dry to very dry (semi-desert).Thisareaisassociated with soils consisting of a sandy top layer (often sandy-loam) underlain by a layeroflimeoraccretion of silica. South African soils are, with few exceptions, classified as low fertility with higherfertilitysoilsassociated with high chemical weathering characteristics.

The area of the route used as an example is related to the soil groups shown by the arrow markers Figure C 5. As shown, these soils associated within the general area can be associated with Acrisols and/or Regosols. Regosols only form about 8 per cent of the sub-region and are usually associated with dry or semi-desert regions with some exceptions. These soils are characterised by shallow, medium- to fine-textured, unconsolidated parent material that may be of alluvial origin and by the lack of a significant soil-horizon (layer) formation, due to dry climatic conditions. Regosols can show accumulations of calcium carbonate or gypsum in hot, dry climatic zones. The normal description of Regosols does not currently fit the general description of the area in which the example route is situated, indicating that they probably formed under past climates.

Acrisols typically form on an old landscape, such as that associated with an original Craton that developed into a continent over millennia. They are normally associated with an undulating topography and a humid tropical climate. The soil is associated with woodlands that gradually give way to tree-savannahs associated with seasonal burning. The age, mineralogy, and extensive leaching of these soils result in low levels of plant nutrition, excess aluminium and high erodibility with resultant problematic agriculture potential. However, acid-tolerant crops or plants, normally adapt well to conditions associated with Acrisols. The example route is associated with a relatively wet area for South Africa, associated with a hot, humid seasonal climatic region with high weathering characteristics that could more easily be associated with Acrisols.

Climatic zones and classification

It must be noted that all the available climate maps and zones included are based on long-term climate records. As the climate changes, any classification or boundaries between climatic zones based on temperature, rainfall or evaporation/ evapotranspiration (e.g., Köppen, Thornthwaite, Weinert, etc.) will be constantly changing until full climate-change mitigation efforts limit such changes. It is, however, a relatively simple calculation to determine the Weinert (Weinert 1980) or Thornthwaite index (Thornthwaite, 1848) at any point using weather data from a local weather station.

The climate is a major factor affecting roads both in terms of the weathered materials resulting from climatic effects on the local geology as well as the hydrology and drainage in the area. Due to its large area, South Africa has a wide range of rainfall and temperature conditions, with large variations from year to year. The Köppen Geiger weather zones are shown in Figure C 6, with most of the country being arid and temperate and a small area of Tropical savannah.

In terms of material weathering characteristics, the Weinert N-value (Weinert, 1980) (Figure C 7) and Thornthwaite Moisture Index (Thornthwaite, 1848) (Figure C 8) are widely used in pavement design as an indication of granular material weathering due to chemical decomposition. It can be seen that the two maps have similar trends, both being based on various combinations of temperature, rainfall and evaporation. The important boundaries on these maps are the N-values of 2, 5 and 10 which relate to wet, moderate and dry areas and the difference between the decomposition and disintegration of rocks. The equivalent Thornthwaite values are +20 (wet), 20 - -20 (moderate) and < -20 (dry).

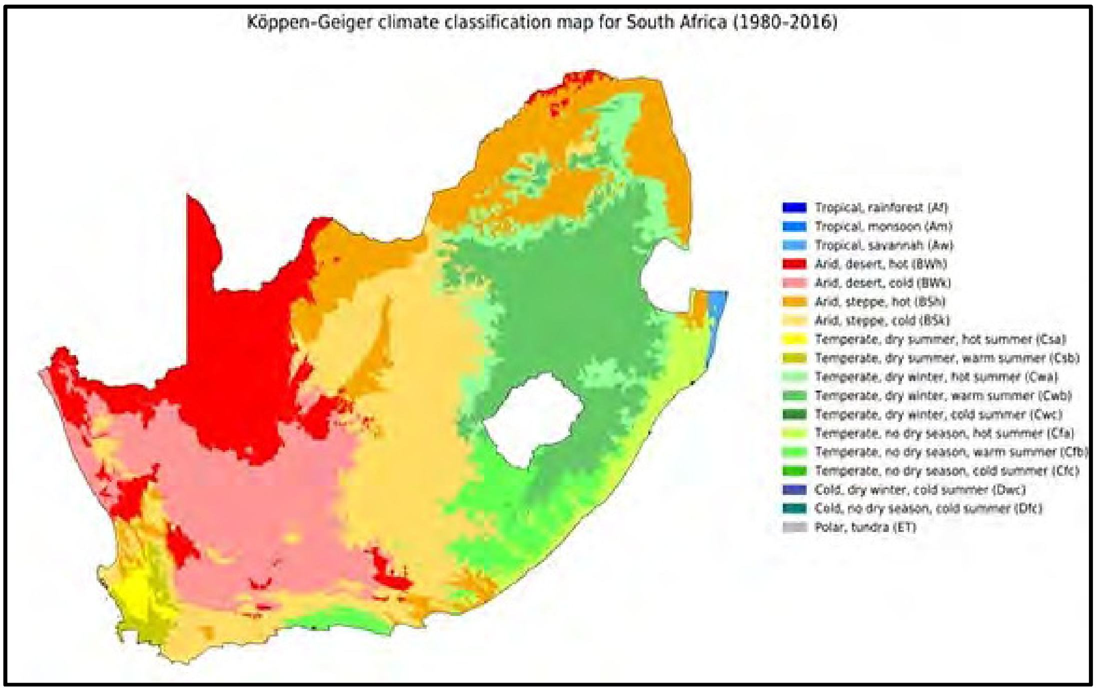


Figure C 6 Köppen Geiger climatic zones of South Africa

Source: (https://en.wikipedia.org/wiki/Climate_of_South_Africa#/media/File:Koppen-Geiger_Map_ZAF_present.svg)

Figure C 7 Simplified Weinert N-value map for South Africa

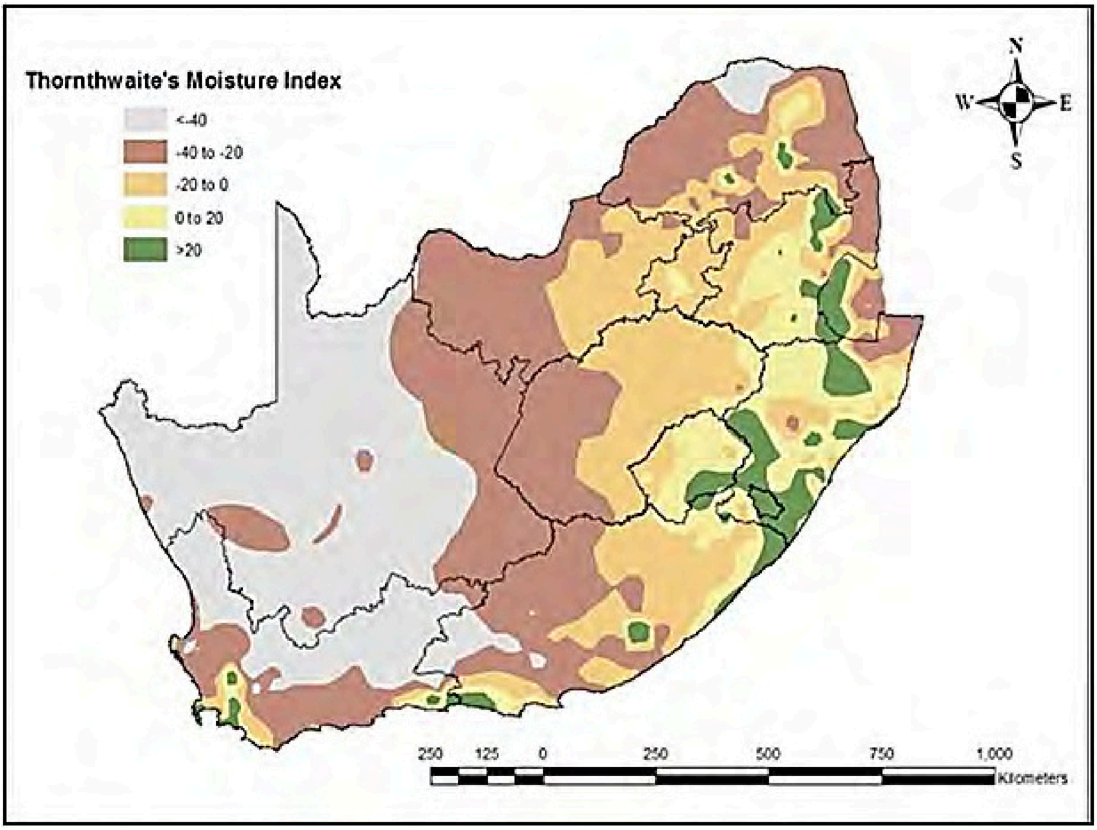


Figure C 8 Thornthwaite Moisture Index map for South Africa

Appendix D. Laboratory DN Testing and Selection of a Moisture Regime

Introduction

This appendix provides guidance for testing the adequacy of materials in a laboratory to perform well in the upper layers of a pavement in a selected climatic environment at specific densities.

Climatic environment – Refer Appendix C (Figures C6, C7 & C8)

The Climatic Zones (Figure C6) the Thornthwaite Moisture Index (Figure C7) and the Weinert N-value have been correlated against each other (taking into consideration that this is not an exact correlation of as these climatic indicators are based on different input values), as shown in Table D 1.

Taking into consideration the various climatic classification systems described in Appendix C, a climatic adjustment factor (Cf) has been correlated as shown in Table D 1. Table D 1 is then used to determine the Climatic Adjustment Factor (Cf), which is used as the expected equilibrium moisture content under which the upper layers of the pavement will perform.

Table D 1 Climatic areas

Adjusted Moisture Regimes	Climatic Adjustment Factor(Cf)	Climatic Zones of the World (Köppen, 1923)*	Thornthwaite Moisture Index	Weinert N-value
M1A: (Dry) - Arid	0.75	Bwh; Bwk	< - 40	> 10
M1B: Semi-Arid	0.90	Bsh; Bsk	-20 to -40	5 - 10
M2A: (Optimum) - Temperate	1.00	Csa; Csb; Cwa; Cwb	-20 to 0	2 - 5
M2B: Temperate-Wet	1.10	Csc; Cwc	0 to 20	< 2
M3A: (Wet) - Wet-humid	1.25	Cfa; Cfb; Cfc	20 to 60	
M3B: Sub-Tropical	1.35	Aw; As	60 - 100	
M4: (Soaked) - Tropical /Monsoon	1.50	Af; Am	> 100	

Preparation of test samples

The samples must be prepared following SANS 3001–GR30, as described below:

Procedure 1 – Scalping Method that applies to materials that have 30 per cent or more (by mass) retained on the 20 mm sieve, may be summarised as follows:

- Remove material passing the 37.5 mm sieve and retained on the 20 mm sieve and lightly crush by means of a steel tamper so that all the material passes the 20 mm sieve, and
- Recombine a portion of the crushed material, representing 30 per cent by mass of the original sample, with the rest of the original sample and mix thoroughly before testing.

Procedure 2 - Crushing Method that applies to materials that have 30 per cent or less (by mass) retained on the 20 mm sieve, may be summarised as follows:

- Screen field sample on20 mm sieve;

- Remove material retained on the 20 mm sieve and lightly crush by means of a steel tamper so that all material passes the 20 mm sieve, and
- Recombine the crushed material with the rest of the original sample and mix thoroughly before testing.

Note: *Care should be taken that the aggregate is not crushed unnecessarily small. If the material contains soil aggregations, these should be disintegrated as finely as possible with a mortar and pestle without reducing the natural size of the individual particles.*

Some natural, particularly pedogenic gravels (e.g., ferricrete, calcrete) can exhibit a self-cementing property in service, i.e., they gain strength with time after compaction. This effect must be evaluated as part of the test procedure by allowing the samples to cure/equilibrate before testing in the manner prescribed below:

Thoroughly mix andsplit each borrow pit sampleinto nine sub-samples for DN testing inaCBR mould at three moisture contents andthreecompactionefforts, asshownin **Table D 2.**

Table D 3 Sample requirements per Compaction effort and Moisture regime

Compaction effort	Moisture regime		
	Soaked	OMC	0.75 OMC
Light (4.5 kg rammer, 5 layers, 11 blows/layer)	3 samples	3 samples	3 samples
Intermediate (4.5 kg rammer, 5 layers, 22 blows/layer)	3 samples	3 samples	3 samples
Heavy (4.5 kg rammer, 5 layers, 55 blows/layer)	3 samples	3 samples	3 samples

The compacted samples should be allowed to equilibrate for the periods shown below before DN testing is carried out to dissipate pore-water pressures and compaction stresses and to allow the moisture content to equilibrate within the sample.

- 4-days soaked: After compaction, soak for 4 days, allow to drain for at least 15 minutes, then undertake a DCP test as described below in the CBR mould to determine the soaked DN value;
- At OMC: After compaction, seal in a plastic bag and allow to “equilibrate” for 7 days (relatively plastic, especially pedogenic, materials (PI > 6)), or for 4 days (relatively non-plastic materials (PI < 6)), then undertake a DCP test in the CBR mould to determine the DN value at OMC, and
- At 0.75 OMC: Air dry the compacted samples in the sun (pedogenic materials) or place the sample in the oven at a maximum of 50°C (non-pedogenic materials) to remove moisture. Check from time to time to determine when sufficient moisture has been dried out to produce a sample moisture content of about 0.75 OMC (it does not have to be exactly 0.75 OMC, but as close as possible). Once this moisture content is reached, seal the sample in a plastic bag and allow it to cure for 7 days (pedogenic materials) or for 4 days (non-pedogenic materials) to allow moisture equilibration before undertaking the DCP test at approximately 0.75 OMC. Weigh again before DCP testing to determine the exact moisture content at which the DN value was determined.

Test procedure

The procedure to be followed for determining the DN value of a material is similar to that for the more traditional CBR test except that a DCP is used to penetrate the CBR mould instead of the CBR plunger. Each of the specimens should be subjected to DCP testing in the CBR mould as summarised below.

A. Secure the CBR mould to the base plate, place the mould on a level (preferably concrete) floor, and place the annular weight on top of the mould;

B. Measure the height of the compacted specimen inside the mould. This is to enable the operator to stop the test just before the tip of the cone hits the base plate;

C. Place an empty CBR mould upside down or another device (e.g., bricks or cement blocks) next to the full mould, as shown in 1 to support the base of the DCP ruler level with or slightly higher than the top of the full mould;

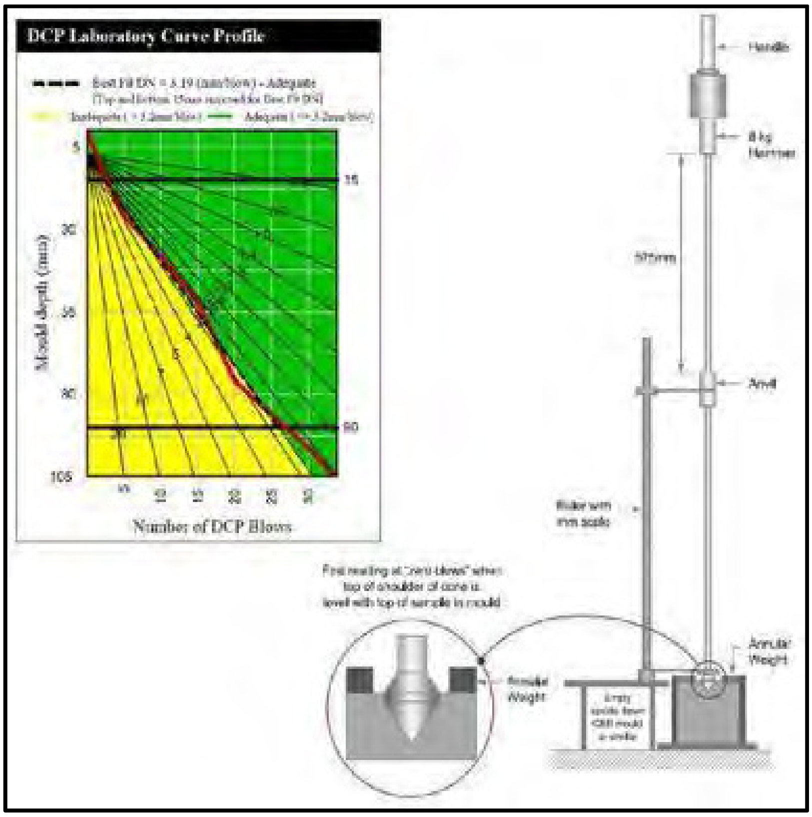


Figure D 1 Set-up and typical output from the laboratory DN test

D. Position the tip of the DCP cone in the middle of the CBR mould,hold the DCP in a vertical position, knock it down carefully until the top of the 3 mm shoulder ofthe cone is level with the top of the sample and record the zero reading;

E. Knock the cone into the sample with “n” number of blows and record the reading on the ruler after every “n” blows. At OMC and 0.75, OMC “n” may be any number between 1 and 10 depending on the hardness of the sample. At 4-days soak “n” may be 1 or 2. “n” does not have to be the same number for all readings;

F. Stop just before the tip of the cone touches the base plate in order not to blunt the cone (the last reading minus the “zero blows” reading must be less than the height of the sample inside the mould);

G. Enter the test data (sample description, number of blows and corresponding readings, etc.) into a spreadsheet or the Laboratory Module of the AfCAP LVR DCP Software. With a laptop at hand, the data can be entereddirectly as the test is carried out, and

H. Take a representative sample from the middle of the specimen for determination of the actual moisture content at which the DN value was determined.

Analysis of the test data

A typical output from the Laboratory Module of the AfCAP DCP DN software from the test of one sample is shown in Table D 3. The representative DN value for the specimen is taken as the slope of the “best fit” line from the middle of the mould. The DN value in the top and bottom 15 mm of the specimen often diverges from this “best fit” DN due to a lack of vertical confinement at the top and possibly a higher density at the bottom.

Note that the densities of each specimen for the same compaction effort and moisture content will never be exactly the same, as illustrated in Table D 3. It is therefore imperative that the volume of each mould is pre-determined, and that the laboratory equipment (particularly the scales) is properly calibrated to ensure that the actual densities of each specimen can be calculated with the required level of accuracy.

Table D 4 Summary of typical laboratory DN test results

[redacted]

Table D 3 shows a summary of a typical laboratory DN test, as described above. Plot the “best fit”DN values against the actual densities (average values of three specimens) in a diagram, as shown in Figure D 2**.**

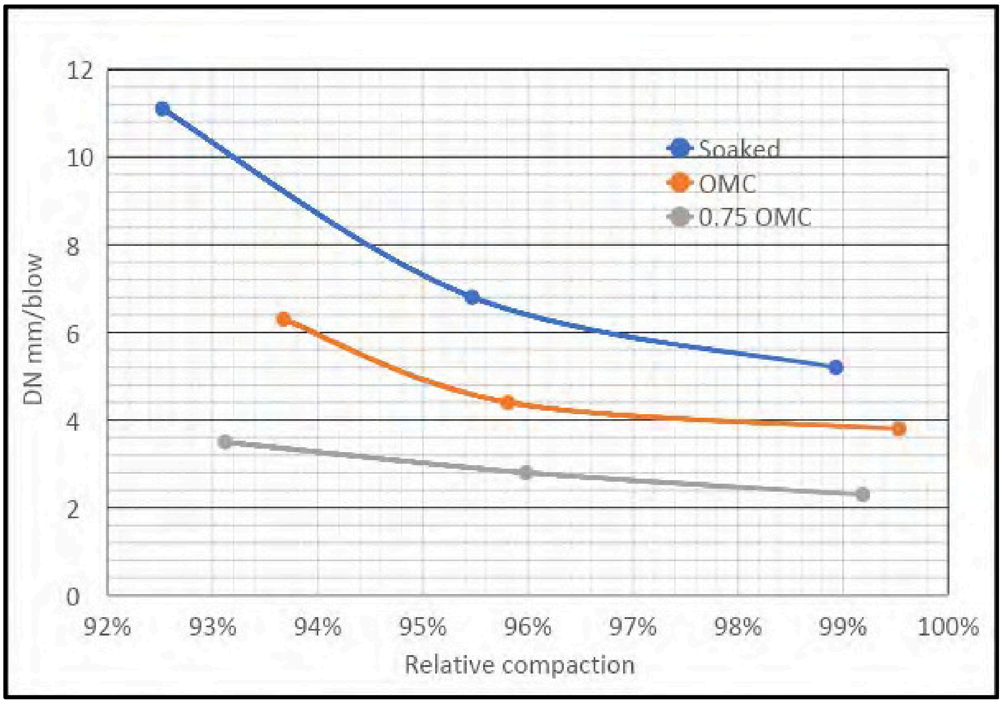


Figure D 2 DN/density/moisture relationship

Figure D 2 illustrates the relationships between DN, density and moisture content for a naturally occurring material. This will enable the designer to determine whether the material is suitable for use in the pavement, and where in the pavement it can be used based on the anticipated long-term moisture condition and the minimum field density of the layer(s) after compaction, by comparison with the requirements specified in the DCP-DN design catalogue for each pavement layer.

Figure D 2 also illustrates two critical factors that crucially affect the long-term performance of the road:

- The need to specify the highest level of density practicable (so-called “compaction to refusal”) by employing the heaviest rollers available. This will result in a stronger material with lower voids and reduced permeability, enhancing the overall properties of the material. Compaction to refusal (without degrading the material) is indicated by the number of roller passes, established through compaction trials, at which no additional density is achieved for any specific compaction effort. Additional compaction thereafter is a waste of time and money and may result in the breakdown of individual particles of the material. Compaction meters can help with identifying the optimum compaction effort.
- The need to ensure that the moisture content in the outer wheel track of the road does not rise above OMC. This will require careful attention to drainage, as discussed previously

Appendix E. Projects Specifications

Introduction

An “End product specification” will apply for the selection of a MC-NME stabilising agent using the test procedure as specified under C1003 – no alternative test procedure will be allowed. Should more than one stabilising agent meet the engineering specifications, the stabilising agent with the least cost for the stabilisation and improvement per cubic metre of the naturally available material, will be selected. The stabilising agent also needs to meet the minimum required specifications of stability on site without an increase in viscosity of more than ± 10 per cent and any visible separation.

The recommended project specifications apply to all categories of roads and are not restricted to the upgrading of unpaved roads. The criteria contained in Table C1002/1, applies to the upgrading of unpaved roads, the design of new roads and rehabilitation of roads, applicable both to lower-order and higher-order roads.

In rems of clarification, an NME stabilising agent is defined as:

Materials Compatible New Modified Emulsion (MC-NME) stabilising agents or similar where an emulsion is defined as any additive in the form of a solution, including any additive added to the construction water, including (but not limited to):

- Bitumen emulsions with/without a modified emulsifying agent (e.g., aggregate adhesive, water-repellent agents (e.g., organo-functional-silanes) and/or with the addition of polymers (micro- and or nano-polymers);
- Material-compatible polymers (micro- and/or nano-polymers, e.g. Nano Polymers Nano Silanes (NPNS)), or
- Any “alternative” rock/aggregate/soil stabilising agent.

Reference to a NME stabilising agent will be interpreted as to have the same definition as that of a MC-NME.

In the context of this document, MC-NME may be considered as an abbreviation covering the use of any or all of the above-mentioned stabilising or material improvement additives. However, the engineering requirements in terms of strength criteria, sample preparation and test protocol contained in this document must be met in all cases.

The **END PRODUCT SPECIFICATIONS** require an MC-NME to be verified prior to usage **AND GUARANTEED** by the contractor and/or supplier. It is important to note that the NME stabilising agent (or equivalent) is **costed in terms of cubic metre of the material that is being stabilised and not by the quantity of the stabilising agent.** The cost of a stabilising agent depends on the end result and not on the quantity added to the material.

Project Specifications

Add the New Section 5.6 to COTO (2020);

A5.6 CONSTRUCTION OF PAVEMENT LAYERS USING COLD IN-SITU STABILISATION WITH A MATERIAL COMPABIBLE NANO MODIFIED EMULSION (MC-NME) STABILISING AGENT

CONTENTS

In all cases, reference should be made to applicable sections within COTO, 2020. However, MC-NME stabilisation is not specifically addressed within COTO, 2020. Hence, these “Product Specifications“ have been compiled as complementary to COTO, 2020.

PART A: SPECIFICATIONS

A5.6. 1 SCOPE

This section covers work required for the construction of new roads (including upgrading of existing unpaved roads) or the rehabilitation of the upper pavement layers (base and sub-base) using the cold in- situ recycling process with (a) labour-intensive construction methods with a mixture of conventional equipment (b) conventional equipment, i.e., water-cart, grader(s) and compaction equipment (b) recycler and (c) central mixing plant. The construction of new pavement layers, using a MC-NME stabilising agent (or alternative stabilising additive) in an emulsified state (to be applied together with the construction water), is aimed at the use of naturally available materials (often in-situ) from the area of the road that can cost- effectively be utilised in the upper pavement layers.

The use of a MC-NME stabilising agent for the rehabilitation of existing roads is aimed at the optimum use of damaged or weathered in-situ materials in a cold in-situ recycling process. This may include a pre-stabilisation process of the milling and breaking-up of existing pavement layers (e.g., existing surfacing) and the mixing of the milled materials, with or without the addition of new materials to achieve a uniformly mixed material to be stabilised with the MC-NME. In such cases, the size diameter of the pre-milled materials should not exceed a third of the total thickness of the layer that is to be stabilised in-situ. After a homogeneous mix has been achieved, the material is stabilised in place with the MC-NME stabilising agent to produce a homogenous mix, which is spread, cut to level and compacted to the required specification. This section also covers the use of an applicable prime as a temporary surface for early trafficking. It is important to note that the prime must also be Material Compatible (MC) with the NME stabilising agent to ensure adequate adhesion.

A5.6. 2 DEFINITIONS

The relevant definitions in the standard specification are applicable. Additional definitions for this Section are included here.

Conventional equipment–thisisequipmentthat is normally used for the construction of the Works, including graders, water-bowsersandcompaction equipment. This equipment excludes equipment specifically designedandusedforin-situreconstruction works and/or for the recycling of materials.

Pavement rehabilitation–involvemeasuresused to improve, strengthen or salvage existing deficient road pavement structuressothatthesecancontinue (with adequate maintenance) to carry traffic at adequate speed, safetyandcomfortinacost-effective way (refer draft TRH12 – Road pavement rehabilitation investigationsanddesign).Roadpavement rehabilitation may involve various options, including:

- Complete pavementreconstruction;
- Partial reconstructionorin-siturecyclinginvolving the strengthening of existing pavement layers, with or withoutanapplicablestabilisingagent before re-surfacing;
- Asphalt and/orgranularlayerswithasuitable wearing course (surfacing);
- Concrete inlaysandoverlays;
- Levelling courses;
- Resealing withorwithoutrut-filling;
- Improvementorprovisionofdrainage(surface and/or sub-surface, and
- Any combinationoftheidentifiedoptionsas specified in the Contract Documentation.

MC-NME – Material Compatible New Modified Emulsion (MC-NME) - where an emulsion is defined as any additive in the form of a solution, including any additive added to the construction water, including (but not limited to):

- Bitumen emulsions with/without a Material Compatible modified emulsifying agent (e.g., aggregate adhesive, water-repellent agents (e.g., organo-functional-silanes) and/or with the addition of polymers (micro- and or nano-polymers);
- Polymers (micro- and/or nano-polymers) with/without a Material Compatible modified emulsifying agent (e.g., aggregate adhesive, water-repellent agents (e.g., organo-functional-silanes), or
- Any “alternative” rock/aggregate/soil Material Compatible stabilising agent.

Reference to a NME stabilising agent will be interpreted as to have the same definition as that of a MC-NME. **Slushing** - the process of wetting the surface of a compacted layer accompanied by rolling with a smooth-drum roller and/or a pneumatic tyre roller to generate saturated fine material, a slush, on the upper surface of the compacted layer. **Uniform pavement section** - an uniform pavement section has pavement layers with similar layer materials characteristics, similar layer bearing capacity properties and similar layer thicknesses throughout the section. A pavement section is considered as uniform when the Coefficient of Variation (CoV) of the measured properties is less than ± 25 per cent. Uniform pavement sections shall be clearly identified in the Contract Documentation. **In-situ materials** – materials within the existing pavement structure. In the case of an unpaved road in-situ materials would refer to the existing granular materials comprising the unsurfaced road.

A5.6. 3 GENERAL

A5.6. 3.1 Traffic accommodation

The traffic accommodation arrangements required during construction of roadworks in urban and rural areas are specified in Chapter 1 of the specifications.

A5.6. 3.2 Material selection

The material specifications in this section refer to:

- Reclaimed material from existing pavements shall be utilised as specified in the Contract Documentation. All reclaimed material from existing pavements, shall be broken down and oversize material removed, to comply with the maximum size and grading requirements for the particular use of the reclaimed material as specified in the Contract Documentation;
- Material Compatible Nano Modified Emulsion (MC-NME) shall be material sourced by the Contractor whereby the Contractor will take full responsibility and liability for using a stabilising agent not meeting the END-PRODUCT specification, and
- Material classifications must be in line with design specifications and material classification as contained in theContract documents.

A5.6. 3.3 Construction limitations

The Contractor shall arrange the processing and stabilisation of pavement layer operations in such a manner as to minimise the disruption of public traffic. Every effort shall be made to ensure that the safety of the travelling public on existing roads is prioritised throughout the site of the works at all times. In-situ processing and stabilisation operations shall be carefully planned and executed following the following limitations:

(a). Individual work areas shall be clearly demarcated with traffic signs, delineators and traffic control facilities as specified.

(b). Individual work areas shall be planned in such a manner that all processing and stabilisation of pavement layers and the compaction thereof as specified in Clause A5.6.7.13 be completed within the same day or period specified.

(c). No priming shall be done unless the processed and stabilised pavement layers have been tested, inspected and accepted by the Engineer. In cases where access needs to be given to the public, priming will be done on the instruction of the Engineer. With the enrichment of the processed and stabilised layers, light traffic (urban) can be allowed to use an un-primed layer with confidence, depending on the characteristics of the materials and the NME stabilising agent used, without any serious damage being inflicted on the stabilised layers. In such cases, the same procedures should be followed before priming and/or surfacing as discussed with light traffic being allowed to use a primed surfacing.

(d). Within each working area, the contractor shall make adequate provision for drainage of milled, excavated and/or asphalt overlay areas where water can pond or be contained within or on a road layer surface. No separate payment item will be made for the provision and use of standby pumps and de-watering equipment for cutting drainage slots and/or channels to effectively drain the roadway surface as instructed by the Engineer in the interests of safety for the travelling public. The Contractor shall make allowance for this drainage in this tendered rates.

(e). Delineators shall be placed along each longitudinal step exceeding 30 mm between adjacent lanes of the roadway. The maximum allowable step within a lane opened to traffic shall be restricted to 40 mm. If, due to plant breakdown or other unforeseen circumstances, a longitudinal or transverse step higher than 20 mm occurs within a lane, the strip shall be feathered off using quick-drying NME slurry or compacted asphalt over a distance of 500 mm to the satisfaction of the Engineer.

(f). In the event of rain occurring during the stabilisation process, the work must be stopped and the area must be sealed using a single roller pass. The continuation and stabilisation using the MC-NME stabilising agent shall only commence when the moisture content of the area has reduced to the level it was before it started raining or to an acceptable level with the necessary adjustments in the construction water and the NME stabilising agent as a percentage of the construction water.

A5.6. 3.4 Weather Limitations

No in-situ processing and stabilisation of materials shall commence if the threat of rain is present. The in-situ moisture condition should allow for the dilution of the NME in the construction water as described. Materials earmarked for stabilisation should be allowed to reach a moisture condition that allows for the mixing of the stabilising agent at the required moisture content. The ripping of the materials and exposure thereof to sunny conditions could assist with the natural drying of materials before the processing and stabilisation are to proceed.

A5.6.3.5 Protection and Maintenance

The Contractor shall protect the completed base layer from all damage until the surfacing is complete, or if opened to traffic, ensure that the surfacing complies with the required condition to the satisfaction of the Engineer. Any damage occurring to the completed base or any defects that may develop due to faulty workmanship shall be made good by the Contractor at his own cost and to the satisfaction of the Engineer.

Repairs shall be made in a manner approved by the Engineer to ensure an even and uniform surface.

During the working and construction of the base layer, precautionary measures shall be taken to prevent kerbs and channelling and concrete works from being damaged or shifted. Care shall be taken to protect all pre-cast units from chipping and breakage. Concrete kerbing and channelling, as well as other structures adjacent to the road, shall be protected against staining, by the NME product and the subsequent surfacing of the road. Any work stained by the NME and/or surfacing shall be broken down and replaced unless all such NME or surfacing material is completely removed so as not to show any stains. Painting over stained work will not be allowed.

Where the cold in-situ processing and stabilisation are to be carried out at existing structures, care shall be exercised to avoid damage to concrete elements, expansion joints, manholes, catch-pits, etc. Damage caused to any element forming part of the permanent works shall be repaired by the Contractor at his own cost.

Damaged caused by the Contractor through careless operations shall be repaired at his own costs. New construction shall be done following the drawings and the Specifications. The Contractor will be held responsible for the timely adjustment of all covers and frames in advance of surrounding construction, whether they are indicated on the drawings or by the Engineer or not. No claims for delays arising from the failure of the Contractor to affect the necessary adjustments in good time will be allowed.

The type of surfacing and selection of the binder or modified binder should allow for evaporation of moisture to continue (similar to any other type of pavement layer (e.g. granular, cement stabilised, etc.) that will continue to dry and reach an equilibrium moisture content due to evaporation over a period of at least two seasons). It should be noted that some modified binders inhibit the ability of the evaporation of moisture to occur, leading to the trapping of and concentration of moisture underneath the surfacing and formation of water below the surfacing which could result in early problems in terms of stripping of the surfacing and/or, in the case of chip-seals, punching of the stone (chips) into the base, resulting in severe bleeding of the surfacing and early failure (refer SABITA Manuel TG1 – The use of Modified Bituminous Binders in Road Construction - Table 12 : Advantages and disadvantages of modified binders compared with conventional binders).

A5.6.3.6 Construction Tolerances and Finish Requirements

Care shall be exercised to avoid damage to any concrete elements, expansion joints, joint nosing, manholes, kerbing, catch pits and any other roadside furniture during reconstruction of the layers. Damage causedto any element forming part of the permanent works **shall be repaired by the contractor at his own cost.**

A5.6.3.7 Programme of reconstruction work

All reconstruction work shall only take place in accordance with the accepted reconstruction programme which the Contractor shall compile and submit to the Engineer prior to commencing the reconstruction of each uniform road pavement section. The programme shall be updated and the updated programme shall be submitted to the Engineer at the end of each week.

Prior to the start of each single-operation of work, the Contractor shall prepare a M&U plan detailing proposals for the work. This plan shall at least include the following:

- Overall layout of the length and width of road intended to be reconstructed during the single-operation. The width shall be divided into the number of parallel cuts required to achieve the specified width of treatment;
- Location of and overlap width (minimum overlap of 200 mm) at each longitudinal joint between adjacent cuts;
- Location of the inner and outer wheel paths of each construction lane affected by the reconstruction;
- Sequence and length of each cut to be reconstructed before starting on the adjacent or following cut, and

- Estimateofthetimerequiredforthereconstructionalongeachcutandforfinishing off the work.

A5.6.3.8 Contractor plans for the reconstruction of existing roadworks

The Contractor shall prepare and submit an M&U plan for the RR of existing roadworks to ensure that it is worked in a sustainable and sensitive manner, to ensure that the environmental impact is minimised, that material use and haulage are optimised and that the work is carried out in a cost- effective manner.

The M&U plan shall at least take cognizance of the following and provide detail of the following as appropriate:

The pavement layer construction/rehabilitation programme;

- A method statement and programme for the construction of each of the pavement layers including the reclaiming of existing road materials, the breaking down and processing in-place of an existing pavement layer and the completion of each layer;
- Details of the programme for the movement of materials to ensure that the material is not handled unnecessarily;
- The survey methods to be used to set out and control the levels and width of the pavement layers for each processed layer;
- A method statement for the construction of a trial section using a recycler;
- A method statement of how oversize material will be dealt with;
- Measures to comply with the general and specific conditions of the road environmental management plan;
- Measures to comply with the latest applicable Construction Regulations;
- Measures to comply with safety regulations and obligations in terms of the latest Occupational Health and Safety Act;
- The full quality and process control testing detail for the applicable materials tests along with the frequency and quantity of such testing for each constructed section of each layer to ensure full compliance of the constructed layer in terms of compaction density, material quality and stabilisation testing (visual and laboratory), and
- Procedure for the regular monitoring, auditing and reporting.

The RR of an existing pavement layer shall only commence once the Contractor's M&U plan for that layer has been reviewed and accepted by the Engineer.

A5.6.4 DESIGN BY THE CONTRACTOR / PERFORMANCE BASED SYSTEMS

The Contractor will take full responsibility and liability for using a stabilising agent not meeting the END PRODUCT SPECIFICATION (EPS).

During the design phase, the Design Engineer must test and ensure that products are available that will meet the specifications with the given NAGM or mixture of materials (e.g., milled surfacing with NAGM base layer with/without additional NAGM).

A5.6. 5 MATERIALS

The use of a MC-NME stabilising agent (or alternative stabilising additive/product) aims to optimally use naturally available material (new or in-situ) in the upper pavement layers of a road meeting the minimum design requirements as specified in Table **A5.6.5/1** (applicable during construction for quality control and use during the detailed material design in the laboratory as detailed).

TABLE A5.6.5/1: Standard specifications for MC-NME stabilised materials

Test or Indicator	Material[1]	Material classification			
		NME1	NME2	NME3	NME4
Minimum material requirements before stabilisation and/or treatment (Natural materials)					
Material spec. (minimum) Unstabilised material: Soaked CBR2 (%) (CBR as % of MDD)	NG /(CS)	> 45[2] (95%) ACV < 30%	> 25[2] (95%)	> 102 (93%)	> 72 (93%)
Grading Modulus (GM)	NG	> 1.5	> 1.0	-	-
	GS	NA	> 1.0	-	-
Sieve analysis: % < 0.075 mm (P0.075) XRD scans: - Total sample - 0.075 mm fraction (P0.075)	ALL	< 25 %	<25 %	< 35 %	< 50 %
% Material passing 2 µm (P0.002) (e.g. Clay & Mica & Talc) as a % of	ALL	Required	Required	Required	Required
Material (with Talc <10%)	ALL	Required	Required	Required	Required
(XRD-scans of the material passing the 0.075 mm sieve are used to determine the % clay, mica and talc in the material – In this case P0.002 = P0.075 x (Pclay, etc. in P0.075)	MC-NME stabilisation with micro-meter (µm) emulsion particle sizes				
	< 15 % ALL	< 15 %	< 15 %	< 15 %	
	MC-NME stabilisation with emulsion containing micro-scale as well as nano-scale particles (adjusted according to material grading)				
	ALL	NA	< 35 %	< 35 %	< 35 %
	MC-NME stabilisation with emulsion containing nano-scale and pico-scale particles (grading adjustments) together with technologies addressing workability of materials on site				
	ALL	NA	NA	> 35 %	> 35%
Material specifications after stabilisation and/or treatment					
In-situdensity to berequired after stabilisation and compaction (% of MDD)	Base	>100 %	> 100 %	> 98 %	> 97 %
	Sub-base	NA	> 98 %	> 97 %	> 95 %
DCP(DN mm/blow)(Quality control in field testing - base only) (stabilised and compacted = wet; 7 days cured = dry)	DCP-DN	NA	NA	< 2.6(wet) < 2.0(dry)	< 3.5(wet) < 2.3(dry)
Density (% of MDD) (for laboratory testing)		> 100 %	> 100 %	> 100 %	> 100 %
*UCSwet (kPa) (150 mm Φ Sample)	**Design[3]**	**> 2 500**	**> 1 500**	**> 1 000**	**> 750**
	Construction[4]	**> 2 200**	**> 1 200[5]**	**> 700[5]**	**> 450[5]**
Retained Compressive Strength (RCS): (UCSwet/UCSdry) (%)	RCS	> 85	> 75	> 70	> 65
RCS in relation to minimum UCSwet(criteria) = RCSeffective = (RCS x (UCSwet/UCSwet(criteria))) (%)	RCSE	>100	> 90	>85	> 80
*ITSwet (kPa) (150 mm Φ Sample)	**Design[3]**	**> 240**	**> 200**	**> 160**	**> 120**
	Construction[4]	**> 220**	**> 180[5]**	**> 140[5]**	**> 100[5]**
Retained Tensile strength (RTS): ITS_{wet}/ITS_{dry} (%)	RTS	> 85	> 75	> 70	> 65
RTS in relation to minimum ITSwet(criteria) = RTSeffective = ((**RTS** x (ITSwet/ITSwet(criteria))) (%)	RTS-R	>100	> 90	> 85	> 80

[1]CS – crushed stone;NG–naturalgravel; GS – gravel soil, and SSSC – sand, silty sand, silt, clay.\
[2]CBR only used as reference to traditionally used test procedures as a broad first indicator

*Definitions: UCS = Unconfined Compressive Strength; ITS = Indirect Tensile Strength);
UCSdry; ITSdry = testing after rapid curing; UCSwet; ITSwet = testing after rapid curing and 4 hours in water (as per testprocedure specified for the testingof cementitious stabilising agents (SANS 3001-GR32:2010, 2010));
Design3 = Minimum criteria to be met in the laboratory during the design phase
Construction4 = Minimum criteria to be met during construction as part of quality control
[5]Criateria based onreference TG2 (Asphalt Academy,2009)
RCSeffective and ITSeffective are used to obtain and effective Material Classification, i.e., NME1 to NME4

The aim is to cost-effectively utilise NAGM as an alternative to new crushed-stone materials in both the upgrading of existing unpaved roads, design and construction of new roads as well as the rehabilitation of existing pavements, through the improvement of appropriate available materials normally considered to be “non-standard”, “marginal”, “low-cost”, or even “sub-standard” in terms of the standard material indicator tests.

A MC-NME stabilising agent will be able to neutralise the effect and possible negative impact of secondary minerals formed during weathering as a result of chemical decomposition and nullify any possible risk associated with the use of the potentially water sensitive natural materials by meeting the material classification criteria specified in Table **A5.6.5/1** for the design material class (NME1 to NME4).
Materials from existing pavement layers shall be classified as follows for excavation and processing purposes:

A5.6.5.1 Existing bituminous materials

Bituminous material shall be an asphalt surfacing or a bituminous seal from an existing layer. Where the asphalt surfacing and bituminous seal are recycled together with the underlying layers, the mixture will not be classified as bituminous material.

A5.6.5.2 Granular Materials

The base and sub-base pavement layers in the existing pavement shall be classified as granular materials. Granular material shall include crushed stone, gravel soil and natural gravel and can consist of cemented or non-cemented material. Crushed stone obtained from existing pavements and processed as gravel material will be paid for as gravel material and not as crushed stone.

The mixture of bituminous material (RA) and base and sub-base material shall be classified as granular material.

A5.6.5.3 Extra material

Extra material as specified consists of:

(a). Naturally Available Granular Materials (NAGM) (and (if cost-effective) crushed stone materials). The pavement layers will be designed based on the requirements of the design traffic loadings and the material specifications required for the various pavement layers as designed, complying with Table **A5.6.5/1.**

(b). Crusher dust.
No crusher dust is to be used with a NME stabilising agent unless specified for that specific alternative stabilising agent.

(c). Gravel.
The gravel material shall be of a minimum quality as per Table **A5.6.5/1.** (Higher quality materials will normally require less of the MC-NME stabilising agent and/or the modifier contained withing the stabilising agent, depending on the inherent mineralogy.)

A5.6.5.4 Material stabilisation/improvement products/additives

(a) Stabilising Agent: MC-NME as defined in the preamble to the Project Specifications. During the Detailed Design Phase of the project, the Design Engineer must identify the potential use of an NME for the improvement of materials not adhering to the design characteristics and the volume of material for such stabilisation calculated for inclusion in the Bill of Quantities (BOQ). Contractors and their suppliers must show proof of concept and provide guarantees to the following:

The MC-NME stabilising agent must be environmentally stable and produce/release NO adverse negative substances during the process of hydrolysis (i.e., when mixed with the construction water) and condensation (i.e., when attachment to the material/soil occurs). A Safety Sheet to this effect must be produced by the supplier. The specified cold-mix NME must be stable in containers (i.e., flow-bins or tankers) on site (with or without minimum maintenance (e.g. weekly circulation of the stabilising agent - **the cost of which will be included in the cost of the stabilising agent**)) for a minimum period of at least 4 months. At all times during site storage, the MC-NME stabilising agent will be workable tobe used with thetested material to meet the applicable designcriteriaascontained in Tables **A5.6.5/1. The supplier/contractor shall take full responsibility (and cost implications) for using an NME stabilising agent resulting in inferior test results and/or stability as per Clause A5.6.4.**

The NME stabilising agent as provided by the contractor with his supplier as guaranteed by the contractor, must at all times meet the specified criteria for the specific pavement as contained in Tables **A5.6.5/1.** It should be **noted that different specifications are applicable for the design in the laboratory and quality control during construction** to allow for laboratory versus site variations and conditions. The prescribed test procedures are detailed in Clause **A5.6.9.2**.

The MC-NME stabilising agent must have a guaranteed minimum on-site storage stability exceeding **4 (four)** months and a workable Viscosity during all seasons of the year without pre-heating, allowing for the in-situ cold recycling of the available materials, taking into account storage athigher ambient temperatures duringthesummer months and possible cold temperatures during winter months. The contractor **will take full responsibility for maintaining the stabilising agent on-site to ensure that it will remain stable during storage with no visible separation and without an increase in viscosity during storage. The NME must meet the following minimum specifications proven by the supplier/contractor:**

- A guaranteedshelflifeon-site(e.g.,in flow bins if applicable) **exceeding (at least) 4 (four) months or as specified by the engineer**. (The shelf life can normally be increased to atleast 6 to12monthsthroughthe circulation of a quality MC-NME mix once a week using a normal circulation pump.)
- Laboratory testresultsusing the prescribed rapid curing test procedure on available materials from site testingtheUCS (dry and wet) and ITS (dry and wet) and meeting the required Retained CompressionStrengths (RCS) (UCSwet/UCSdry in percentage) and Retained Tensile Strengths (RTS) (ITS_{wet}/ITSdry in percentage), as well as the required Effective, Retained CompressiveStrength(RCSeffective = RCS x (UCSwet/UCSwet(criteria))) and Effective Retained Tensile Strengths(RTSeffective=RTS x (ITSwet/ITSwet(criteria))). **The RCSeffective and ITSeffective will be used for thematerialNME classification**. The average values of at least 3 tests shall be used to obtainthelaboratory results. The laboratory results should meet the criteria for the design phaseascontained in **Table A5.6.5/1** (the higher design criteria take into account variations betweenlaboratory and on-site conditions). The RCSeffective and ITSeffective are used to get the Materialclassmost closely associated with the NME stabilisation.
- Additional testsamplesshall be prepared and cured at 22-25°C for 28 days and retested. The test results shouldeithershow similar or higher results as tested after the initial rapid curing process as prescribedinTable **A5.6.5/1** to ensure that no negative mineral and or stabilising agent interactionordegeneration of polymers (where applicable) occurs.

The prepared MC-NMEonsite must be ready for immediate dispersion within the construction water (using a standardcirculation pump) and ready for stabilisation. It is important to note that all containers and water tankers must be thoroughly cleaned before the MC-NME is added. Unclean (contaminated) equipment could result in activating any residual bituminous mix left in the container orwater tanker when the MC-NME is added,resulting in anunusablesticky substance, suchas ballsor strings ofbitumen. **Any losses occurred during construction due to the use of contaminated equipment will be at the cost of the contractor.**

(b) Additives for granular material stabilisation/treatment alternatives other than those defined in Item

The material stabilisation/treatment additive must have a guaranteed on-site stability exceeding 4 (four) months takingintoaccount storage at high ambienttemperaturesduringsummermonths andpossiblecoldtemperaturesduringwintermonths. **The supplier/contractor will take full responsibility for maintaining the stabilising additive/product on site to ensure that during storage, before application, the additive /product will remain stable with no visible separation of particles and without any change in measurable properties during storage (e.g., an increase in viscosity). The stabilised mix must meet the following minimum specifications proven to be the supplier/contractor:**

- Aguaranteed shelf-life on-site (e.g., in flow bins if applicable) exceeding 4 (four) months. (The shelf-life can normally be increased to at least 6 to 12 months by maintaining the additive/product regularly as required by the supplier.);
- Laboratory test results using the prescribed rapid curing test procedure on available materials from site testing the UCS (dry and wet) and ITS (dry and wet) and meeting the required Retained Compression Strengths (RCS) (UCSwet/UCSdry in percentage) and Retained Tensile Strengths (RTS) (ITSwet/ITSdry in percentage), as well as the required Effective, Retained Compressive Strength (RCSeffective = RCS x (UCSwet/UCSwet(criteria))) and Effective Retained Tensile Strengths (RTSeffective=RTS x (ITSwet/ITSwet(criteria))). **The RCSeffective and ITSeffective will be used for the material NME classification** The average values of at least 3 tests shall be used to obtain the laboratory results. The laboratory results should meet the criteria for the design phase as contained in Table A5.6.5/1 (the higher design criteria takes into account variations between laboratory and on-site conditions), and
- Additional test samples shall be prepared and cured at 22-25°C for 28 days and retested. The test results should either show similar or higher results as tested after the initial rapid curing process as contained in Table **A5.6.5/1** to ensure that no negative mineral and or stabilising additive/product interaction or degeneration of the additive/product (where applicable) occurs as an indication of durability. The prepared stabilising additive/product on-site must be ready for immediate dispersion within the construction water (using a standard circulation pump) ready for stabilisation or the supplier must clearly specify the process of application during the construction process to ensure that auniformmix with uniformqualities is achieved. **The differences in methods of application will be to the cost of the contractor.**

It is important to note that all containers and water tankers must be thoroughly cleaned before any stabilising additive/product is added. Unclean (contaminated) equipment could result in the activating of any residual mixleft in the containerorwater tankerwhenthe stabilising additive/productis added, resulting in anunusablesubstance. **Any losses occurred during construction due to the use of contaminated equipment will be at the cost of the contractor.**

c) Water.

Water used for diluting the stabilising additive/product shall be potable water (clean and free from salts and contamination)that will cause the stabilising additive/product to be adversely affected by these chemical impurities. The stabilising additive/product will be tested for compatibility with the compaction water. Water must be potable and the pH shall not exceed 7 (or as required for the use of the specific stabilising additive/product). Should local sources be considered, prior laboratory testing toensure acceptability willbe required. The quality of the water must adhere to the requirements given in Table A5.6.4/1 **Any additional requirement for the construction water as required by the supplier of the stabilising additive/product will be the cost of the contractor.**

d) Chemical modification of material

No additional chemical modification of the stabilised material will be allowed if not contained in the original specification. **In all cases, the requirements as given in Table A5.6.5/1 must be met.**

e) Stabilisation of sub-base

In the case of the rehabilitation of an existing road or the construction of a new road, the sub-base shall conform to the requirements of the layer as per design. In all cases, the possible consequences and compatibility of the layer characteristics, in terms of the expected behaviour of the pavement structure as a whole, needs to be assessed by the Engineer.

A5.6.5.4 Composition of Recycled Mixes

During the rehabilitation of existing pavement layers, the recycled material shall consist of the existing surfacing (where present), granular material from existing pavement layers, additional material where required and an applicable NME stabilising agent/product. The actual composition of the mix shall be determined by design requirements. The NME stabilising agent with proof of concept will be provided by the contractor and approved by the Engineer to comply with the testing requirements as specified in Table A5.6.5/1 as obtained using the test methods as detailed under Item A5.6.9.2. Any NME stabilising agent not meeting the requirements of a specific layer during construction will be to the cost of the contractor

Adjustments to the actual mix constituents are not normally required as it is already accounted for in the differences in specifications for the design versus in-field conditions during construction (some slight adjustments may be authorised by the Engineer, based on the results of the trial section taking into account additional factors such as equipment used, e.g. conventional equipment vs recycler vs central mixing plant and climatic conditions) – in all cases such adjustments must be authorised by the Engineer. The Engineer reserves the right to adjust the composition of the mix at any time should he deem it necessary. The Contractor and Supplier shall provide the Engineer with the proposed final mix proportions based on the required test results and the Engineer must approve the results before any materials are ordered. **The risk of alternative designs using any alternative additive/product not specified remains with the Contractor as per normal contract specifications.**

The average values for in-situ moisture contents shall be tested by the Contractor and confirmed by the Engineer prior to any work commencing on any specific day for adjustments in the amount of construction water together with the stabilising agent to be made if necessary.

Table A5.6.6.4/1: Water classification for Construction Testing

Property	Unit	H0	H1	H2	H3	H4	H5	Method
		Water Quality Classification Code						
Property	Unit	Pure water (AR) water	Clean (Rain)	Treated water (Municipal)	Silty (muddy) water with low salt content	Highly mineralised chloride sulphate water (brackish)	Waste brick, sewage, marsh, sea, etc. water	Method
PH*	-	7.0	5.7 – 7.9	4.5 – 6.5	4.5 – 8.5	9.0	-	SABS M113 SM 1990 - SABS 213
Dissolved solids*	ppm	0	1000	1500	3000	-	-	SM213 1990 - SABS 215
Total hardness*	-	None	None	Temporary	Temporary	Permanent	-	SM 215 - 1971 SABS 1049
Suspended matter	ppm	0	2000	2000	5000	-	-	SM 1049 - 1990 SABS 1057
Electrical conductivity	mS/m	0	200	200	500	-	-	SM 1057 – 1982 SABS 212
Sulphates (SO4)	ppm	0	200	300	500	1000	-	SM 212 - 1971 SABS 202
Chlorides (Cl)	ppm	0	500	1000	3000	5000	-	SM 202 - 1983 SABS 241 - 999
Alkali Carbonates (CO3) & Bicarbonates (HCO3)	ppm	0	500	1000	1000	2000	-	
Sugar	-	Negative	Negative	Negative	Negative	Negative	-	SABS 833
Quality of water required		Untreated layer works	a	a	a	a	Investigate effect on the quality	
		Chemically treated layer works	a	a	Investigate the effect on the quality of the stabilised material	Investigate the effect on the quality of the stabilised material		
		Concrete mass	a	a	a	Investigate the effect on the quality		
		Concrete prestressed	a	a	References: 1. Concrete Technology– Dr S Fulton (1989) 2. Materials Manual (PAWC)			
		Slurry & emulsion	a	a				
		Soil/gravel tests	a	a				
		Chemical or control tests	a	a				

A5.6. 6 CONSTRUCTION EQUIPMENT

A NME stabilising agent is usually highly reactive. Hence, it is imperative that all storage tanks, water tanks, etc., must be thoroughly cleaned (normal good housekeeping site operations), with no residue from previous mixes present in these tanks. The contractor shall allow the engineer to inspect the equipment before use, to ensure that the equipment is suitable for use with the NME stabilising agent or any other alternative as submitted for use by the contractor and his supplier. In all cases the supplier shall ensure that the stabilising agent application is clearly specified and the contractor shall take full responsibility to meet the specifications of the supplier. The NME stabilising agent in use must be freely available to the Engineer to test for quality control purposes at any time.

A5.6.6.1 Conventional Plant

A heavy-duty motor-grader is an essential item of plant for NME stabilisation, irrespective of the combination of any of the other plant items used. This grader is required to pre-shape the material prior to being treated, for processing the material and thereafter, to cut the layer to final levels. Processing by grader includes mixing the material prior to treatment and mixing in of the NME diluted within the construction water or alternative additive/product as specified and guaranteed by the contractor and his supplier.

In the case of in-situ recycling of existing surfaced pavement layers, a milling machine will be required to adequately mill asphalt or multiple seals and/or high-strength cemented material to produce a material of a size suitable for the stabilisation or treatment with the stabilising agent. When in-situ material is to be supplemented with imported material, a milling machine can also be used effectively to blend the two materials after the correct quantity of additional material has been levelled out on top of the in-situ material and pre-shaped with a grader.

Alternatively, layers that have developed high in-situ strength can be broken down using a “woodpecker-type” attachment fitted to an excavator. The resulting chunks of pavement material can then be transported to a single-stage crusher to be crushed and transported back to the road for further processing.

A5.6.6.2 Recycling Equipment

The plant shall be so equipped that it will be able to recycle pavement layers to depths up to at least 300 mm in one operation. The plant shall be equipped so that the stabilising agent mixed in with the construction water as per calculations, can be added uniformly in a calibrated and controlled manner directly to the material being recycled or processed. Width reduction must be possible on the application nozzles when overlap recycling is done. The recycling depth shall be controlled electronically.

Pre-mixing of the layer(s) to be stabilised with the surfacing (when specified) will be done to ensure that a uniformly mixed layer is present before stabilisation with the recycler is to be done. In the case of the upgrading of an existing unpaved road, ripping the material to the specified depth should be done. Oversized material can be removed by labour-intensive hand picking before the layer is stabilised, although the recycler often breaks down this material if not too hard.

The direction and speed of the recycling machine and the speed of rotation of the scarifying drum shall be adjusted to obtain the required grading and sufficient mixing of all the components of the recycled material. The machine shall be capable of making a neat vertical cut at the outer edges when recycling the layer.

The recycler should, as a minimum, be equipped with:

- Self-cleaning nozzles, and

- Be equipped with a micro-computer, able to adjust the application of the water and stabilising agent according to the speed of the recycler – the proper working of this equipment is essential to ensure that the stabiliser is applied to specification. The Contractor shall ensure that equipment operators receive the necessary training to operate the equipment to enable the required specifications to be met.

The recycler will be pre-tested using clean water to ensure that all systems, as per specification, are in proper working order, that operators are fully trained and that the stabilising agent will be added as adjusted by the speed of the recycler.

A5.6.6.3 Water Tanker

Self-propelledwatertankers,witha15000Lcapacity,areessentialplantitemsforthesuccessful

constructionofastabilisedlayer.Inadditiontosupplyingthestabilisingagent/additive/productformixing, watertankersarerequiredtoensureproperfinishingofthetreatedlayerofmaterialaftertheinitialmixing and processingstagehasbeencompleted(ATNOSTAGESHOULDWATERWITHOUTTHE STABILISING AGENT BE ADDEDTO THE LAYER).

Sufficientconstructionwatermixedwiththestabilisingagentmustbeaddedtothemixtoaccountforaloss of moistureduringprocessing,takingintoaccounttheequipmenttobeusedandclimaticconditionsto ensurethatcompactionstartswiththelayerpreferablyatapproximatelyOMC.(Resultsfromdetailed testingunderactualaswellasresearchconditionsindicatethattheOMCofthematerialisreducedby approximately10%whenusingawater-repellentmodifierandthatthemoisture/densityrelationshipmay not beascriticalcomparedwiththatofstabilisationwithouttheNMEstabilisingagentsnotcontaininga water-repellentmodification.Experiencehasshownthatthebestresultsareusuallyobtainedwhenfinal compactionisachievedatamoisturelevelof0.5percentto1.0percentbelowOMC(takingintoaccount the totalfluidcontentandnotonlythewatercontentofthestabilisingagent).Unusualhighpercentagesof problematicmineralswithinthein-situmaterialstobestabilisedusingaNMEmayrequirecompactionto be doneatlowermoisturecontents.Insuchcasestrailsectionsareessentialtodetermineoptimum moisturecontentsforthestabilisationandcompactionofthepavementlayer(s).Sufficientwatertankers must beprovidedtoensurethattheprocessingofthematerialisacontinuousprocedurewithnostopping to waitforawatertanker.

Whereapplicable,watertankersinvolvedwiththetreatmentanddistributionofastabilisingagentshould be earmarkedonlyforthetransportationofthestabilisingagentinvariousstagesofdilutionasdictatedby the in-situmoisturecontentofthematerialtobestabilised.InthecaseofNMEstabilisation,itis recommendedthatasmallpercentageoftheNMEmixtureberetainedinthetankerinthecasesoftheuse of conventionalequipmenttotreata“dry”surfacebeforeorduringcompactionwhenthemoisturelossis deemed tobeexcessiveforoneoranotherreasonthatmayoccurinpracticeduetonumerousunforeseen (e.g., weather)conditions.Asurfaceisvisuallyconsideredtobetoodrywhenfinecracksappeardirectly behind therollers.Supervisionpersonnelmustbeonsiteduringstabilisationoperationstovisuallynote any changesthatmayoccurduringthestabilisationprocess.

Due to materialvariations,somesectionsalongaroadmayalsocontainexcessivemoisture.Inthese cases, a small“wave”willforminfrontofthecompactionequipment.Whenthisphenomenonisobserved, the sectionshouldberippedandallowedtoexpelsomemoisture(evaporation)beforebeingrecompacted. This operationshouldnotexceedaperiodtotheendofcompactionof6hours.Inallcases,reworkedlayers forthematerialclassspecified.

needtomeetthematerialspecificationscontainedinTable **A5.6.5/1**

The contractorwilltakefullresponsibilityforanyreworkingofthelayernotmeetingtherequired specifications.

All water tankers used for NME treatment must be equipped with a circulating pump system to circulate the diluted NME after standing for an extended period and for circulating during the dilution process – in all cases contractors will take full responsibility for the end product specifications to be met with maintenance being carried out as required. Water tankers must not be fitted with a conventional spray bar but with valves (such as a clam-lock valve) which will not easily clog. The application of the diluted NME is a cold process and a modified stabilising agent containing a water-repellent agent considerably reduces the possibility of blockages of the nozzles. However, it is the responsibility of the Contractor to ensure that no blockages occur during the stabilisation process, resulting in the uneven distribution of the stabilising agent. In cases where such blockages do occur, the Engineer will require the layer to be remixed using conventional equipment or that the layer be reworked in total. Tankers must be properly flushed should they need to stand empty for extended periods (e.g., overnight).

A5.6.6.4 Rollers

The equipment to be used for the conventional breaking-up and excavation of existing pavement layers will be determined by the size and depth of the pavement section to be processed or excavated, taking into consideration the fact that work may have to be carried out in restricted areas.

One heavy-duty grid roller and an adequately powered pneumatic tyre tractor that will pull the grid roller when fully loaded, or an equivalent self-propelled sheep foot roller, may be required in the case of very coarse material to break down the material suitable for the construction of the layer. The breaking down of the material should be done prior to the addition of the NME. During the NME stabilisation and compaction of the layer compaction equipment should be used with a minimum risk of further breaking down of the NAGM as new surface areas created after addition of the NME will not be covered by the water-proofing agent, resulting in a reduction of the test results. The use of a sheep-foot roller is not recommended for use for the final compaction of the layer stabilised with a NME stabilising agent.

The compaction of a stabilised base layer is normally adequately achieved with a vibratory smooth drum roller in combination with a pneumatic wheel roller to achieve a surfacing finish, meeting the required specifications of the layer in terms of density as well as a finish suitable for a surfacing consisting of a chip seal only or even a NME slurry seal as per the design. It is the responsibility of the Contractor to ensure that operators of the compaction equipment are fully trained in the importance and effect of amplitude and frequency adjustments when compaction is done using vibratory rollers.

A5.6.6.5 General

Static tanks shall be provided to store sufficient quantities of the stabilising agent for the needs of the project. Normally such tanks will have a capacity of between 30 000 litres and 120 000 litres. Static tanks must be fitted with a circulating pump system that will enable the stored stabilising agent to be properly circulated from time to time in the static tank, as per the requirements of the supplier. These tanks must be fitted with a flowmeter to ensure that the required volume of the stabilising agent is carefully measured and added to the construction water.

A5.6.7 EXECUTION OF THE WORKS

A5.6.7.1 Removal of grass and weeds

Before commencing in-situ recycling, all grass, weeds, etc., encroaching into or onto the road surface or growing between the edge of the existing surfacing and kerbs, channels, etc., shall be removed.

A5.6.7.2 Preparing the pavement surface

Before any cold in-situ processing by any equipment may commence, the pavement surface shall be clean and free from any material that could be harmful to the execution of the works and affect the quality thereof.

For rehabilitation works, any asphaltic surface with granular sub-layers and/or cemented layers will be pre-milled before the preparation of the layer. Where specified/required, additional material shall be spread to the thickness and width as specified and milled together with the part of the existing pavement. The area to be processed shall be properly demarcated. No payment will be made for cold, in-situ reworking/processing of materials beyond the required width.

Before cold in-situ processing may commence, the moisture content of the in-situ materials to be reworked must be determined in an approved manner to determine the amount of water required to reach optimum moisture content. In the case of the measured moisture content exceeding the optimum by more than 0.5 per cent with the addition of the diluted stabilising agent, the layer shall be ripped and left to dry until the moisture content has reached an acceptable level before applying the stabilising agent and reaching the required moisture conditions.

A5.6.7.3 Construction in confined areas

In such an event where any material stabilisation as specified has to be executed in an area the width of which is less than 1.0 m or the length of which is less than 50 m and the area is less than 50 m2, it shall be classified as work in restricted areas.

A5.6.7.4 Recovery of bituminous material

When specified, existing bituminous material shall be milled out as indicated by the design. Excavated pavement material intended for reprocessing but which cannot be reprocessed in place or, in the opinion of the Engineer, cannot be windrowed next to the excavation, nor placed in position directly at any other place, and material intended for recycling or reprocessing in a plant, shall be transported to approved stockpiles with the written permission of the engineer.

Stockpile sites for material intended for recycling or reprocessing in a plant shall be set out at the corresponding mixing or crushing plant or at such other locations as approved by the engineer. The stockpile site shall be cleaned and all loose stones. Vegetation and other materials which may cause contamination shall be removed. The site shall be graded smooth with an adequate slope to ensure proper drainage of water.

The limits of milling shall be demarcated clearly and these limits shall not be exceeded by more than 100 mm. Areas milled outside the specified limits shall be repaired by the Contractor at his own cost and to the satisfaction of the Engineer.

A5.6.7.5 Spreading of extra material on a layer before reprocessing

Where the existing road layer or surfacing level is too low, or existing material has to be spoiled due to unsuitability and/or where specified or instructed by the Engineer, suitable pavement material shall be added to the layer to make up the shortfall before the processing and stabilisation of the layer. Suitable pavement material for addition to make up a layer shortfall shall consist of NAGM as specified (and tested) as directed by the Engineer.

The extra pavement material shall be spread uniformly over the full area of the underlying shortfall layer by means of an approved type of mechanical spreader to such thickness as to comply with the requirements specified in Clause A5.6.3.6 after the final compaction. Segregation of the materials shall be avoided and the additional material shall be placed free from pockets of course and fine materials. Extra material shall only be spread on the section to be processed and stabilised and only immediately before the processing operation.

A5.6.7.6 Application of stabilising agent diluted with water

At no time whatsoever should an undiluted stabilising agent (such as an NME) be applied to the layer of material that is being processed. The NME must be added to the construction water (taking into account the total fluid content of the NME (a water-repellent modified emulsion effectively reduces the OMC of the material). Hence, not only the water percentage within the emulsion needs to be taken into account but the total fluid content, to ensure that the mix is properly distributed throughout the layer and that the compaction can be done to meet the specified density criteria. The supplied NME needs to be diluted by a factor of between 1:4 (1-part NME and three parts water) and 1:1 (50-50) to ensure proper distribution of the stabilising agent. A high percentage of fine material (in the order of more than 20 to 25 per cent passing the 0.075 mm sieve size), will normally require higher rates of dilution (depending on the particle sizes of the NME and the specifications of the supplier) to ensure that a thorough distribution of the stabilising agent is achieved.

Coating of all the granular particles within the layer will not take place when the NME is added separately to the construction water (as is possible with modern recycling equipment). Any “wetting” of material before stabilisation will be detrimental to the material adhesion between the aggregate and the stabilising agent to be achieved. As a consequence, the in-situ moisture content of the untreated layer must never be so high that it cannot accommodate the NME stabilising agent that has been distributed within the construction water. The construction water is effectively used as a carrier of the NME stabilising agent, ensuring that all granular particles within a layer will be covered.

A5.6.7.7 Pre-treating an unsurfaced base layer

A material-compatible designed NME stabilising agent will not require the pre-treatment of materials to account for “problem” minerals such as smectites, muscovite (Mica), etc. The NME must be tested to automatically address the presence of such minerals during the detailed design phase and must be specifically designed to neutralise the effect of these minerals. In cases with high contents of specifically identified minerals, a pre-treatment may be prescribed using an appropriate co-product prior to the stabilisation process. The identification of the need for pre-treatment shall be done as part of the detailed design process through the detailed testing of the mineral composition of available materials (using XRD-scans), to be used in the upgrading, construction or rehabilitation of a road pavement.

Testing during the design development stage was undertaken as given in the project information. However, the contractor is required to undertake testing to ensure material compatibility and performance with the NME product that is preferred by the Contractor.

A5.6.7.8 Breaking down of material using conventional methods

During rehabilitation works, the existing pavement material shall be broken down to the specified depth and processed in place either through pre-milling or ripping as previously discussed.

The ripped material shall then be broken down in situ with a fully loaded grid roller hauled by an adequately powered tractor. During the process of grid rolling and breaking the material, the material shall be windrowed constantly and any oversize material shall be removed.

Unsuitable material for sub-base and base shall, as directed by the Engineer, be removed and spoiled and will be paid under pay Item C5.6.9.

Where sub-base layers need to be constructed, the base material shall be windrowed to the side and the sub-base layer should be inspected first. After inspection by the Engineer, the demarcated sub-base area should be reworked and re-stabilised as per design or required by the Engineer.

A5.6.7.9 Adding diluted NME

The emulsion tanker supplying the diluted NME (containing the mix of the NME and the required construction water as measured and calculated) shall be equipped with an approved measuring device (e.g., dipstick) to enable the site staff to take control calibrated depth measurements at intervals specified by the Engineer. The material processing and stabilisation operation will be cancelled/interrupted by the Engineer until this required specification is met.

The method of introducing the various materials comprising the final mix shall be done as per design and subject to the Engineer's approval. Care shall be taken to prevent excessive loss of moisture between the time when the materials are mixed and when they are compacted on the road (taking into account climatic conditions as mentioned).

A5.6.7.10 Spreading

The recycled mix shall be spread and levelled with a motor grader to the required width and to such thickness as to comply with the requirements specified in Clause A5.6.9.1 before final compaction. Segregation of the materials shall be avoided and the layers shall be free of pockets of course or fine materials.

A5.6.7.11 Stabilisation

(i) Mixing Recycler

The recycled base/sub-base material, extra material, and NME stabilising agent diluted in the construction water shall be thoroughly mixed by the recycling mixing process with plant as specified in Clause A5.6.6.

The NME diluted in the construction water, shall be measured by mass and quantities, calculated in accordance with the formulas given in Clause A5.6.5.4. It shall be introduced continuously in a controlled manner into the material that is being stabilised, proportionally to the speed of the recycler, to ensure that the correct quantity of the stabilising agent is added to the full width of the section being recycled. Care should be taken that all nozzles are fully operational during the recycling process. In cases where an uneven distribution of the stabilising agent is noticed, the layer will be re-mixed using conventional blade mixing with graders, at no extra costs or reworked in total as per instruction of the Engineer at no additional costs.

(ii) Conventional Method

Blade mixing by grader is undertaken by using the blade to move the material from side to side. This mixing process is often supplemented with the use of ploughs and/or rotavators. Where the width of the treatment restricts the horizontal movement of the material, extra use should also be made of the grader rippers with specially designed "shoes" welded onto the rippers. Such shoes are in the shape of a horizontal "V", with the sharp end of the V pointing in the direction of travel of the grader. The rippers with their V-shaped shoes are lowered to the treated depth and the "fast forward" gear of the grader is used to plough through the layer. In this manner, the material is pushed aside, ensuring that proper mixing is achieved, even when working in confined widths.

The NME must first be dilutedwiththecompaction water to a residual NME content of between a 1:1 to 1:4 dilution and applied in severalapplications onto the material over the width and length previously determined. Water tankers areusedtoapply the NME and the grader(s) must travel directly behind the water tanker, immediately coveringthefreshly sprayed NME with material, thereby preventing excessive loss of moisture and the NMEfromimmediate breaking (where applicable). The volume of diluted NME applied is determined by the designed percentage of the NME, expressed as a percentage of the mass of the layer that is being treated.

Should weather conditions be particularly hot or dry, adjustments to the construction water must be made to ensure that the compaction moisture content (containing the NME stabilising agent) is achieved. This process is exactly the same as for the compaction of any granular layer, requiring the same care during construction to achieve the required densities.

Care should be taken to ensure that the diluted NME is applied in such a way that no rivulets are formed, that the NME does not run off the layer before it has been mixed into the layer and that the exact application rate is achieved.

During mixing, attention must be paid to the fluid content of the mix. The fluid content is the total quantity of fluid in the mix, including hygroscopic moisture, the diluted NME still in suspension and the water in the NME.

The addition of the post-mixed construction water (mixed with the NME stabilising agent) should not be so high as to result in deformation of the surface under final compaction. (Observed as a “wave” forming in front of the compaction equipment.) The required total mixed construction water as determined in the laboratory before the start of the stabilisation process may be amended based on on-site observations, allowing for the type of compaction equipment used.

Additional adjustments in the pre-mixed construction water may be required when working with porous materials. Such materials will absorb some water leading to a need for a higher percentage of pre-mixed water to achieve the required results. The design process, as recommended, should identify the presence of materials that will require higher than normal percentages of pre-mixed construction water. However, due to the limits to which pre-testing can be done, the Engineer on site should be aware of this possibility and require adjustments as recognised on site. Where the existing asphalt surfacing or cemented base layer is being recycled with the underlying gravel layer using conventional construction equipment, the asphalt layer must first be milled off and left in a windrow on top of the granular base that is to be recycled. Once the asphalt layer has been milled off in this manner then the base layer can be milled or ripped and broken down. The stabilisation of the layer using a material-compatible NME should only commence once the milled asphalt layer and the existing gravel base material have been thoroughly blended to form a uniform material.

A5.6.7.12 Preparation before the stabilisation/treatment of the material

The following will need to be determined in advance for input into the Moisture Calculation Sheet:

- Length, width and depth of section to be stabilised; MOD, OMC and in-situ moisture content; Content of water tanker in litres; Water tanker volume will also need to be calibrated and marked out on a volume measuring gauge.

Preparation before stabilisation:

- Prior to applying the stabilising agent, the NME shall be mixed with water in the water tanker to form a diluted NME which, when applied to the material, will act as a carrier of the diluted NME to the soil fines.
- The Contractor shall determine the rate of dilution of the additive using the Moisture Calculation Sheet, which may range from 1 litre of NME to between (5 litres and 40 litres) of water depending on the type of material/soil, in-situ moisture content and percentage of the NME stabilisation required. This calculation sheet shall be submitted to the Engineer daily for approval, both before and after the completion of each section to be stabilised. Experience has shown that NME stabilised material/soil will reach optimum strength when final compaction is done at a moisture content of

just below OMC taking into account the total fluid content (taking into consideration that a water-repellent modification will normally reduce the OMC by about 10 per cent - the contractor and his supplier will confirm the implications of any specific stabilising agent with the Engineer before the start of any operations to enable quality control to be effectively executed). To reach this target OMC, it may be necessary to apply 1.0 per cent to 2.0 per cent moisture above OMC (depending on climatic conditions which could result in the drying and loss of moisture due to evaporation during very hot conditions and the mixing equipment used – e.g., conventional grader mixing will take longer and will allow more moisture to escape (evaporate) than mixing with a recycler). Compaction at moisture conditions which are too low will lead to the formation of fine cracks (immediately visible after the roller) which will compromise the integrity of the top of the layer, resulting in the formation of a weak inter-layer at the top which may result in the failure of the seal by separation from the rest of the base layer (the appearance of fine “cracking” when compaction commences can be addressed through a further application of some diluted NME (kept in reserve in the water-tanker) which will increase the surface moisture to achieve the desired compaction densities and a uniform layer. Too high moisture conditions will be seen when the layer is moving in front of the roller (kneeing) – in these cases, the drying out of the layer may be required by ripping, drying and re-compaction (as per previous discussions and guidelines). Such operations should not exceed more than 6 hours. The following processes may be followed:

1. The diluted NME may be sprayed onto the road surface using a spray bar fitted to the water tanker or by hand spraying in places with difficult access.
2. Initial thorough and complete mixing of the NME with the construction water is essential. The NME products using a double emulsification process usually result in small particles that distribute easily through the construction water without much additional effort. However, it is the Contractor’s responsibility to ensure that the NME is evenly distributed within the construction water. In the cases where constant mixing of the stabilising agent with the construction water is required to prevent separation (usually a function of the particle size of the stabilising agent), an electrical or petrol-driven stirrer must be used. In such cases, the contractor must ensure that:

    (i) The pump has sufficient capacity to circulate the entire contents of the tank in 15 minutes;
    (ii) There are no internal baffles in the tank restricting circulation, and
    (iii) Before the commencement of spraying, the contents are circulated for at least 20 minutes.

A5.6.7.13 Compaction

The completed compacted layer shall have a minimum in-situ dry density as specified for the specific layer (as per the requirement of the designed layer as in Table A5.6.5.3/1 and Table A5.6.10). It shall be the responsibility of the Contractor to determine the maximum dry density and Optimum Moisture Content (OMC) of the material to be stabilised for purposes of quality control (compaction control). The Contractor may select any suitable compaction technique to achieve the required compaction, subject to the following conditions:

1. The initial compaction shall be carried out with plant, which achieves stability suitable for subsequent compaction, without causing undue displacement of the material or deformation of the layers. The rolling pattern shall be designed to retain the shape of the layers as far as possible;
2. The types and number of compaction equipment to be used and the amount of rolling to be done shall be such as to ensure that specified densities are obtained without damage being done to

lower layers or structures. During compaction, the layer shall be maintained to the required shape and cross-section, and all holes, ruts and laminations shall be removed;

3. Compaction equipment shall be adequate for obtaining the specified density within the specified time limits;
4. The compaction equipment and techniques shall be capable of producing the specified surface finish and density without any interruption, and
5. Not more than four (4) hours shall elapse between the time of starting the mixing process and that of starting to compact the material.

From the time when the diluted NME is added, not more than six (6) hours shall elapse until the compaction has been finally completed.

It is important to note that when adding water to material only diluted NME should be used.

The only time when the clean water can be used on its own is **during the pre-wetting of the completed layer before priming if required as per specification, depending on the type of product and supplier specification. This information must be shared with the Engineer before the start of any works and tested as per a test section to ensure that materials are compatible and approved by the Engineer**.

At no time is it allowed to "cut back" materials, to achieve levels without remixing the layer – materials added by "cutting back" material will result in "biscuit" layers and the disintegration (breaking up) of the top of the layer. Under such circumstances, high penetration of the stone with associated bleeding within the wheel tracks will occur when a surfacing consisting of a seal is used. A ring and ball test performed on top of the base course before sealing should normally expose this weakness and potential risks. The normal criteria used to evaluate ring and ball tests are applicable.

A5.6.7.14 Rejected work

The Contractor shall note that should he fail to meet the specified requirements for the NME stabilised layer placedatambienttemperatures,he shall remove the unacceptablelayerand **will rework or replace it with approved material as instructed by the Engineer, at his own costs.** Reworking of an existing layer may be allowed by the Engineer by ripping of the stabilised layer, adding 50 per cent of the original NME stabilising agent (this may be a function of the characteristics of the stabilising agent used) and compaction at the required OMC as per the original process to achieve the required results. It should be noted that the OMC of the material may have changed due to the first NME application. The

reduction of the OMC is a function of the mineralogy of the granular material used,but normallyinthe order of 10per cent. **Such reworking of the layer will be at the risk of the Contractor who will not be paid extra for the reworking of rejected works.**

A5.6.7.15 Providing a temporary wearing course

Immediately after completion of the compaction described in subsection (l), a material-compatible prime shall be applied to the finished surface using a water truck, binder distributor or hand sprayer at a spray rate of 1 litre/m2 (or as specified for a specific supply). The spray rate may be adjusted by the Engineer following a trial section of not less than 100 m in length. Costing is to be done per constructed m2 and not per litre, accounting for differences in product requirements.

As an alternative, a 50:50 diluted NME may be sprayed onto the layer and compacted using a steel-wheeled roller with a mass of not less than 12 tons, and/or with pneumatic rollers.

The following process is to be followed:

- Immediately after compaction, slushing of the surface will commence: Spray 1 litre/m² of the diluted NME onto the surface followed immediately by further compaction utilizing a 13-ton vibratory roller that must follow directly behind the water cart. A 22-ton Pneumatic Tyre Roller (PTR) must then follow directly behind the vibratory roller;

- Turn around and on the same strip have the water cart first drench the surface with a further 1 litre/m² diluted NME. This time the pneumatic tyre roller follows directly behind the water cart and the vibratory roller follows closely behind the PTR. It is important that the water cart and roller must work in close tandem at all times; to prevent any pick-up of the material by the drum of the vibratory roller (this is usually not a problem with the use of a material-compatible, water-repellent NME stabilising agent);
- Continue with the above points until the total area to be worked is completed, and
- The area treated with a prime (recommended a diluted (50:50) NME similar to that used in the stabilisation of the base layer) is to be kept closed to traffic for the prime to properly set and dry (until the top 50 mm of the layer has dried out) with a moisture content of < 50% of OMC. The time of required closure is dependent on the prevailing weather and may be as short as 1 hour in the case of a material-compatible, water-repellent NME. Due to the addition of the water-repellent modification of a stabilising agent, a hydrophobic material surface is created and water is effectively repelled from the layer. Hence, stabilised layers constructed using a water-repellent modifier in the NME stabilising agent normally dry much quicker than pavement layers treated using traditional emulsion stabilisation processes that depend only on evaporation as a method of drying. In dry and hot conditions, a pavement layer will dry sufficiently within less than 24 hours to reach 50 per cent of OMC. The final surface should be smooth, tightly knit and free of undulations, corrugations, holes, bumps or loose material.

The application of a compatible prime (i.e., a recommended compatible NME-based prime) at a time when the base has reached a moisture content of 50 per cent of OMC should prevent most damage under conditions of light trafficking in urban areas. Heavy brushing with soft bristles is recommended before the application of the prime to remove any dust or loose materials on the surface, not disturbing the surface itself. The instructions of the supplier should apply - the risk remains with the contractor to achieve an acceptable base condition after the application of the prime. Experience has shown that a material compatible with NME prime will dry within an hour. In cases where the surfacing is applied immediately, the prime may be substituted by an appropriately specified tack coat. However, this is only applicable to cases where the contractor can ensure that the surfacing material and equipment are available for immediate application of the surfacing.

A5.6.7.16 Reconstruction of pavement layers using conventional equipment

Uniform pavement sectionsshallbeclearlyidentified and detailed in the Contract Documentation. In accord with these uniform pavementsectionsanin-place gravel base layer or crushed stone base layer may be specified in the ContractDocumentationtobe reconstructed using conventional construction equipment.

The Contractor shallfirstremoveanyasphalt surfacing to spoil or to stockpile as specified in the Contract Documentation beforereconstructingthebase layer. A bituminous seal surfacing is normally not removed before reconstructingthebaselayerunlessspecified otherwise in the Contract Documentation.

The exposed in-placegravelbaselayerorcrushed stone base layer shall then be scarified to the full depth of the existing layerortothedepthasspecified in the Contract Documentation. In order to comply with the grading specificationintheContractDocumentation the scarified material shall then be broken down and all oversize materialremoved.Compliantmaterial may also be added and thoroughly mixed in as specified in this Chapter if requiredtoimprovethegrading and/or other properties of the in-place material or to increase the layer thicknessasspecifiedinthe Contract Documentation.

The Contractor shall then reprocess the layer as specified for new pavement layers in this Chapter. All required stabilisation of material shall be done as specified in this Chapter.

A5.6.7.17 Reconstruction of pavement layers using a recycler

Uniform pavement sections shall be clearly identified and detailed in the Contract Documentation. In accord with these uniform sections an existing gravel or crushed stone layer may be specified in the Contract Documentation to be reconstructed in-place, using a recycler.

a) Establishing construction levels – minor level changes

Beforecommencinganyin-placereconstruction,theContractorshallestablishreference and level beacons for thesetting-outandcontroloftheworks.

Whenonlyminorlevelchanges(lessthan15mmupordown)willbemadetotheexisting vertical alignment and/ortotheroadcross-fallorcamberinordertorestoretheridingqualityoftheroad, then new road design levels willnotusually be providedintheContractDocumentation.

Ateachlevelcontrollocation,theContractorshallrecordtheexistingroadsurfacelevels at the centre- line andattheouterlimitsofeachlaneincludinganysurfacedshoulders.TheContractor shall use the existing roadlevelstodeterminethenewconstructionlevelsalongthecentrelineandtheouter limits of each traffic laneandanysurfacedshoulders.Alineofbestfitshallbeusedtodeterminethe final levels for the reconstructed layer taking intoaccountthefollowing:

- Therequiredcamber or super elevation.
- Theminimumrequirements governingchanges in the vertical alignment.
- Thethickness oftheexistinglayer tobereconstructed.
- Minimisingtheamountofpreparatoryworkrequiredaheadofreconstruction, such as minimising the importation of material.

Atleasttwocalendarweeksbeforereconstructionworkisprogrammedtocommence on any specific uniformpavementsection,theContractorshallsubmitthelevelproposalstotheEngineer in sufficient detail toenabletheproposedreconstructionlevelstobereviewed.Thedetailshallincorporate a schedule as well asadrawing,ofallthedesignlevelsandthegradelinesrespectively.Onceagreement has been reached regardingthe proposedlevels,reconstruction work may commence.

TheContractorshallestablishaseriesoflevelcontrolpolesplacedataconstantoffset on both sides of theroadpriortocommencinganyconstructionworkatamaximumintervalasindicated in Table A5.3.8-2. TheEngineershalltakecontrolmeasurementstodeterminetheaccuracyandadequacy of the level control poles and shall instructthe Contractor tomakeany adjustments as required.

b) Establishing construction levels significant level changes

When significant levelchanges(morethan15 mm up or down) will be made to the vertical alignment and/or to the road cross-fallorcamber,thereconstructed layers shall be reconstructed to new design levels provided in the ContractDocumentation.

Before commencinganyin-situreconstruction, the Contractor shall establish reference and level beacons for the setting-out andcontroloftheworks.

The Contractor shallsurveytheexistingroad levels and compare these with the new design levels and prepare a scheduleoftheareaswherethere will be surplus material and of where there will be insufficient material. This schedulewillbeusedtoprepare a layer material transfer diagram which will enable the transfer of surplusreconstructedmaterialto areas where there is a shortage of material. The material transfer diagram shallbesubmittedtothe Engineer for review at least two calendar weeks before reconstruction workisprogrammedtocommence on any specific uniform pavement section.

The Engineer shall subsequently instruct the Contractor regarding the proposed reuse or spoil of surplus material, or the need to import any additional new material prior to the commencement of the reconstruction work.

The Contractor shall establish a series of level control poles placed at a constant offset on both sides of the road prior to commencing any construction work at a maximum interval as indicated in Table A5.3.8-2. The Engineer shall take control measurements to determine the accuracy and adequacy of the level control poles and shall instruct the Contractor to make any adjustments as required.

c) Preparation of the road surface

Before any reconstruction work may commence, the surface of the existing road shall be prepared as follows:

- Remove all vegetation, dirt and other foreign matter including from any adjacent lanes or shoulders that are not to be reconstructed.
- Remove road studs from the full road width.
- Remove standing water.
- Establish an off-set reference line, for each cut, for the recycler to follow and ensure accurate steering.
- Record the location of all road marking features that will be obliterated by reconstruction.
- Mill off the asphalt or bituminous seal surfacing to spoil or stockpile where specified in the Contract Documentation.

A5.6.7.17 Disposal of surplus material

Recovered pavement material remains the property of the Employer. Surplus materials, including waste or oversized material, bladed or skimmed off the road, shall be stockpiled at designated areas within a free-haul radius of 5 km as directed by the Engineer with approval from the Client, considering environmental implications. Should the Employer decide not to use the surplus material, the Contractor shall then dispose of the material to the satisfaction of the Client within a free-haul distance of 5 km.

A5.6.7.18 Checking moisture content and surface condition before priming and/or surfacing

The mixing and placing of asphalt or seal will not be allowed if:

(i) Free water is present on the working surface or when rain is imminent – no surfacing will be allowed during adverse weather conditions as this could result in the detachment of the surfacing from the base layer;

(ii) The moisture content of the upper 50 mm of the recycled base exceeds 50 per cent of the Optimum Moisture Content (OMC);

(iii) Loose material is present on the surfacing - in cases where the base has been primed and exposed to trafficking, the surface needs to be cleaned of all loose material and any localised problem area repaired using an NME slurry mix (the same NME used for the stabilisation of the base layer) It is usually a good idea to prepare small quantities of slurry to ensure excellent bonding with the existing base layer).

A5.6.8 SETTING OUT OF THE WORKS

A5.6.8.1 Setting-Out and Control of The Work

The Contractor shall establish his own reference and level beacons for the setting out and control of the works. The Contractor shall indicate his own reference and control beacons to the Engineer at least one week before the work is programmed to commence. The Engineer will take control measurements to determine the accuracy and adequacy of the reference/control beacons and may instruct the Contractor to correct any faulty work and to take and provide such additional measurements and details as may be deemed necessary. This survey work will not be measured and paid for directly and compensation for any work involved in staking or setting out will be deemed to be covered by the rates tendered and paid for the various items of work included in any contract. No payment will be made for any inconvenience or delay caused by compliance with these requirements.

A5.6.8.2 Trial Sections (Refer COTO, 2020)

Where ordered by the Engineer, the Contractor shall construct trial sections with the preferred material-compatible NME stabilising agent (first proven through laboratory testing as per the test protocol contained in A5.6.9.2), to evaluate in practice the construction process, the compatibility of materials and the ability of the modified stabilising agent to be able to meet the specified criteria as per Table A5.6.5/1. During the trial sections, any adjustments in terms of the addition of water and applicable OMC should be finalised. The latter is of importance, especially if layers above 150 mm thick are to be stabilised in one operation (not advised). The water released and repelled by the NME will be pushed upwards towards the top part of the layer, requiring an adjustment in the pre-mixed construction water.

Trial sections shall be carried out at locations approved by the Engineer.

A5.6.8.3 Work Outside Normal Working Hours (Refer COTO, 2020)

Any work carried out outside of normal working hours must be approved by the Engineer. The Contractor shall give the Engineer at least 48 hours' notice of his intention to do work outside the normal working hours. The closure of traffic lanes will only be permitted during these times. The provision and layout of lighting for the works and warning lights for the accommodation of traffic shall be approved by the Engineer. No additional payment will be made for the provision of additional warning lights for work done outside of normal working hours. The Contractor shall allow for the provision, erection and maintenance of additional items required in his tendered rates.

A5.6.9 WORKMANSHIP

A5.6.9.1 Construction Tolerances and finish Requirements

(a) Construction tolerances (Refer COTO, 2020)

The applicable construction tolerances are the relevant tolerances indicated in the project specifications as related to the Category of Road. Where the existing granular base abuts kerbs or channels or New- Jersey barriers, the new work shall extend to the edge of these facilities. Unless otherwise specified, the processed and stabilised base shall be constructed to the existing levels,
cross-section profile and cross-fall to allow for a surfacing layer as specified.

(b) NME stabilising agents

The average rate of application of the diluted NME as measured at operating temperatures in the water cart shall be within 5 per cent of the specified rate of application.

(c) Uniformity of mix (chemical stabilisation)

Unless specified by a specific supplier and results proven as per specification, no additional chemical stabilisation agent (e.g., cement) is required with the use of a material-compatible NME stabilising agent.

(d) Statistical judgement schemes (Refer COTO, 2020)

Routine inspections and tests willbe carried out by the Engineer to determine the quality of the materials and workmanship for compliancewith the requirements of this section.

The statistical judgement schemes to be used to determine whether the requirements specified are being complied with shall be those set out in the prescribed contract documents and/or design and quality control methods.

A5.6.9.2 (a) Testing

The Contractor shall give the Engineer at least 24 hours' notice of his intention to process/stabilise/recycle/rework any materials so that the actual process can be monitored and tested (quality control) by the Engineer. Unless otherwise agreed in advance, the Contractor shall only process/stabilise/recycle/rework any materials when the Engineer or his representative is present. **(b) Test Methods for determining UCS and ITS values – applicable during the design as well as quality control process. The number of tests done during construction as part of quality control will be done in accordance with the instructions of the engineer.** The following material test methods shall be used for the testing of NME stabilising agents or equivalent (engineering properties in terms of UCS and ITS values):

- As an input into the testing of the UCS and ITS of the material, the Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) are to be determined using normal prescribed test procedures (SANS 3001-GR51), and
- The testing of the Unconfined Compression Strength (UCS), and the Indirect Tensile Strength (ITS) of the stabilised materials shall be done according to the protocols prescribed in the following paragraphs.

In all the above test methods, the +37.5 mm material must be screened off and discarded. The aggregate passing the 37.5 mm sieve and retained on the 19.0 mm sieve must not be crushed and must be used in the testing process. A pH test must be performed to determine the acidity/alkalinity levels of the material.

The curing and testing process of the 152 mm diameter samples (127 mm high) shall be as follows:

The MC-NME stabilising agent is mixed in with the construction water and the sample is prepared at Optimum Moisture Content (OMC). For example, if the OMC of the material is 8 per cent and 1 per cent of the MC-NME stabilising agent is added and the in-situ moisture content is 3 per cent, the addition of (8 - 3) 5 per cent moisture should be added to the material to achieve OMC. The 5 per cent to be added will consist of a mixture of 4 per cent construction water and 1 per cent MC-NME as per the total requirement. (Accordingly, the total fluid content (i.e., the total percentage of the MC-NME) is added as part of the compaction water – not only the water percentage of the MC-NME).

No cement or lime is added to a material-compatible NME stabilised material (unless specified by the supplier). Hence, the samples are not placed in plastic bags to assist with the hydration of the cement (as per usual, Bituminous Stabilised Materials (BSM) designs, contain cement as an additive and hence, the samples need to be placed in plastic bags in the oven during the rapid curing process to assist in the hydration of the cement in the mix):

1. The prepared 152 mm diameter by 127 mm height samples are to be prepared as per SANS 3001 – GR 50: 2013 and SANS 3001 – GR51 with the following changes:
2. **When no cement is used as part of the stabilising agent the samples are not to be enclosed in a plastic bag. (Plastic covering is required when cement is included in the mix to assist in the hydration of the cement).**
3. Samples are cured for 24hours in an oven at 22-25°C before being subjected to a "rapid curing" process in an oven for 48hours at 40-45°C (temperatures in the oven should NOT exceed 50°C).

4. After 48 hours the samples must be allowed to “cool off” for twenty-four (24) hours. This is preferably to be done in the oven at 22-25°C for 24 hours (SANS 3001 – GR 50: 2013; SANS 3001 – GR51) .
5. Directly after the “cooling off” period, three (3) samples each must be crushed to determine the ITS and UCS values. The values obtained are called the DRY ITS and the DRY UCS values (as per the test procedure specified for the testing of cementitious stabilising agents (SANS 3001-GR53:2010, 2010 and SANS 3001-GR54:2014)).
6. Six (6) samples must be placed in a bath of water with a temperature of 22-25°C for four (4) hours (as per the test procedure specified for the testing of cementitious stabilising agents (SANS 3001-GR53:2010, 2010 and SANS 3001-GR54:2014)) and thereafter removed from the bath and allowed to drain off excess water before determining the wet ITS and wet UCS values. The values obtained are called the WET ITS and the WET UCS values.
7. If approved by the Engineer, the “wet” tests (UCS and ITS) may suffice during the quality control during construction. For the lower-order roads (Category D and E), DCP tests done (as specified in Tables C1002/1 and C1014/1 for the specific material class) at randomly selected spots, may be approved for quality control as approved by the Engineer.
8. During the design stage 3 samples, each (twelve (12) in total) must be preserved outside the moulds for 28 days at temperatures of 22-25º C. After 28 days the UCS (wet and dry), as well as the ITS (wet and dry), should be tested as per the procedure described above. The results of the 28-day tests should not show a decrease in the tested values of the respective UCS and ITS tests (dry and wet) compared with results obtained after the rapid curing process (an increase in tested UCS and ITS values is normally expected with the use of a material-compatible MC-NME stabilising agent).

9. **It is important to note that sample preparation must be done in strict compliance with the prescribed procedures and NO deviation shall be allowed**, including:

   9.1 The moulds in which the samples are prepared are not to be **treated with grease or any other lubricant** to facilitate the easy removal of the sample as this could influence the loss of moisture or seal the sample and hence, the measurements of UCS and ITS;

   9.2 **No additional soaking of samples** in any “covering” liquid or any other material will be allowed as this will make any comparison and application of test requirements invalid and not comparable to what is practically achievable during construction,

   9.3 **Compaction of the samples** for testing will be done in strict compliance with the specified procedure in SANS 3001 – GR 50: 2013.

A5.6.10 TREATMENT OF RELATIVELY POOR-QUALITY IN-SITU MATERIALS AS A SUPPORTING FOUNDATION FOR THE CONSTRUCTION OF A MC-NME STABILISING LAYER OR PROTECTION OF GRAVEL SHOULDERS AGAINST EROSION OR GRAVEL PRESERVATION ON GRAVEL UNSURFACED ROADS All preparations of the NME materials and construction processes and testing as per normal construction and rehabilitation of roads as discussed under items Table A5.6.9.2 also apply to the treatment of relatively poor in-situ materials to for a supporting foundation for the construction of a NME stabilised layer using NAGM. In such cases, Table A5.6.5/1 is supplemented by Table A5.6.10/1. This is also applicable for the treatment and protection of gravel shoulders against erosion and for gravel preservation on unsurfaced gravel roads.

In cases where the in-situ material consists of very fine materials (percentage passing the 0.075 mm sieve in excess of 50 per cent) the in-situ material may be treated with a NME consisting of a Nano- Polymer Nano-Silane (NME-NPNS) which is transparent in nature or slightly milky coloured, retaining the natural colour of the material treated. After compaction an application of a Micro Polymer Nano-Silane (NME-MPNS) should be applied to bind the surfacing together.

Table A5.6.10/1: Recommended material specifications for the treatment of relatively poor in-situ materials, gravel protection and gravel perseverance (Jordaan and Steyn, 2020))

Test or Indicator	**Material1**	**Material classification MC-NME(NPNS)- EG5**
Minimum material requirements before stabilisation and/or treatment (Natural materials)		
Material spec. (minimum) Unstabilised material: Soaked CBR (%)(CBR as % of MDD)	NG/GS/SSSG (CS)	-
Sieve analysis % passing the 0.075 mm sieve (P0.075)		Required
XRD scans: - Total sample - 0.075 mm fraction		Required Required
% Material passing 2 µm (P0.002) (e.g. Clay & Mica & Talc), with Talc <10%) (XRD-scans of the material passing the 0.075 mm sieve is recommended for use to determine the % clay, mica and talc in the material).	MC-NME stabilisation with emulsion particle size > 2 µm	
	ALL	< 15 %
	MC-NME stabilisation with emulsion containing micro-scale as well as nano-scale particles (adjusted according to material grading)	
	ALL	< 35%
	MC-NME stabilisation using Nano Polymer with Nano Silane (NPNS) (special design and treatment)	
	ALL	> 35%
Material specifications after stabilisation and/or treatment		
In-situ density to be required after stabilisation and compaction (CBR as % of MDD) (minimum)	Base-layer	>97%
	Support	>95%
DCP(DN mm/blow)(Quality control in field testing - base only) (stabilised and compacted = wet; 7 days cured = dry) Density (% of MDD)	Base-layer	< 3.5 (wet) < 2.3 (dry)
	Support	< 5.5 (wet) < 3.5 (dry)
(for laboratory testing) *UCSwet (kPa) (150 mm Φ Sample)		> 100% **> 750** **> 450** > 65 > 75
	Design[3] **Construction4**	**> 70** **> 50**
	RTS RTS-E	> 65 > 75
Retained Compressive Strength (RCS) = (UCS_{wet}/UCS_{dry}) (%)	**Design** **Construction4** RTS RTS-E	
RCS in relation to minimum UCSwet (criteria) = $RCS_{effective}$ = ($RCS \times (UCS_{wet}/UCS_{wet\ (criteria)})$) (%)		
*ITSwet (kPa) (150 mm Φ Sample)	3	
Retained Tensile strength (RTS) =: ITSwet/ITSdry (%)		
RTS in relation to minimum ITSwet (criteria) = $RTS_{effective}$) = (($RTS \times (ITS_{wet}/ITS_{wet\ (criteria)})$)) (%)		

[1]NG – Natural Gravel; GS – Gravel Soil,and SSSC–Sand, Siltysand,Silt,Clay.
Design3 = Minimum criteria to be met in the laboratory during the design phase
Construction4 = Minimum criteria to be met during construction as part of quality control

A NME consisting of a NPNS treatment can be done as a surface enrichment and strengtheningaction or used for the protection of gravel shoulders against water erosion or as a gravel preservation product for the protection of the gravel wearing courses on unsurfaced gravel roads. Treatment of the surfacingonly can result in a relatively deep penetration (> 60 mm), to bind the surfacing together (especially where the in-situ material consists of a very fine material containing a high percentage of problematic material, presenting problems in terms of workability and compatibility. Such treatment will enable the formation of a supporting layer on which a NME layer can be constructed in a conventional way. The supporting layer should be bladed to the required geometric requirements before the NME-NPNS is applied and then compacted using a smooth drum roller.

The dilution of the NME-NPNS should be pre-determined through testing in a laboratory using a standard Marshall mould to ensure that a depth of penetration of 60 mm is achieved, binding the material together. Typically, dilution rates of 1 to 5; 1 to 10, 1 to15 and 1 to 20 (1 being the NME-NPNS diluted in various ratios in water) applied at a rate of about 2 litres/m2 (applicable application rates should preferably be established on a trail section). After application the layer should be compacted using a smooth drum roller.

For deeper penetrations and and/or treatment of a typical 150mm base/surfacing layer as part of a supporting layer, the in-situ material can be ripped, sprayed, grader mixed and bladed before compaction. The testing requirements shown in light yellow in Table A5.6.10/1 is not applicable to material testing in the field for the treatment of in-situ material or gravel surfacings. Quality control of the treatment efficiency is to be done using the DCP penetration rate (mm/blow) of the treated layer. The curing of this layer should conform to the DCP-DN values as given in Table A5.6.10.

Quality control of a NME-NPNS can be done in the field on each container delivered on site by spraying the required dosage on a building sand placed in a Marshall mould (60 mm in depth). After 48 h in an oven at 40 – 45ºC, the total depth of the building sand in the Marshall mould should be bound together. Water placed on the bottom of the building sand in the Marshall mould should form droplets not penetrating the bound building sand as an indication of the waterproofing achieved with the supplied NPNS.

In the case of a 150mm deep treatment, enrichment surface sprays with NME-MPNS may be needed as a maintenance action.

The surface of the wearing course shall receive additional treatment as described under Item A5.6.7.15.

Additional protection of the surface can be provided by the application of an applicable seal, including an NME-MPNS sand seal, slurry or “clear seal” to maintain a natural look as may be required by any specific road agency. A clear seal consists of a combination of a water-repellent-modified graded polymer. The clear seal is applied as per product specifications using a diluted (as little as 5 per cent dilution dependent on the type and quality of the polymer) compatible water-repellent modified graded polymer (applied at 0.6 litre/m2 to 1.5 litre/m2) which is transparent when applied, similar to a traditional prime or enrichment layer, but with extended expected service life, especially on fine graded materials.

B5.6 RE-CONSTRUCTION OF PAVEMENT USING LAYERS COLD IN-SITU STABILISATION WITH A NANO MODIFIED EMULSION (NME) STABILISING AGENT

PART B: LABOUR ENHANCEMENT

CONTENTS:

B5.6.1 SCOPE

This Section covers the work requirements for the Reconstruction of existing road pavement layers. This section covers work required for the construction of new roads (including upgrading of existing unpaved roads) or the rehabilitation of the upper pavement layers (base and sub-base) using the cold in-situ recycling process with (a) labour-intensive construction methods with a mixture of conventional equipment (b) conventional equipment, i.e., water-cart, grader(s) and compaction equipment (b) recycler and (c) central mixing plant. A relatively large proportion of activities as defined in Part A under the various sections are therefore suitable for labour enhanced methods of construction**.**

B5.6.2 DEFINITIONS

Definitions as provided in Clause A5.6.2 apply. B5.6.3 GENERAL

Any activity specified in PartA, where handworkis givenasan alternative, shall be executed in such a way astomaximise labour **.**

B5.6.4 DESIGN BY CONTRACTOR/PERFORMANCE BASED SYSTEMS

The provisions of Part A shall apply. B5.6.5 MATERIALS

The provisions of Part A shall apply. B5.6.6 CONSTRUCTION EQUIPMENT

Where reference is made in Part A to appropriate equipment, the use of light equipment shall be evaluated during trial sections.

B5.6.7 EXECUTION OF THE WORKS

For the reconstruction of pavement layers, oversized material can be removed by labour-intensive hand picking before the layer is stabilised are suitable components for labour enhancement.

B5.6.8 WORKMANSHIP

The provisions of Part A shall apply.

C5.6 CONSTRUCTION OF PAVEMENT LAYERS USING COLD IN-SITU STABILISATION WITH A NANO MODIFIED EMULSION (NME) STABILISING AGENT

PART C: MEASUREMENT AND PAYMENT

(i) Preamble

The tendered rate for each pay item shall include full compensation for providing, maintaining and decommissioning upon completion, of all the equipment, labour, tools, incidentals and supervision to carry out the activity or construct the works in the pay item, unless otherwise stated.

Any prime cost or provisional sums shall be paid in accordance with the provisions of the conditions of contract. The charge or mark-up tendered or allowed for is a percentage of the amount actually paid under the prime cost or provisional sum. This percentage shall cover all the Contractor’s handling, supervision, profit and liability costs to provide the services in the prime cost or provisional sum pay item.

(ii) Items not measured in this Section

The following required activities will not be measured or paid for separately and the Contractor shall include the cost thereof in other items as deemed appropriate:

- Drainage and protection of the pavement layers from all damage that may occur for any reason until the Employer has taken over the works;
- Protection of all existing or new kerbs, channels, sidewalks, lined drains, catch pits, kerb inlets, gratings, culverts, bridges, structures, buildings, road signs, guard rails, street lights, fencing, service pipes or cables and any other items adjacent to, over or under the road that could be damaged by the Contractor‘s vehicles, construction equipment, or by public traffic being accommodated on or alongside the pavement layers, during the construction of the pavement layers, until the Employer has taken over the works;
- Repair of all damage to the existing pavement layers after access to the construction site has been given to the Contractor and that may occur before, during or after the construction of the reconstructed or rehabilitated pavement layers up until the Employer has taken over the works;
- Provision of additional material in excess of the compacted volume of the layers calculated using the layer dimensions given in the Contract Documentation for whatever reason including additional material required for the correct placing, mixing, levelling and compaction of the layers;
- The removal of oversize material up to 5% of the compacted layer volume;
- Construction of tie in joints to new or existing road layers or surfacing;
- The preparation and the inspection for cracks in an underlying layer after removal of a pavement layer;
- Excavation of benches in pavement layers when widening an existing pavement;
- The provision and maintenance of covers for stockpiled reclaimed materials;
- The provision of method statements and of the programme of reconstruction work along with regular updates of the programme, and
- The brooming during the slushing process whether by hand or by mechanical means.

(iii) Items to be measured and paid for using payment items specified elsewhere in the specifications

For activities in Table C5.6-1 payment items specified in other Chapters or Sections of the specification, where they relate to work under this Section, will be listed in the Pricing Schedule.

Table C5.6-1: Payment items from other Chapters or Sections

Activity	Clause reference	Section or Chapter
Traffic accommodation	A5.6.3.1	Section C1.5 of Chapter 1
Stabilising agents	A5.6.5	Section A5.6
Construction equipment Processing of pavement	A5.6.6.1 & A5.6.6.2	Section A5.6.6
Curing a stabilised layer	A5.6.9.2	Section A5.6.9
Tack or prime a layer	A5.5.3.7	C9.1.3 of Chapter 9
Surfacing a reconstructed layer	A5.6.3.5	Section A5.6

(iv) Payment items specifically for this Section of the Specifications

Item	**Description**	**Unit**
C5.6.1	Compiling and implementing M&U plans for the reconstruction of an existing road pavement number ……………………………………………...	(No)

The unit of measurement shall be the number of M&U plans for the reconstruction work. Several plans shall be required as specified in Clauses A5.6.3.8

The tendered rate shall include full compensation for gathering all information, compiling the plans and for ensuring the implementation of the plans during the RR construction work.

Item	**Description**	**Unit**
C5.6.2	Reconstruction preparatory work ………………………………………………………..	km
C5.6.2.1	Undivided carriageway ……………………………………………………………...	km

The unit of measurement shall be the kilometre of uniform section of road to be reconstructed and rehabilitated, measured along the centre-line of the existing road. Each uniform section shall be measured separately. In the case of an undivided road carriageway this shall be measured once along the centreline. In the case of a divided road carriageway this shall be measured once along each carriageway separately.

The tendered rate shall include full compensation for undertaking all the work required in preparation for reconstruction. This work includes all survey and survey-related work such as setting out, checking the design levels and the approval of the final design levels.

This work also includes the removal of standing water, grass and weeds from the road surface including the shoulders.

Item	Description	Unit
C5.6.3	Establishment Of Plant	
C5.6.3.1	Establishment of cold in-situ recycling equipment/plant on site …………………	Lump Sum
C5.6.3.2	Establishment of conventional equipment/plant on site …………………………..	Lump Sum

The tendered lump sum shall include full compensation for the provision of any number of recycling machine(s)/plant on the section of the site and the subsequent removal thereof, including additional plant required for carrying out cold in-situ processing, stabilisation and compaction operations.

The lump sum will become payable after the cold in-situ processing and stabilisation work has been completed and the equipment has been removed from the site. Payment will only be made for either C5.6.3.1 or for C5.6.3.2 dependent on the Contractor's chosen method of construction

Payment will not distinguish between the number of recycling machines or conventional units of equipment brought onto and/or removed from the site. No payment will be made for the replacement of the defective plant.

Item	Description	Unit
C5.6.4	Cold in-situ recycled granular layer treated	
C5.6.4.1	Using a recycler	
	(a) Base-layer (depth to be specified) compacted to the specified density (Table A5.6/1) using an NME or equivalent ………	cubic metre (m³)
	(b) Sub Base-layer (depth to be specified) compacted to the specified density (Table A5.6.5/1)using an NME or equivalent ……..	cubic metre (m³)
C5.6.4.2	Using a conventional plant	
	(a) Base-layer (depth to be specified) compacted to the specified density (Table A5.6.5/1) using an NME or equivalent ……..	cubic metre (m³)
	(b) Sub Base-layer (depth to be specified) compacted to the specified density (Table A5.6.5/1) using an NME or equivalent ……..	cubic metre (m³)

The unit of measurement shall be the cubic metre of pavement processed and stabilised to provide the recycled base and or sub-base layer as specified.

The rate tendered shall include full compensation for the provision of all plant, labour, materials and all other incidentals necessary to produce the finished layer as specified but excluding the provision of the NME stabilising layer that shall be measured and paid for under item C10.03. The NME will consist of a material-compatible product as described in the preamble, which will be able to meet the required specifications (the Contractor will take responsibility for using a stabilising agent not meeting the minimum requirements in terms of stability resulting in inferior test results).

The tendered rate shall also include full compensation for the milling of existing pavement layers, blending of the materials in the nominal mix ratios specified, supply, diluting of the NME in potable water and mixing of the diluted NME, spreading and final blading of the recycled mix, compacting the material to the specified density and protecting and maintaining the work in accordance with the specifications.

The tendered rate shall also include full compensation for the cleaning of the surface and the referencing of lane and control survey markings as specified.

Where ordered by the Engineer for the processing and stabilisation of pavement layers to depths other than specified, the payment will be made on a pro-rata basis between the tendered rates for the nominal depths scheduled.

All failures due to the use of contaminated equipment (not thoroughly cleaned) will be for the cost of the Contractor.

Item	**Description**	**Unit**
C5.6. 5	Nano Modified Emulsion (NME) or Equivalent	..............................cubic metre (m³)

The unit of measurement shall be per cubic metre of the material stabilised (different stabilising agents may require different percentage additives to meet criteria) with the stabilising agent to be supplied to meet all the required criteria as specified and as instructed by the Engineer.

The tendered rate shall include full compensation for providing, diluting, mixing and applying the stabilising agent, irrespective of the rate of application. The material-compatible NME will be provided to the site by the supplier to meet the specifications. The Contractor will take full responsibility and liability for using a stabilising agent not meeting the END-PRODUCT specification. During the design phase, the Design Engineer should ensure that products are available that will meet the specifications with the given naturally available materials.

C5.6.6 Chemical additive No chemical additives will normally be required with a material-compatible water-repellent NME stabilising agent. However, should the material characteristics dictate the use of any chemical additives the costs should be included in the cost of the NME stabilising agent (or alternative) must be included as part of Item C5.6.5

Item	**Description**	**Unit**
C5.6. 7	Pre-treating the base layer with an NME stabilising agent	

No pre-treatment of lime, etc. will be required with an NME stabilising agent. Some minerals may require pre-treatment with an appropriate / proven product. Payment is to be included as part of Item 10.03.

Item	**Description**	**Unit**
C5.6.8	Blading of surplusmaterial to windrow ....cubic metre (m³)	

The unit of measurement shall bethe cubic metre of surplus material bladed to the windrow as specified by the Engineer. The tendered rateshall include full compensation for all labour equipment and any other incidentals required for blading toawindrow of surplus material with a motor grader.

Item	Description	Unit
C5.6. 9	Removal from site of surplus material ………………………………………	cubic metre (m^3)

The unit of measurement shall be the cubic metre of surplus material removed. The volume shall be determined as prescribed by the Engineer and shall be the loose volume in stockpiles or the equivalent thereof volume in hauling vehicles. Accurate load and haul sheets shall be kept on site and submitted to the Engineer. The tendered rate shall include full compensation for loading and transporting the surplus material to a designated spoil or stockpile site as approved by the client

Item	Description	Unit
C5.6.10	Construction of a temporary wearing course ……………………………..	square metre (m^2)

The unit of measurement shall be the square metres of stabilised base slushed in accordance with the requirements of section A5.6.7.15 of the Project Specification and the tendered rate shall include full compensation thereof.

Item	Description	Unit
C5.6.11	Trial sections where ordered (extra over items C5.6.4 and C5.6.5)	

(a) Processing and stabilisation of layers……………………………… cubic metre (m^3)

The unit of measurement shall be the cubic metres of processed and stabilised pavement layers as per instruction.

(b) Applying of prime, tack coat or surfacing layer …………………. square metre (m^2)

The unit of measurement of the prime coat shall be the square metres, independent of the applied surfacing as per instruction from the engineer.

The tendered rate shall include full compensation for the construction of the trial section of recycled pavement layers complete as specified.

Item	Description	Unit
C5.6.12	Extra over Item C5.6.4 for adding extra material to the layer	

(a) Gravel Base of a required quality as per specification …………… cubic metre (m^3)

(b) Gravel sub-base of a required quality as per specification ……….. cubic metre (m^3)

(c) RA (when specified as per specific client)………………………… cubic metre (m^3)

The unit of measurement shall be the cubic metre of material added on the instruction of the Engineer, which quantity shall be taken as 70 per cent of the loose volume measured in trucks unless instructed by the Engineer that the quantity be determined by way of cross-sections. The tendered rate shall include full compensation for procuring and adding the specified material to the layer, for spreading the material, for all haul and for other incidentals to add the material to the layer.

Item	Description	Unit
C5.6.13	Milling out existing bituminous material with an average milling depth	
	(a) Not exceeding 30 mm ………………………………………………	cubic metre (m^3)
	(b) Exceeding 30 mm but not exceeding 60 mm ……………………..	cubic metre (m^3)
	(c) Exceeding 60 mm …………………………………………………	cubic metre (m^3)

The unit of measurement shall be a cubic metre of asphalt milled out and removed to approved stockpiles. The tendered rate shall include the compensation for providing milling equipment and milling out the material to the specified depth and in accordance with the requirements for evenness and for all measurements, labour, supervision and incidentals tor executing the work and obtaining milled material which will comply with specified materials

The tendered rate shall also include full compensation for trading and transporting the material to approved stockpiles tor a free-haul distance 1.0 km irrespective of the method of loading and for unloading of the material and placing it in stockpile, also tor screening out the oversize material if necessary. Separate payment will be made for preparing stockpile site.

Payment for milling the material will distinguish between the various average depths of excavation, irrespective of the required number of passes by the plant for milling out material.

Item	Description	Unit
C5.6.14	Providing the milling machine on the site (size indicated) number ……………………	(No)

The unit of measurement shall be the number of milling machines provided on the site, or the number of times & milling machine is brought onto the site where t had to be removed temporarily with the approval of the engineer.

The unit of measurement shall be the number of times the machine is moved for more than 1,0 km, as may be approved or instructed by the engineer, in writing.

The tendered rate shall include full compensation for al! costs involved in such moving irrespective of as to whether the machine is moved to a new section of the site or returned to a previous position for further work), as well as for all delays and production losses. Payment will not be made for moving for the purpose of maintenance and repairs or for replacement with another machine.

Item	Description	Unit
C5.6.15	Break down of in-situ material ………………………………………………	cubic metre (m^3)

The unit of measurement shall be the cubic meter of material measured after compaction. The quantity measured shall be computed by the method of average end areas from levelled cross-sections prepared from the existing road surface before any ripping or breaking down of the existing surface and base course has taken place. All measurements shall be neat and material placed in excess of the authorized cross- section will not be paid for. The tendered price shall include the ripping, breaking down, preparing, processing, shaping and watering of the materials to the specified densities.

Item	Description	Unit
C5.6.16	Application of a prime or "clear seal" square metre…………..…………………	(m²)
	Application of a NPNS in-situ materials treatment ……………………………………	(m2)
	Application of a NPNS gravel surfacing treatment ……………………………………	(m2)

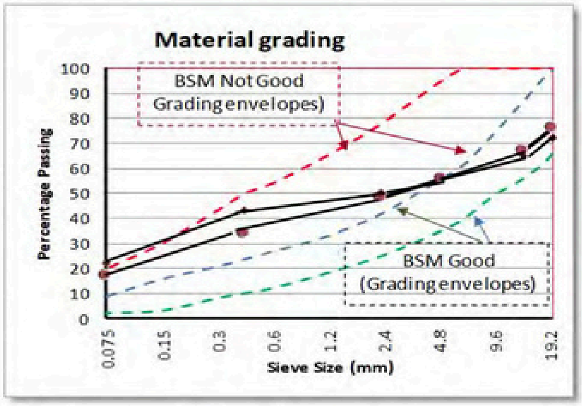
Rates should include the provision of the materials and suitable distribution equipment able to apply the prime or specified "clear seal" to meet the required specifications and at the required rate.

Appendix F. Examples of MC-NME Stabilising Agents Tested in Practice

HVS test site – "G8" base layer; "G7" sub-base layer on G10 sub-grade – design traffic loading – 3 million E80s.

The material properties, XRD-mineralogy tests and UCS and ITS results are summarised in Figure F 1.

Base and Sub-base material for Accelerated Pavement Testing (APT) (MMLS3) of thin (chip seal) surfacings



Material Test results

Fraction	%
Coarse Sand (CS)	29 - 33
Fine Sand (FS)	28 - 35
Coarse Fine Sand (CFS)	10 - 11
Medium Fine Sand (MFS)	11 - 17
Fine Fine Sand (FFS)	6 - 8
Silt and Clay (S & C)	35 - 39
OMC (%)	11.4
MDD (kg/cub m)	2030
GM	1.85
Atterberg Limits	
Liquid Limit (LL)	28 - 30
Plasticity Index (PI)	8 - 14
PI (0.075)	
Linear Shrinkage (LS)	4 - 7
CBR (mod AASHTO)	
95%	10 - 17
93%	9 - 14
Classification	
H.R.B.	A-2-6
COLTO	G8
TRH14	G8

Mineral Percentages present in Material Sample

Minerology	Total sample %		0.075 mm Fraction %	
Mineral Groups	Individual	Combined	Individual	Combined
Quartz	43.2	43.2	23.0	23.0
Plagioclase	14.8		6.6	
Augite	2.4		1.3	
Enstratite	0.0		0.5	
Actinolite	3.8		1.4	
Microcline	6.5		4.2	
		27.5		14.0
Mica: Muscovite	12.2	12.2	36.2	36.2
Clay: Kaolinite	6.1		15.0	
Clay: Smectite	7.5		3.0	
Calcite	0.5	14.1	6.5	24.5
Talc	3.1	3.1	2.3	2.3

Mineral Groups: (Weathering = chemical decomposition)
Primary (Not subject to Weatering)
Primary (Subject to Weathering)
Mica
Secondary minerals
(Nano-scale crystals/molecules)

Results: Stabilisation

Agent	New-age Modified Emulsion (NME)				Conventional Emulsion stabilisation	Unit
%	0.7	1.0	1.2	1.5	1.5% SS60 Emulsion + 1.0 % Cement	
UCS(dry)	3395	4807	4859	2620	3277	kPa
UCS(wet)	1745	1830	1671	1865	656	kPa
UCSw/d %	51	38	34	71	20	%
ITS(dry)	254	420	268	232	167	kPa
ITS(wet)	61	321	221	184	61	kPa
ITSw/d %	24	76	82	79	37	%

Figure F 1 MC-NME stabilisation of "G8" materials

Figure F 1 gives a comparison of the results with the MC-NME percentage stabilising agent varying form 0.7 per cent to 1.5 per cent. The results from an unmodified bitumen emulsion stabilisation consisting of 1.5 per cent SS60 and 1.0 per cent cement are shown on the right of the bottom table. The percentage passing the 0.075 mm sieve and the percentage of problematic minerals within the 0.075 mm fraction are plotted on Figure F 1, as shown in Figure F 2

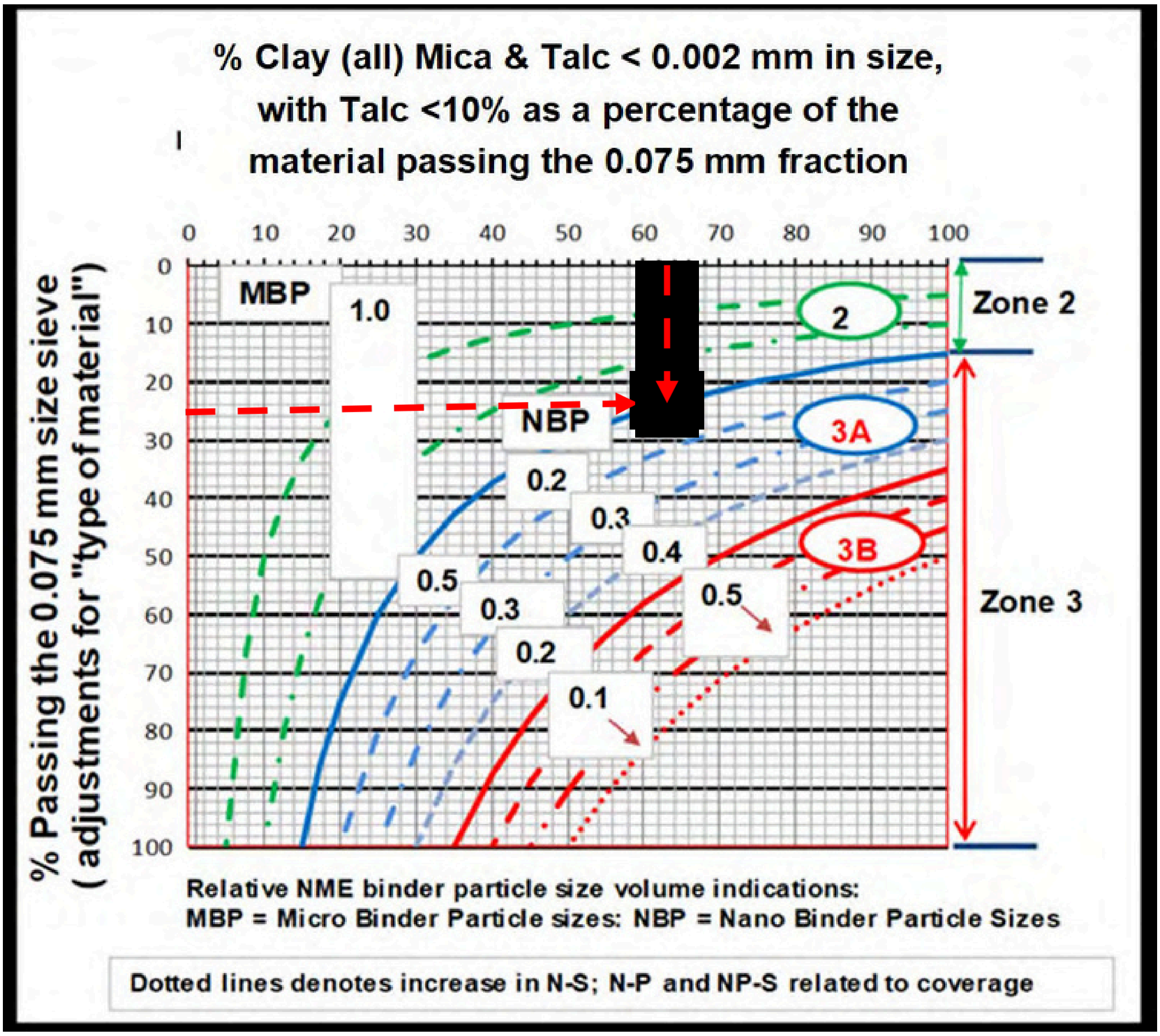


Figure F 2 Percentage ofmaterials passing through the 0.075 mm sieve and the percentage of problematic minerals within the0.075mm fraction of the “G8 material results

The percentage of the granularmaterial passing the 0.075 mm sieve size is 20 to 25 per cent. From the XRD-scan and analysis in FigureF1,it is seen that the percentage problematic materials within the 0.075 mm fraction is in the order of63percent. The combination of these granular material fractions put the material in the proximity whereamicro-size modified binder (in this case bitumen applied in the form of a MC-NME stabilising agent) needstobe supplemented with a nano-size particle size binder (the blue line). It is also seen that the amountoforganofunctional-silane will have to be increased by a factor of about 3 (dotted green lines Figure F 2)toeffectively neutralise all the fine particles within this granular material.

From the results in Figure F 1, it is seen that the UCS as well as the ITS measurements decrease with an increase in the MC-NME stabilising agent. This is explained by the percentage of fines as indicated in Figure F 2**.** The high percentage of problematic minerals of a nano-size in the granular material is now being stabilised with a binder that is more than a thousand times bigger that the clay particle sizes in the material. Although the resultant measurements are still very good, more of the stabilising agent is not very effective and the small granular particles are basically “drowning” in the binder that is more than a 1000 times bigger than the clay particles in the granular materials. A nano-polymer combination within the binder should prove very effective in this case.

It is seen that that the Retained Tensile Strength (RTS) at 1 per cent MC-NME is 76 per cent with the ITSwet at more than 320 kPa. The Retained Compressive Strength (RCS) exceeds 70 per cent at 1.5 per cent MC-NME. In this case stabilisation of the base was done at 1.5 per cent MC-NME where direct wheel-stresses need to be coped with and a high resistance to any water ingress from the top will be a future advantage. The sub-base was stabilised with 1 per cent MC-NME catering for any future increase in required tensile strength at the bottom of the stabilised layers together with a high resistance to any water ingress into the supporting layers.

Comparatively, the traditional emulsion stabilisation showed very poor resistance to the effect of water with low RCS and RTS measurements as shown in Figure F 1. The comparison between the pavement structures of the “traditional design and the MC-NME design for this road is shown in Figure F 3.

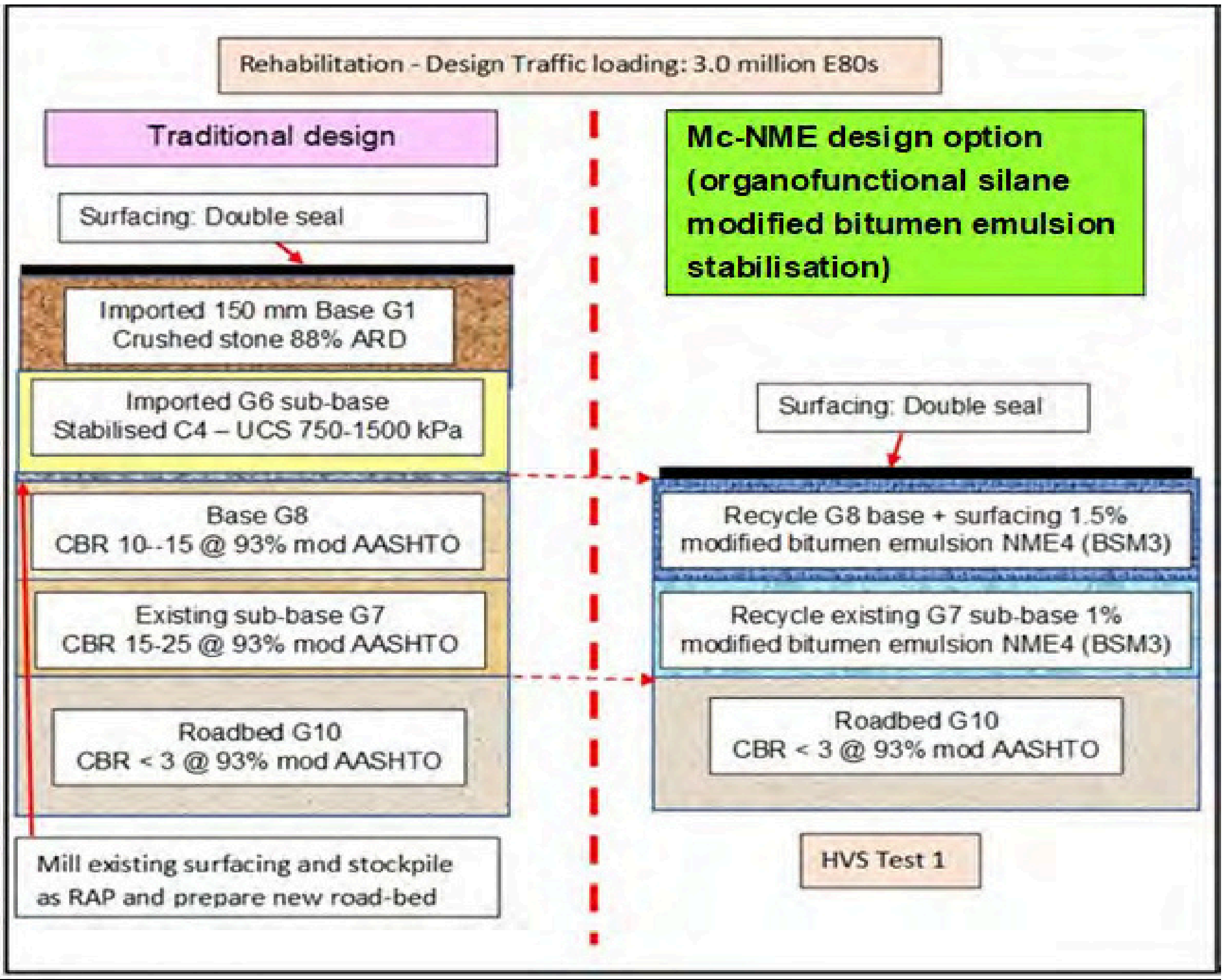


Figure F 3 Comparison between the “traditional” design on the left and the MC NME design on the right, for a design traffic loading of 3.9 million E80s

Upgrading of unpaved road rural road in Mpumalanga – 2.5 million E80s

The appointed contractor invited several possible suppliers to test their NME products using the End Product Specifications and test methods contained in Appendix E. On insistence of the client specifications in line with a NME3 material should be considered. In total, 14 different products from various suppliers were tested as shown in Table F 1. It is seen that only 3 products met the criteria within the “End Product Specification” (Appendix E). The MC-NME designed anionic stabilising agent exceeded the criteria by some margin at less than half the cost of a BSM design that also met the criteria.

These results clearly illustrate the advantages of a scientifically based materials design method based on the generic fingerprint of the granular materials, i.e., the mineralogy of the granular materials.

Table F 1 Results from the testing of various stabilising agents with an in-situ “G7” material with little cohesion

2351	1790	76	136	289	217	75	102	Pass
1585	1166	74	86	171	105	61	40	Fail
1409	887	63	56	121	48	40	12	Fail
1238	705	57	40	106	29	27	5	Fail
1308	739	56	42	112	27	24	4	Fail
1370	798	58	46	138	37	27	6	Fail
2086	1515	73	110	233	166	71	74	Fail
1565	971	62	60	139	86	62	33	Fail
1396	823	59	49	132	45	34	10	Fail
1253	707	56	40	105	23	22	3	Fail
1329	746	56	42	135	29	21	4	Fail
1386	769	55	42	162	39	24	6	Fail
3110	3120	100	313	281	356	127	282	Pass
2090	2840	136	386	181	283	156	277	Pass

Upgrading of Pilot project at Lidgetton (KZN)

Thein-situ material along the section of road has the following characteristics:

- Percentage passing the 0.075 mm sieve size > 80 per cent, and XRD results of the material
- are shown in Table F 2. The highlighted mineral in the fraction
  56.5 per cent consisting mainly of clay (kaolinite (18.8 per cent) and smectite (18.2 per cent)) and 13 per cent muscovite.

Table F 2 Results from the XRD testing of the in-situ and locally available "G7" material

Sample	Quartz	Plagioclase (Albite)	Augite	Actinolite	Muscovite	Kaolinite	Talc	Smectite
Total	25.5	38.3	6.7	0.3	13.8	2.3	1.5	12.1
0.075 mm fraction	15.5	26.7	5.4	1.2	13.0	18.8	1.1	18.2

The in-situ material characteristics in terms of the various percentages are plotted on Figure F 4.

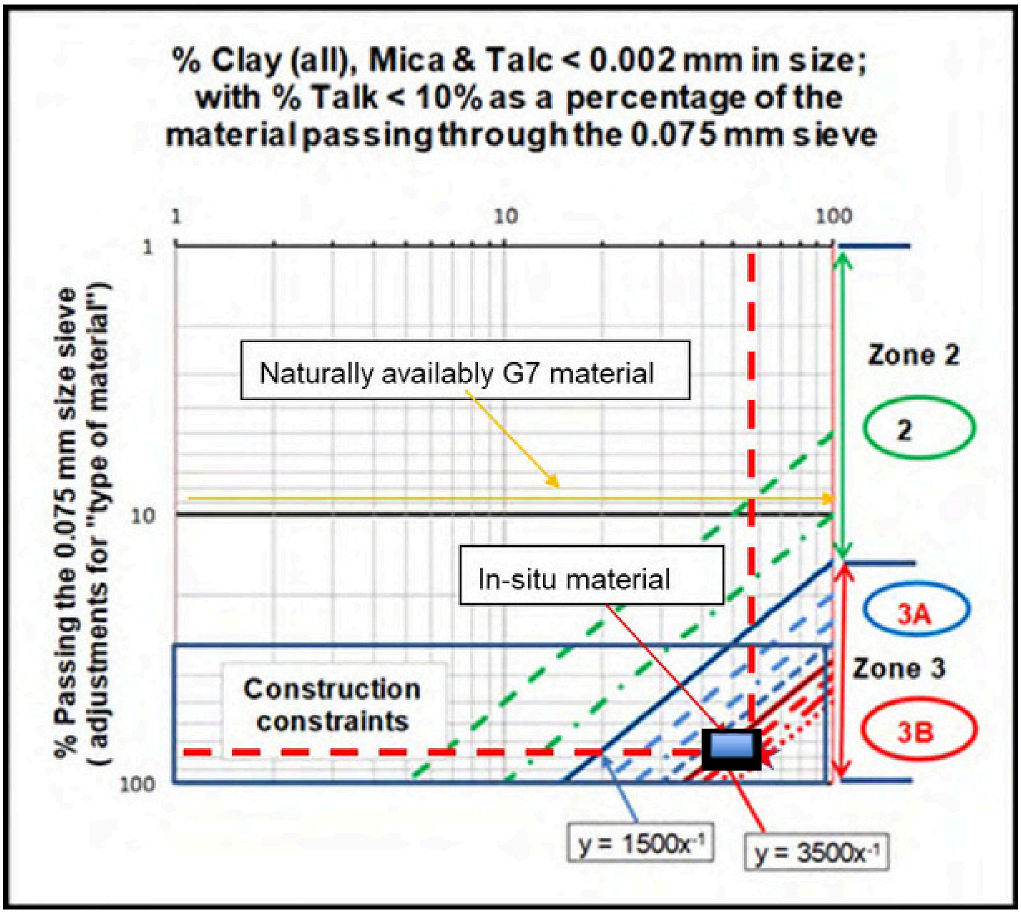


Figure F 4 In-situ material on pilot project Lidgetton

This material is an example of an extreme in-situ material that presents problems both in terms of workability as well as the ability to effectively be stabilised. The addition of any water to this material will result in an unworkable mud that cannot be effective within a pavement structure.

However, the material can be treated in-situ using MC-NME(NPNS) and bound together to form a hydrophobic (water-resistant) supportive layer for the construction works on top of the material as addressed in APPENDIX E “End Product Specifications” as described in **C1014 TREATMENT OF IN-SITUMATERIALSOFRELATIVELYPOOR QUALITY TO FORMA SUPPORT LAYERONWHICH TO CONSTRUCTALAYEROFQUALITYNME4 ORTO BIND LOOSE MATERIAL BEFORESURFACING OF LOWER ORDER ROADS**. To achieve the required penetration of at least 60 mm, a MC-MNE(NPNS) consisting of a high-quality anionic Nano-Polymer Nano Silane (NPNS) was tested to form a supporting layer for the construction of base layer on top of the bounded, hydrophobic support layer. Several applications of the MC-MNE(NPNS) were tested in a laboratory, to obtain the optimum dilution applicable for the specific material as supplied, the results of which are shown in Figure F 4. It is seen that both the 1:5 and 1:10 diluted application resulted in a good hydrophobic layer with well-rounded water particles on top of the layer.

The naturally available G7 material from a quarry close to the road has a percentage passing through the 0.075 mm sieve of less than 9 per cent. From Figure F 4, this material should present no problem with MC-NME stabilisation – even with the same problematic minerals present in the material. Even if the fines should double during construction, the MC-NME materials design should be able to neutralise the problematic minerals, resulting in a well-constructed layer for the upgrading of the road.

After curing within the Marshall mould, the measured DCP-DN value was measured as less than 3.5 mm/blow on the sample treated with a MC-NME(NPNS) diluted at 1:10. Hence, the in-situ material can successfully be treated as a supported layer APPENDIX E, Item C1014.

For a thicker supporting layer (e.g., 150 mm) it is recommended that the material be ripped to the required depth, spayed with the diluted MC-NME(NPNS) at 2.0 litres/m2 material. A test section should be done beforehand to evaluate the workability and practicality of such an approach. The layer should be mixed with a grader and sprayed a second time before shaping and compaction as demonstrated in Figure F 5. (the example shown in Figure F 5 is for the surfacing of a local farm excess road where the in-situ material was treated with a MC-NME(NPNS) before shaping and compaction. In this case it is recommended to finally treat the layer with a MC-NME- Micro Polymer Nano Silane (MPNS) to give more adhesion to the granular material particles exposed to the friction of vehicles. A good MC-NME(MNPS) should contain particle sizes in the order of 0.6- 1.2 µm that will be able to give a longer maintenance free hydrophobic protection to the granular materials on an unsurfaced road while retaining the natural couloir of the granular materials.)

Figure F 5 MC-NME(NPNS)spray-on treatment of in-situ material

Upgrading of a major rural road

This road was constructed in 1965 as a 2-lane road with a total surfaced width of 6.0 m to 6.3 m. Two main options are shown for upgrading the road to a total width of 13.4 m. The design traffic loading was estimated over a twenty-year period to vary between 7 million E80s and 10 million E80s. Two options are shown, i.e.:

- Traditional deign with a 150 mm G1 crushed stone base layer with 2 cement stabilised sub-bases as shown in Figure F 6, and
- MC-MNE stabilised base and sub-base, fully utilising the in-situ top 300 mm of the existing pavement as shown in Figure F 7.

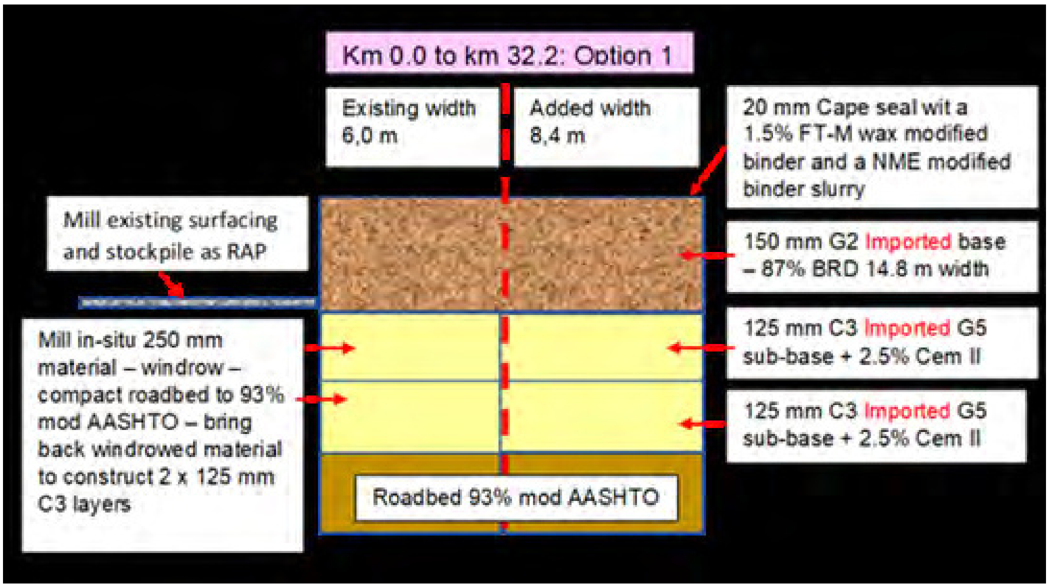


Figure F 6 Alternative - crushed stone base and two C3 cement treated sub-bases

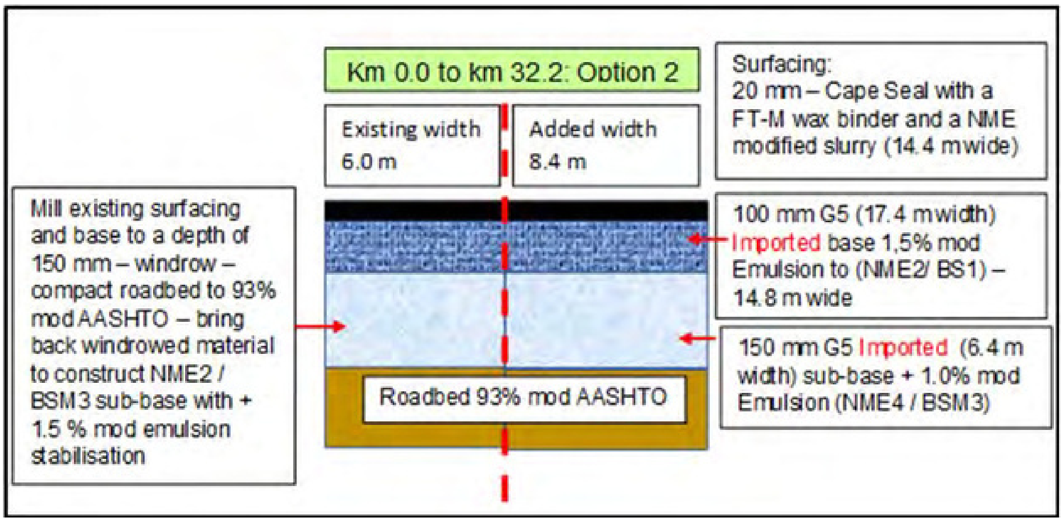


Figure F 7 MC-NME pavement alternative design

The top 300 mm of the existing pavement was sampled and tested per the MC-NME design requirements as contained in Chapter 5 and as an input into APPENDIX E -End Product Specifications. The gradings of the finer fractions of the top 300 mm tested along the length of the road per identified uniform pavement sections are shown in Figure F 8.

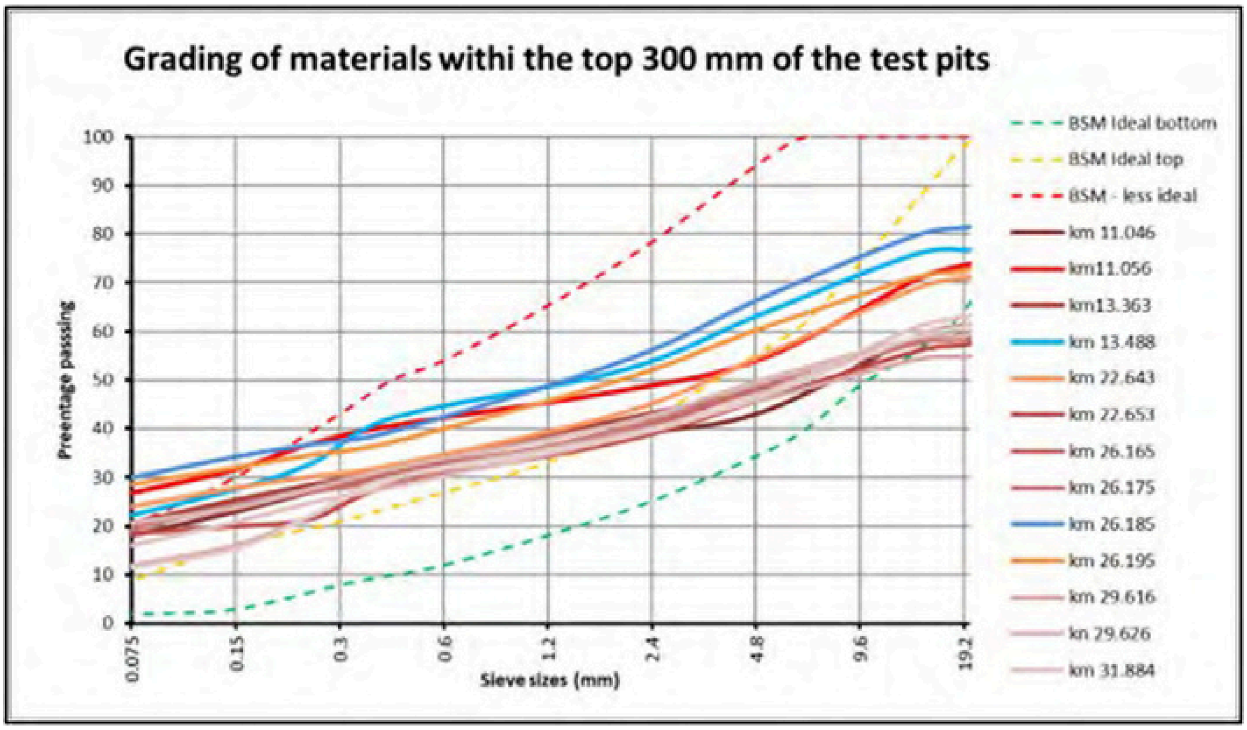


Figure F 9 Grading of the top 300 mm of the materials from each borrow-pit along the length of the road to be utilised within the new pavement structure using MC-NME stabilisation

It is seen from Figure F 10 that the percentage of the material passing through the 0.075 mm, mostly varies between 20 and 30 per cent. It is also clear that the material will not be suitable for a BSM design in terms of the required grading envelopes shown.

The XRD results of the top 300 mm of the samples taken from the test pits as well as the localised potential naturally available materials next to the road are summarized in Table F 3 It is seen that most of the fractions passing through the 0.075 mm sieve consists of quarzitic minerals, ideally suited for MC-NME stabilisation. At worst, the percentage of problematic minerals (highlighted in pink) was estimated at 16 per cent.

The worst combination of particle fractions combined in terms of percentage passing the 0.075 mm sieve size, together with problematic minerals within the 0.075 mm fraction is plotted on Figure F 8 and shown in Figure F 9. From Figure F 9 it is obvious that the material properties in terms of the measured particle sizes should present no problem in meeting those properties as required in a MC-NME design proposal.

The testing of the top 300 mm in-situ material was done according to prescribed test procedure contained in Chapter 6 and APPENDIX E. The results of the material testing using an anionic MC-NME stabilising agent are shown in Table F 3. From Figure F 9 it is seen that a material class of NME4 is required for the sub-base and a NME2 for the base layer. The detailed testing along the length of the road shows that an NME2 class material can be achieved comfortably with 1.5 per cent of an anionic MC-NME stabilising agent and a NME4 class material in most cases with 1.0 per cent anionic MC-NME stabilising agent.

Table F 3 Summary XRD-scans for the various uniform sections along the road taken from the top 300 mm of the existing road

XDR Minerology Scans		Quartz	Hematite	Kaolinite	Muscovite	Biotite	Goethite	Chlorite	Plagioclase	Dolomite	Talc	Gypsum
Pavement Section												
Section 1A Km 3.9 – km 24.2	Total Sample	96.7%		2.8%		0.1%	0.4%					
	0.075 Fraction	82.0%	1.8%	16.0%								
Section 1B Km 24.2 – km 36.04	Total Sample	96.5%	0.7%	2.2%		0.2%	0.1%					
	0.075 Fraction	85.5%	2.0%	12.2%		0.2%						
Section 2 Shoulder Km 32.2 – km 52.2	Total Sample	98.2%	0.3%	0.4%	0.3%		0.2%	0.5%	0.3%			
	0.075 Fraction	96.3%	0.6%	2.4%	0.6%							
Borrow Pits -Mine Dumps next to the road												
Source 1	Total Sample	82.4%			11.4%			3.5%		2.3%		0.4
	0.075 Fraction	70.3%			22.3%			3.6%		0.9%	0.6%	2.3
Source 2	Total Sample	78.0%			16.7%			4.3%		0.4%		0.6
	0.075 Fraction	74.7$			19.4%			3.0%		0.5%	0.3%	2.2

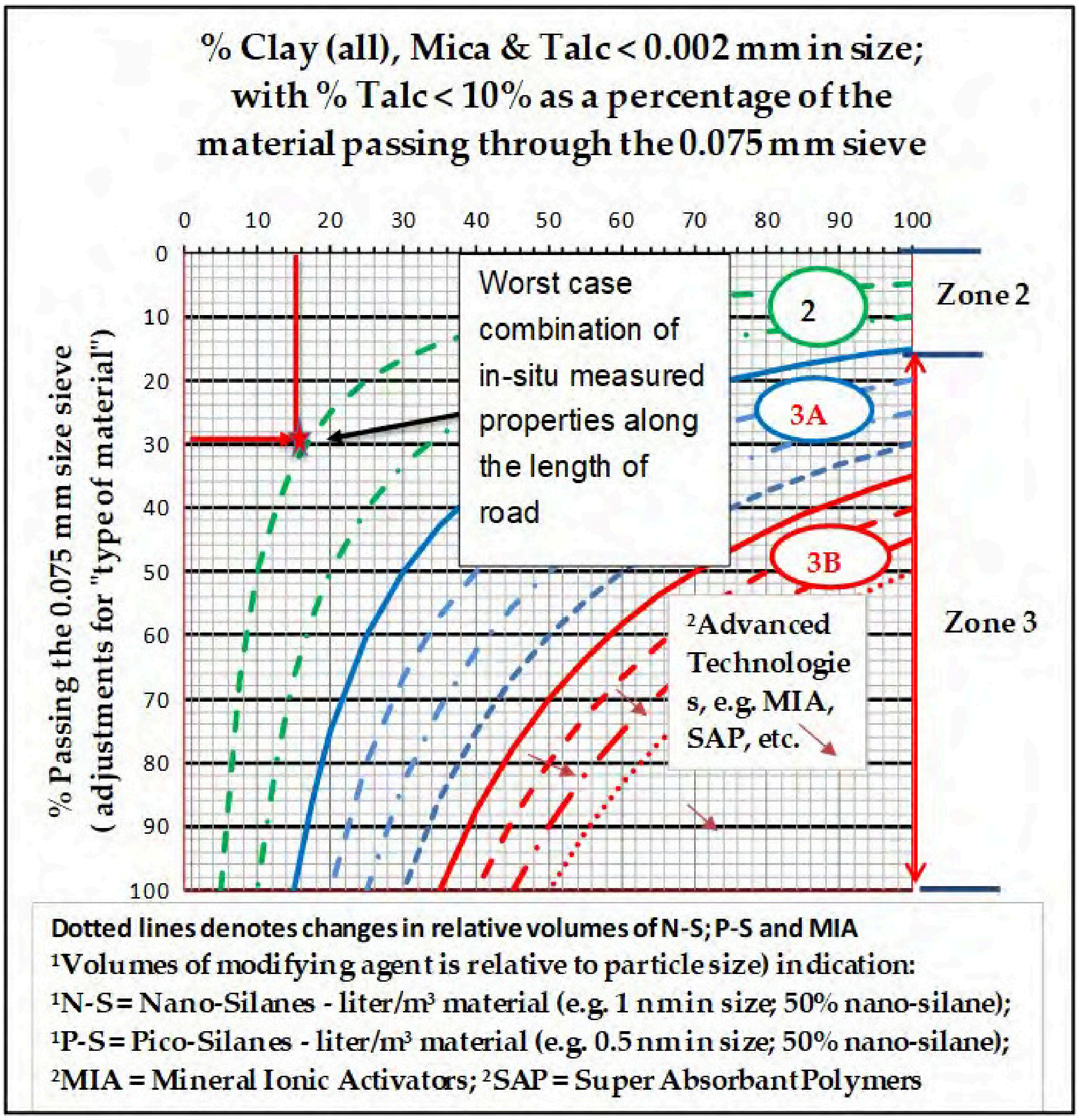


Figure F 11 Worst case scenario of the particle fractions measured along the length ofthe road indicating the potential of the material for utilisation in a MC-NME design

The different design options should be compared in a thorough economic evaluation. The estimated material costs of the two options are shown in Table F 5. These costs exclude savings in construction time and related costs between the options.

Table F 4 Summary XRD-scans for uniform sections along the length of the road - top 300 mm of the existing road

Results Summary : R501 Potch to Carletonville (New Modified Emulsions (NME) - UCS (dry & wet)) and ITS (dry and wet))										
DESIGN STRENGTHS FOR NME (As per NME Test Protocols - Rapid Curing) - refer Table 3.15										
Sample Information	Property	0.7% MC-NME	1.0 % MC-NME	1.3% MC-NME	1.5% MC-NME	Property	0.7% MC-NME	1.0 % MC-NME	1.3% MC-NME	1.5% MC-NME
Ch:11.046km (70-330mm)	UCS (Mpa) - Dry	2.80	3.00	3.10	3.40	ITS (Kpa) - Dry	208.00	239.00	254.00	282.00
80% Red material +	UCS (Mpa) - Wet	1.40	1.69	2.07	2.50	ITS (Kpa) - Wet	101.00	117.00	165.00	217.00
20% Asphalt	RCS	50.00%	56.33%	66.77%	73.53%	RTS	48.60%	49.00%	65.00%	77.00%
	NME CLASS			NME 4	NME 2	NME CLASS			NME 4	NME 2
Ch:11.056km (70-330mm)	UCS (Mpa) - Dry	3.30	3.50	3.65	3.90	ITS (Kpa) - Dry	231.00	275.00	312.00	371.00
80% Red material +	UCS (Mpa) - Wet	2.20	2.40	2.58	30.00	ITS (Kpa) - Wet	144.00	198.00	233.00	279.00
20% Asphalt	RCS	66.67%	68.57%	70.68%	769.23%	RTS	62.34%	72.00%	74.68%	75.20%
	NME CLASS	NME 4	NME 4	NME 3	NME 2	NME CLASS		NME 3	NME 3	NME 2
Ch:13.463km (70-330mm)	UCS (Mpa) - Dry	2.10	2.40	2.50	2.61	ITS (Kpa) - Dry	166.00	181.00	211.00	242.00
80% Red material +	UCS (Mpa) - Wet	1.10	1.30	1.64	2.03	ITS (Kpa) - Wet	79.00	108.00	147.00	189.00
20% Asphalt	RCS	52.38%	54.17%	65.60%	77.78%	RTS	47.59%	59.67%	69.67%	78.10%
	NME CLASS			NME 4	NME 2	NME CLASS			NME 3	NME 2
Ch:22.643km (70-330mm)	UCS (Mpa) -Dry	3.10	3.50	3.95	4.33	ITS (Kpa) - Dry	258.00	277.00	382.00	459.00
80% Red material +	UCS (Mpa) -Wet	1.80	2.28	2.90	3.40	ITS (Kpa) - Wet	146.00	232.00	285.00	358.00
20% Asphalt	RCS	58.06%	65.14%	73.42%	78.52%	RTS	56.59%	83.75%	74.61%	78.00%
	NME CLASS		NME 4	NME 3	NME 2	NME CLASS		NME 4	NME 3	NME 2
Ch:26.165km (70-330mm)	UCS (Mpa) - Dry	2.02	2.13	2.37	2.72	ITS (Kpa) - Dry	136.00	157.00	201.00	243.00
80% Red material +	UCS (Mpa) - Wet	1.09	1.44	1.61	2.10	ITS (Kpa) - Wet	87.00	103.00	133.00	170.00
20% Asphalt	RCS	53.96%	67.61%	67.93%	77.21%	RTS	63.97%	65.61%	66.17%	69.96%
	NME CLASS		NME 4	NME 4	NME 2	NME CLASS		NME 4	NME 4	NME 3
Ch:29.616km (60-290mm)	UCS (Mpa) - Dry	2.41	2.52	3.00	3.44	ITS (Kpa) - Dry	172.00	229.00	245.00	302.00
80% Red material +	UCS (Mpa) - Wet	1.50	1.66	1.96	2.60	ITS (Kpa) - Wet	109.00	152.00	187.00	236.00
20% Asphalt	RCS	0.52	0.66	0.65	0.76	RTS	63.37%	66.38%	76.33%	78.15%
	NME CLASS		NME 4	NME 4	NME 2	NME CLASS		NME 4	NME 2	NME 2
Ch:31.884km (70-330mm)	UCS (Mpa) - Dry	3.22	3.84	4.26	4.45	ITS (Kpa) - Dry	235.00	280.00	321.00	383.00
80% Red material +	UCS (Mpa) - Wet	2.45	2.93	3.40	3.84	ITS (Kpa) - Wet	185.00	223.00	310.00	328.00
20% Asphalt	RCS	0.76	0.76	0.80	0.86	RTS	78.72%	79.64%	96.57%	85.64%
	NME CLASS	NME 3	NME 3	NME 2	NME 1	NME CLASS	NME2	NME 2	NME 1	NME 1

Table F 5 Cost comparison between the crushed stone base and the MC-NME option

Item	Description	Pavement Option Crushed stone base	Pavement Option MC-NME design
		Amount	**Amount**
1 2	Traffic Accommodation	R36375000.00	R24250000.00
3 4	Concrete Drains	R1541000.00	R1541000.00
5 6	Lesser Culverts	R23175000.00 R0.00	R23175000.00
7 8	Mass Earthworks	R279172307.00	R0.00
9	Pavement Layers	R30000000.00	R142266360.00
10	Access Roads	R9975000.00	R30000000.00
11	Guardrails	R660000.00	R9975000.00
12	Fencing	R4122500.00 R800	R660000.00
13	Road Markings	000.00 R3 500 000.00	R4122500.00
14	Road Signage	R7 200 000.00 R6 528	R800 000.00 R3
	Relocation of Services	100.00 R38 000	500 000.00 R7
	Major Culverts	000.00	200 000.00 R6
	Railway Bridges Widening		528 100.00 R38
	Sinkhole Rehabilitation		000 000.00
Sub -Total		**R441 048 907.00**	**R292 017 960.00**
Add 20% P&G's		**R88 209 781.40**	**R68 403 592.00**
Total Excluding VAT		**R529 258 688.40**	**R350 421 552.00**
Total Including VAT		**R608 647 491.66**	**R402 984 784.80**

A full economic evaluation of the various options using a HDM4 analysisisisshown in Table F 6.The comparison for a full upgrading of the road is highlighted in red in Table F6.The HDM4 analysis clearly shows the cost advantages of the implementation of the upgrading of theroad, fully utilising the in-situ materials in the anionic MC-NME stabilisation thereof.

Table F 6 Results of a HDM4 analysis of the various option considered along the length of the road – the full upgrading and comparison between the Crushed stone base with cemented sub-base and the MC-NME option is highlighted in red

HDM-4
HIGHWAY DEVELOPMENT & MANAGEMENT

Economic Indicators Summary

Study Name: R Road Upgrade HDM-4 km0.0-km48.58
Run Date: 31-05-2021
Currency: Rands (R) (millions)
Discount Rate: 8.00%

Sensitivity: No Sensitivity Analysis Conducted

Alternative	Present Value of Total Agency Costs (RAC)	Present Value of Agency Capital Costs (CAP)	Increase i Agency Cost (C)	Decrease i User Cost (B)	Net Exogenou Benefit (E)	Net Presen Value (NPV = B+E-C	NPV/Cos Ratio (NPV/RAC	NPV/Cos Ratio (NPV/CAP	Internal Rat of Return (IRR
Base Alternative	40.323	32.754	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Design Option 1A (120km/h Vert Alig +Traditional Pavemen	750.985	651.512	710.662	1,422.642	0.000	711.980	0.948	1.093	18.0 (1)
Design Option 1A (120km/h Vert Alig + Bitumen Emulsion)	600.852	501.586	560.530	1,761.952	0.000	1,201.422	2.000	2.395	26.5 (1)
Design Option 2 (Climbing Lanes +Traditional Pavement)	795.795	696.322	755.472	1,422.642	0.000	667.170	0.838	0.958	17.0 (1)
Design Option 2 (Climbing Lanes + Bitumen Emulsion Pave	635.242	535.963	594.919	1,764.397	0.000	1,169.478	1.841	2.182	25.3 (1)
Design Option 1B (100km/h Vert Alig + Traditional)	697.498	598.025	657.175	1,422.642	0.000	765.467	1.097	1.280	19.3 (1)
Design Option 1B (100km/ Vert Alig +Bitumen Emulsion)	539.513	440.246	499.190	1,761.952	0.000	1,262.761	2.341	2.868	29.0 (1)
Design Option 3: Crushed stone base & 2x Cemented	589.237	583.860	548.915	1,148.529	0.000	599.614	1.018	1.027	18.3 (1)
Design Option 3: MC-NME base & sub-base	410.974	402.548	370.652	1,744.113	0.000	1,373.462	3.342	3.412	35.3 (1)

Figure in brackets is number of IRR solutions in range -90 to +900

Appendix G. Surfacings for Low Volume Roads

Introduction

Appendix G provides details regarding different surfacing types used on Low Volume Roads and could be divided into bituminous and non-bituminous surfacings.

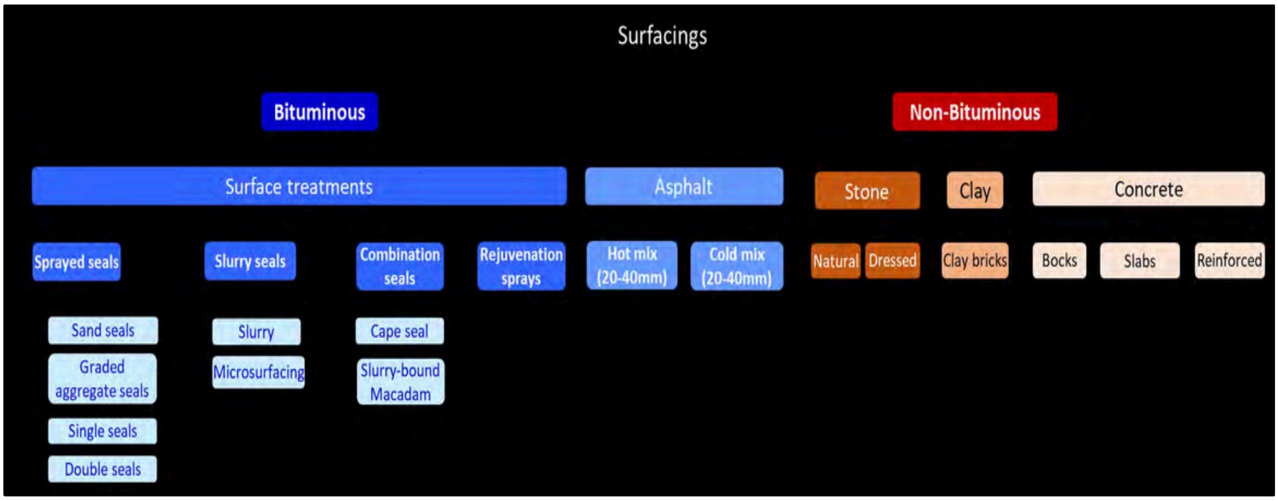


Figure G 1 Surfacing alternatives for LVRs

Bituminous surfacings

Sand seals

Consists of a film of binder (preferably cutback bitumen or emulsion) followed by graded natural sand or fine sand, machine or hand-broken aggregate (max. size typically 6 – 7 mm) which must then be compacted.

Figure G 2 Sand seals

Single sand seals are not very durable but performance can be improved with the application of a second seal within the first year. The double sand seal could then last for another 6-9 years before another reseal is required.

Thick graded aggregate seals

An Otta seal consists of a relatively thick layer of bitumen binder followed by a layer of aggregate that is rolled into the binder using a heavy pneumatic tired roller or loaded trucks. A graded gravel or crushed aggregate (19mm down) is used with a soft hot binder such as MC3000 or 150/200 Pen bitumen. Its success depends on the binder being squeezed up through the aggregate by the action of extensive rolling by pneumatic-tired rollers followed by traffic. A single Otta seal plus a sand seal or a double Otta seal is recommended as initial construction seals.

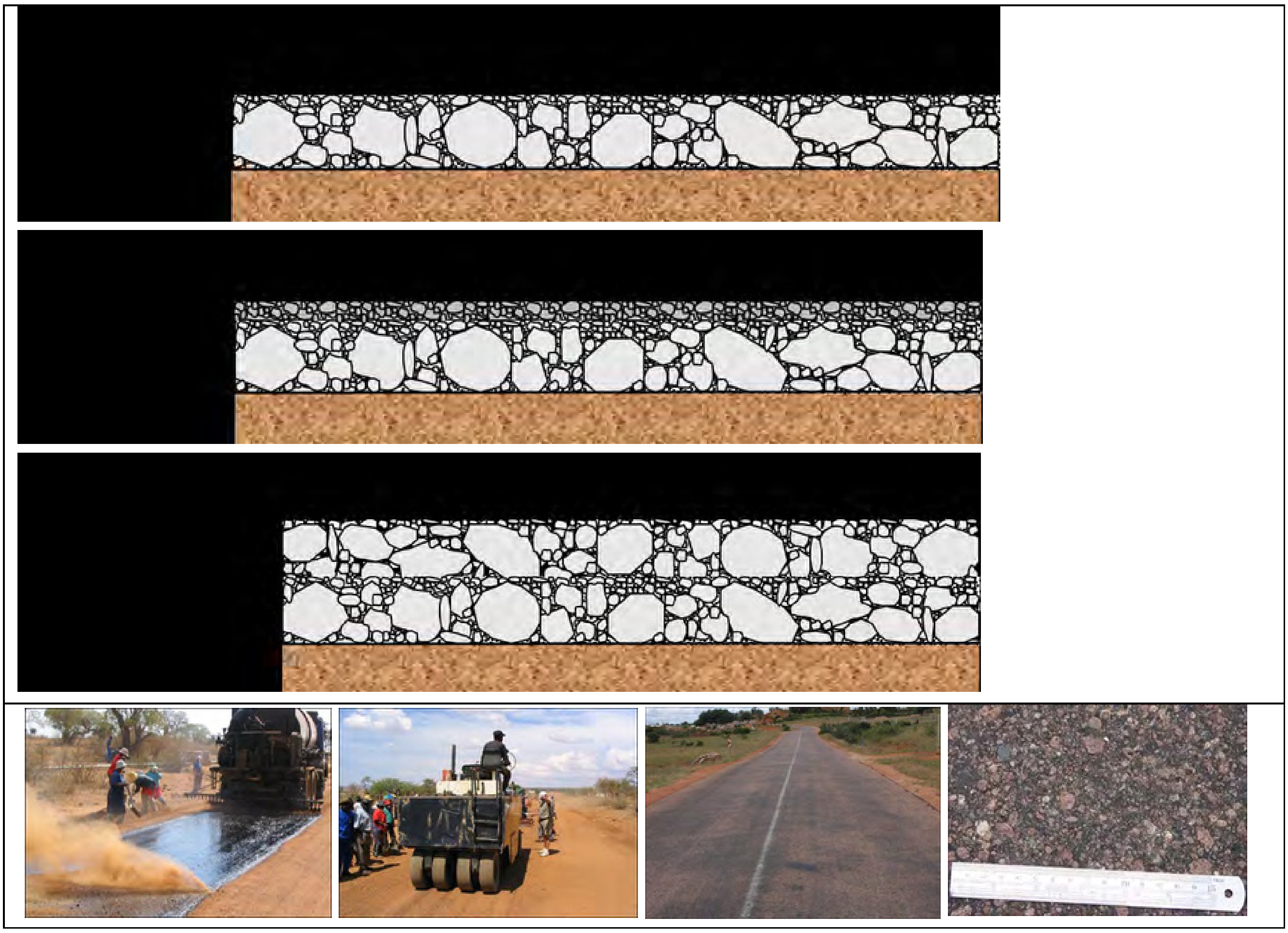


Figure G 3 Graded aggregate seals (Otta seals)

Although not defined as Otta seals, good performance of 10 to 16 mm graded aggregate seals has been recorded, single, double and single with thin sand seals.

Single seals

A single seal comprises the application of a suitable binder, the application of a single-sized aggregate and rolling to orientate and embed the stone in the bituminous binder. Application of an emulsion cover spray reduces the risk of early aggregate loss. An additional application of coarse sand in the emulsion cover spray further reduces the risk of aggregate loss.

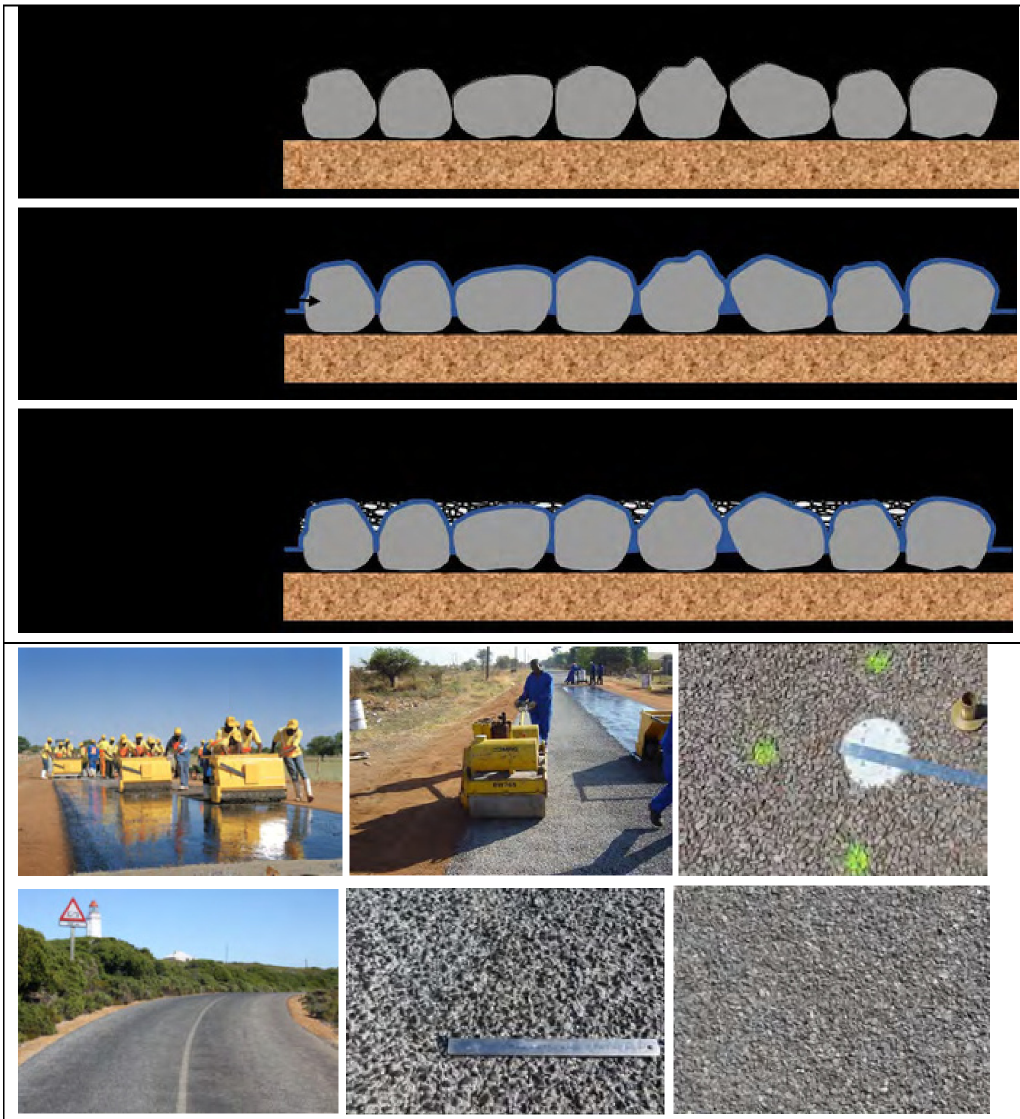


Figure G 4 Single seals

Double seals

A double seal consists of two applications of a suitable binder and spreading and rolling two layers of single-sized aggregate. The second layer of aggregate is normally half the size of the first aggregate layer, providing stability to the seal structure and minimising the risk of early aggregate loss. A diluted emulsion cover spray could be applied as a final layer, further reducing the risk of aggregate loss.

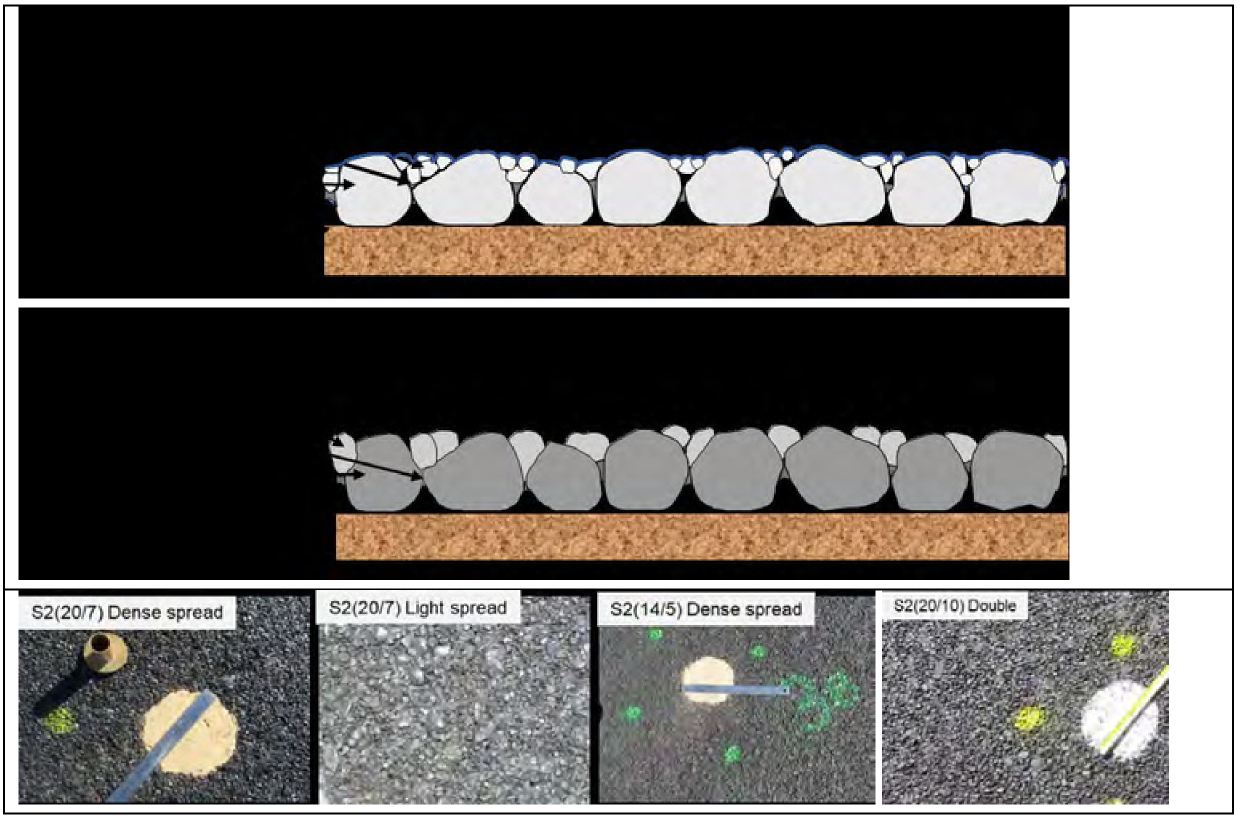


Figure G 5 Double seals

Slurry and Micro surfacing

Slurry Seals are a mixture of well-graded fine aggregate, Bitumen Emulsion, filler (usually Portland Cement or lime), and additional water. They are mixed in a concrete mixer or purpose-built equipment and are spread on a pre-prepared surface using wheelbarrows and squeegees or spreader box/drag spreaders. The slurry seal can be hand spread to the thickness of the large aggregate fraction. Following application at ambient temperature, the water in the emulsion separates from the emulsion and evaporates leaving the residual bitumen in place to adhere to the pavement surface and aggregates.

Micro surfacing differs from conventional slurry in the sense that chemicals are used to speed up the braking process (separation of water). The rapid curing characteristics require application by spreader box only but could be applied to 30 mm thickness and in high humidity conditions.

Recent research confirmed that New Modified Emulsions (NME) could be used in slurries without cement, at lower binder contents, using less water and providing significant additional flexibility.

Figure G 6 Slurry andmicro surfacing

Cape seals

A Cape Seal is a multiple surface treatment consisting of an application of a single bitumen chip seal followed by a single or double application of bitumen slurry seal. Usually, a 14 mm single seal is combined with a single slurry application. A 20 mm first seal is normally combined with a double slurry application. The aim is that on completion the tops of the stone chips are just exposed above the slurry that fills the interstices between the stones.

Figure G 7 Cape seals

The Cape Seal is durable (typical initial life 8 to 16 years) and enables the heavy-duty surfacing to be constructed with minimal equipment.

Slurry-bound Macadam seal

The slurry-bound macadam seal is a combination of single-sized aggregate and fine slurry. A dry layer of 14 mm or 20 mm aggregate placed at a thickness of 20 to 50 mm, levelled and compacted.
A fine slurry is then vibrated into the stone matrix, using a pedestrian roller. After curing the slurry, the layer is rolled with a static roller and a final slurry layer (4 to 6 mm) is applied.

Figure G 8 Slurry-boundMacadam seal

Rejuvenation sprays

Diluted stable-grade emulsion or invert cut-back emulsion is sprayed on an existing surface treatment to prolong the effective service life. Typical rates of application are 0.8 litre/m2 for diluted emulsions and 0.45 litre/m2 for invert cut-back emulsions. Most aggregates in Africa are negatively charged resulting in anionic emulsions being preferred to run into the seal structure and not adhering immediately to the stone.

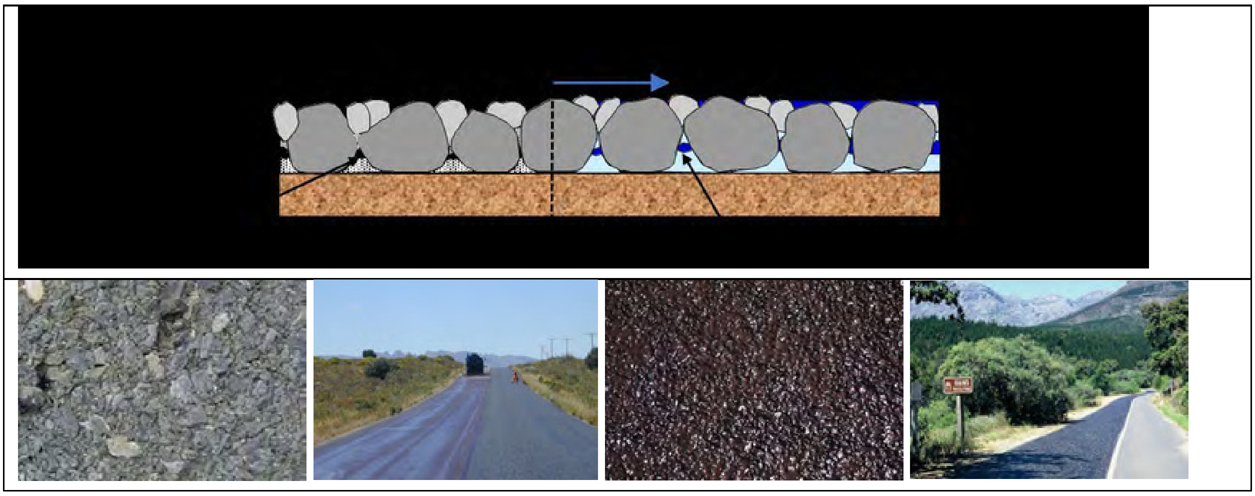


Figure G 9 Rejuvenation sprays

Asphalt surfacings

Hot premix asphalt consists of graded crushed aggregate, bitumen and an active filler e.g. lime, normally mixed in a plant, paved with a custom-built paver and compacted. **Note:** Could be mixed on site with small plant, spread by hand and compacted. Thickness could vary depending on nominal size aggregate

Cold mixes normally consist of a mixture of graded crushed aggregate, a filler and a stable, slow-breaking emulsion that is mixed by hand or in a concrete mixer. After mixing the material is spread on a primed road base and rolled. Thickness (20 to 40 mm) could vary depending on nominal size aggregate. Very suitable for labour-based construction, requires a very simple construction plant and reduces the potential hazard of working with hot bitumen.

Figure G 10 Asphalt (premix)

Non-Bituminous Surfacings

General

Surfacings constructed from materials such as stone, clay and concrete can be considered for use on LVRs instead of conventional bituminous surfacings. The current practice of utilising concrete pavements through villages, on very steep grades or where there is a risk of water overtopping the road is an example of an environmentally judicious choice of surfacing in circumstances where bituminous surfacings often do not perform well.

The non-bituminous surfacings listed all act simultaneously as a surfacing and base layer and provide a structural component to the pavement because of their thickness and stiffness. Bricks and blocks require the use of a sand bedding layer that also acts as a load transfer layer for the overlying construction.

In some circumstances (e.g., on steep slopes in high rainfall areas and areas with weak subgrades and/or expansive soils) it may be advantageous to use mortared options. This can be done with Hand-packed Stone, Cobblestone (or Dressed Stone), and Fired Clay Brick pavements. The construction procedure is largely the same as for the un-mortared options except that cement mortar is used instead of sand for bedding and joint filling.

Concrete blocks

Concrete brick paving is a well-established technique used in many countries for a variety of applications including successful adoption as an option for low-volume rural roads. The application is based on the proven ability of individual concrete bricks to effectively disperse load laterally to adjacent bricks through the sand joints. This option comprises rectangular concrete bricks (usually around 70 mm thick) being laid in a herringbone or other pattern to camber within confining edge kerbs (cast either before or after brick placement). They are compacted into place, with sand brushed in at the joints. A sand cement mortar joint or bituminous seal may be specified to be used to waterproof the finished surface as a separate operation, although this is usually unnecessary on a well-constructed sub-base. As a refinement, the concrete bricks may be cast with a top-edge chamfer to assist surface drainage.

Figure G 11 Concrete blocks

Clay bricks

Fired Clay Bricks are the product of firing moulded blocks of silty clay and are commonly used in low-cost road pavement construction in areas with a deficiency of natural gravel or rock materials. This surfacing consists of placing a layer of edge-on engineering quality bricks within previously installed edge constraints. The bricks are laid in an approved pattern on a sand bedding layer. Joints between the bricks may be either in-filled with suitable sand or the bricks may be mortared in.

Figure G 12 Clay bricks

Dressed stone

A dressed stone surfacing is a historically well-established technique that has been adapted successfully as a robust alternative option for low-volume rural roads where there is a good local supply of suitable stone. Strong isotropic rocks such as granite that have inherent orthogonal joint stresses are ideal. Dressed stone surfaces have good load-spreading properties.

This technique comprises 150 to 200 mm thick dressed stones being laid to lines and levels between previously installed edge restraints and compacted into a sand bedding layer followed by cement mortaring of the joints. The dressed stones shall normally be hand cut from solid rock and trimmed (dressed) if necessary to form a regular rectangular shape, free from flaws and discontinuities with a reasonably smooth top surface.

Figure G 13 Dressed stone

Cobble stone

Cobble Stone Paving is a historically well-established option consisting of a layer of roughly cubic-shaped or selected stones of thickness about 100 to 150 mm, laid on a bed of sand or fine aggregate within the mortared stone or concrete edge restraints. The individual stones should have at least one fairly smooth face, to be the upper or surface face when placed. Each stone (or cobble) is adjusted with a small (mason's) hammer and then tapped into position to the level of the surrounding stones. Sand or fine aggregates are brushed into the spaces between the stones and the layer and then compacted with a roller.

Note: Stone sets are a neater alternative and consist of a layer of cubic-shaped stones of approximate size 80 to 100 mm laid on a thin bedding sand layer (20 to 50 mm). The sets can be cut by hand from suitable hard rock such as granite or basalt, which easily breaks into smooth-faced pieces. Sand is brushed into the joints between the laid stones and they are compacted using a vibrating plate or light roller. An edge restraint or kerb constructed of large or mortared stones is required for durability. Sand-cement mortar joints can be used to improve durability and prevent water from penetrating the foundation layers and weakening them.

Figure G 14 Cobble stones

Concrete

Non-reinforced cement concrete is a well-established form of rigid pavement designed to spread the applied load due to traffic through a slab effect. The option as applied for LVRs usually involves the casting of 5 m long slabs between formwork, normally with load transfer dowels between them. In some cases, where continuity of traffic demands it, these slabs may be half carriageway width. The concrete slabs are cast onto a previously prepared and compacted sub-base. The concrete requires to be cured, by covering it with moisture-retaining material and kept moist, normally for a minimum period of 7 days.

It is most suitable for construction on high rainfall, steep gradient alignments and on routes prone to seasonal flooding and other major climatic impacts.

Continuously reinforced concrete could be used as an alternative, allowing a thinner layer, but higher skill levels.

Figure G 15	Concrete

Appendix H. Maintenance Concepts

Introduction

The purpose of road maintenance is to ensure that the road remains serviceable and is kept to the specified LOS standards to provide safety and access to essential services at the least cost. Key aspects recorded include:

- Maintenance prolongs the life of the road by reducing the rate of deterioration, thereby safeguarding previous investments in construction and rehabilitation;
- Lowers the cost of operating vehicles on the road by providing a smooth-running surface;
- Keeps the road open for traffic and contributes to more reliable transport services;
- Sustains social and economic benefits of improved road access, and
- The importance of routine maintenance, particularly as regards drainage, cannot be over-stressed concerning pre-emptive measures to reduce the likelihood, or impact, of natural disasters.

Obligation of the Roads Authority

TMH22 provides guidance as to how Roads Authorities are required to manage the road infrastructure assets according to the Committee of Transport Officials (COTO) Road Infrastructure Asset Management Policy (RIAMP). This is the Policy framework setting RSA requirements for Roads Authorities to Manage Road Infrastructure Assets.

Road authorities in South Africa must plan, design, construct and maintain the road network, to protect the public investment in the road infrastructure, ensure the continued functionality of the transportation system and promote the safety of traffic on the road network. Authorities must also provide a reliable, effective, efficient and integrated transport system that supports the sustainable economic and social development of the country.

In terms of the maturity level of asset management, the minimum requirement is to have Level II systems operating in Provincial Road Authorities and larger municipal authorities (Refer to TMH22).

The “Direct line of sight” in terms of Road Asset Management processes is summarised in Figure H 1.

Road maintenance management forms part of the total asset management process and aims to apply appropriate strategies, planning and operational procedures to achieve the long-term objectives of the organisation.

The typical objectives incorporated in a Road Authority Policy Statement are:

- Preserving road asset condition by adopting a life-cycle approach;
- Minimising Total Transport Costs/ Society costs while maintaining acceptable levels of service;
- Improving road safety;
- Providing and maintaining access;
- Achieving stakeholder and customer satisfaction;
- Adopting a sustainable approach to the environment;
- Maximising social benefits;
- Reducing risk to the Roads Authority;
- Embracing new technologies to do more with less;
- Ensuring clarity on responsibility for road assets, and

- Accountability for the use and management of resources.

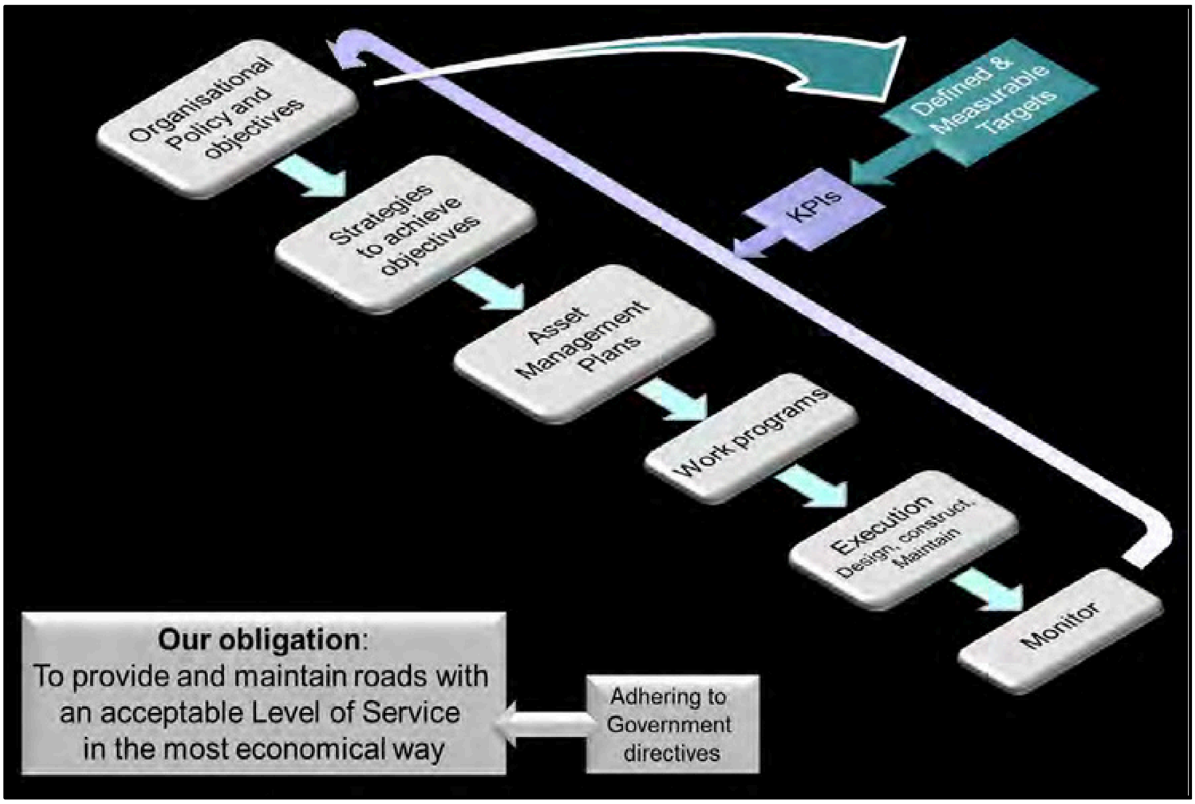


Figure H 2 Direct line of sight

Strategies are developed and the cost is determined to achieve the set objectives.

The policy and objective of Rural Development are to provide and maintain accessible and safe roads at an appropriate Level of Service (LOS). To achieve and maintain the selected LOS, stable long-term funding must be secured

The strategy development is followed by the development of Asset Management Plans, scheduling of works (Work Programs) and the execution thereof.

The success of the organisation in meeting the policy objectives is determined through monitoring Key Performance Indicators (KPI) defined in the LOS for the different road categories.

Cost of Maintenance

Taken from a responsible road authority with an established road network, a spread of approximately 80 per cent of the road network unpaved and, a drive towards upgrading, the typical distribution of funds is shown in Figure H 2. This distribution highlights that approximately 50 per cent of the available funding is allocated to the maintenance of the existing road infrastructure.

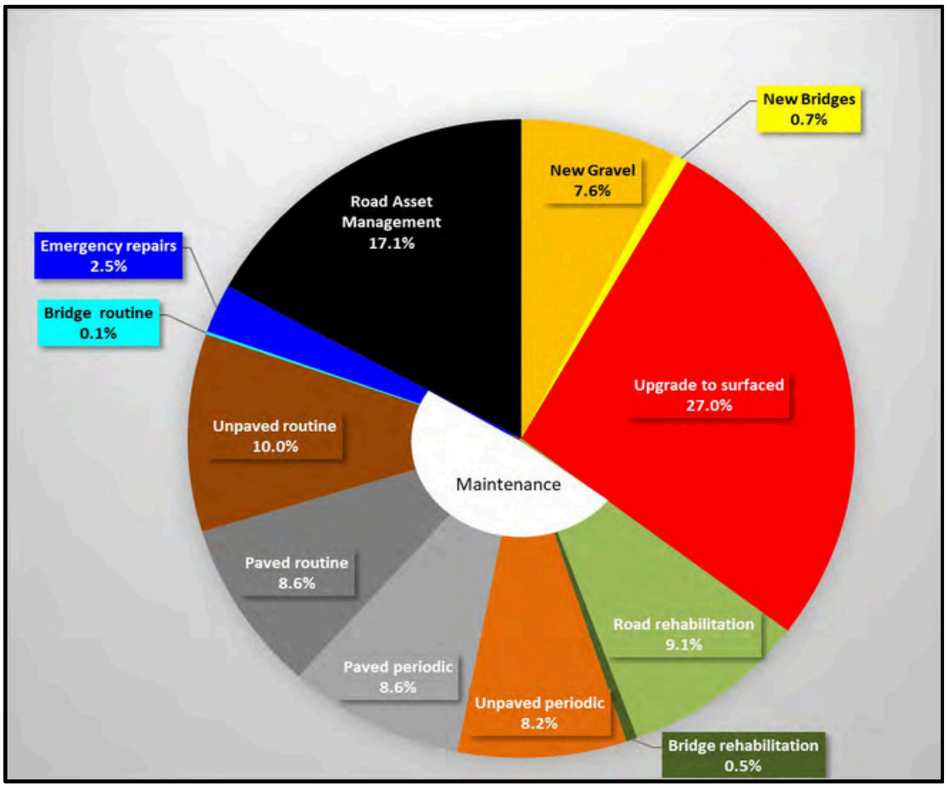


Figure H 3 Typical fund distribution

Road performance

Road performance is characterised by the deterioration of the functional and structural properties of a road. Performance indicators could either be individually measured defects or combined indices, describing the condition of a road at a particular point in time. Typical individual performance indicators are road roughness, expressed in terms of the International Roughness Index (IRI), rut depth, skid resistance, percentage cracking etc. Combined indices are often used to describe the current condition and change over time and are normally an aggregation of different defects. A typical scale used is where 100 per cent defines the perfect condition and 50 per cent defines an unacceptable condition. The effect of maintenance on the condition is shown in Figure H 3, highlighting that both routine maintenance and periodic maintenance are required to extend the effective service life before rehabilitation is required.

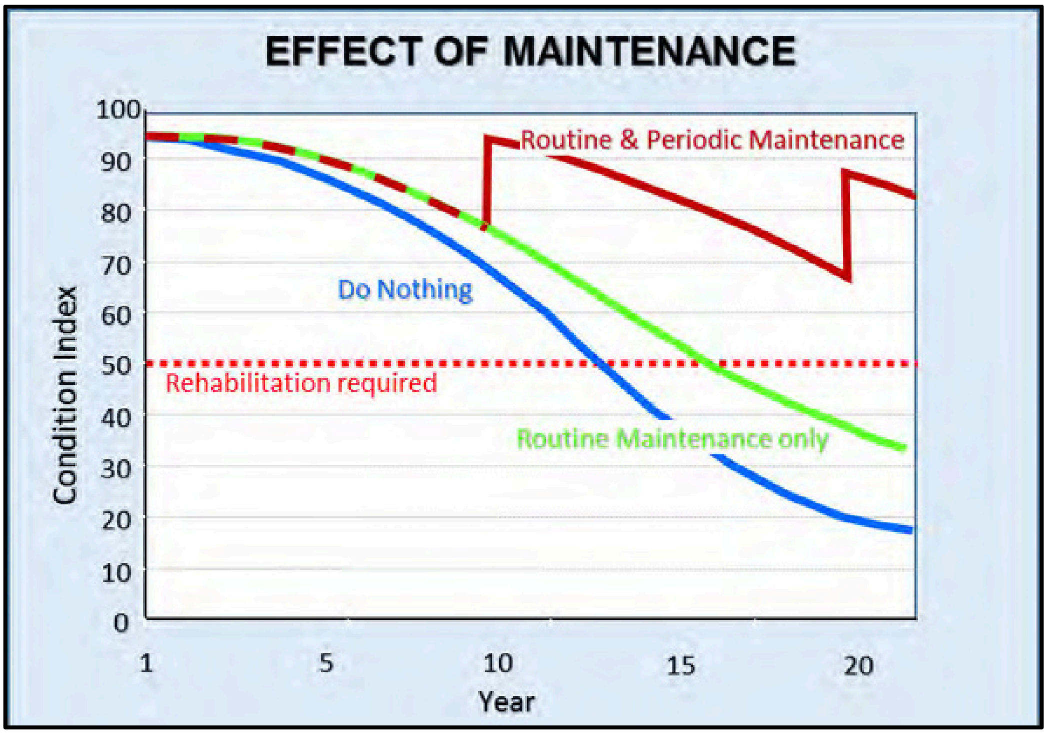


Figure H 4 Importance of routine and periodic maintenance

The performance of a surfaced road is influenced by the selected pavement structure and surfacing, traffic load and actions, environmental conditions as well as the maintenance life-cycle strategy applied and quality thereof.

Bituminous surfacings become hard/brittle and permeable with time resulting in water ingress into and softening of the granular base. Any loads applied result in cracking of the surfacing, further moisture ingress and potholing, “The proverbial example of a glass plate on a foam mattress”. The mechanism is shown in Figure H 4 and Figure H 5.

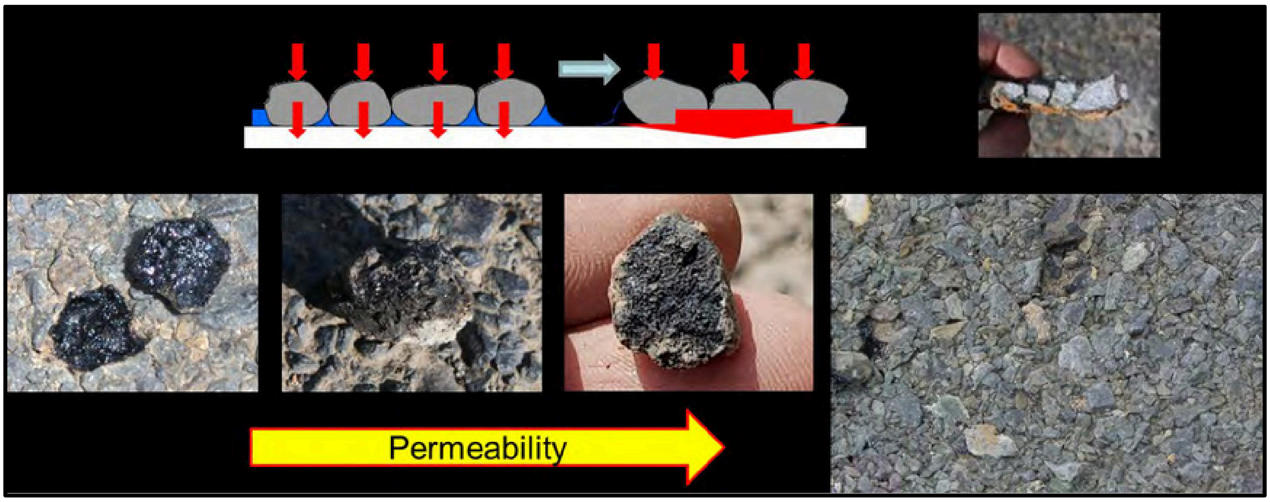


Figure H 5 Ageing of bituminous surfacings leading to permeability

Figure H 6 Moisture ingress resulting in cracking and potholing

The average effective life of bituminous surface treatments on low-volume roads, reported in South Africa, Australia and New Zealand, is approximately ten years. Resealing (waterproofing) before fine cracking starts to occur extends the effective pavement life. The result of effective periodic maintenance is that well-maintained surfaced road networks in southern Africa are still in a "Good" condition with an average age of the pavement structures exceeding fifty years.

Life-cycle strategies

A life-cycle strategy defines the timing of sequential maintenance activities executed on a road throughout its life. The immediate effects, longer-term effects, sequence, timing and costs are utilised to obtain an optimised strategy for maintaining a selected level of service at the least possible cost. For a surfaced road, the optimum life-cycle strategy is also a function of the pavement structure composition and selected initial surfacing.

As an example, and assumingthatthe pavement structure is adequate to carry the traffic load for 20 years, three different surfacing typescould be considered as initial surfacings e.g. 30 mm Continuous graded asphalt (AC), a double surfacetreatment (DS) and a single sand seal (SS). Dependent on the rate of deterioration and defects developing, different life-cycle strategies would be required to maintain the road in an acceptable condition. Threepossible scenarios are presented in Figure H 6, Figure H 7 and Figure H 8, showing the timing and costsofexpected periodic maintenance activities. By discounting the costs of the different activities and theremaining life value to current-day costs after 20 years (Net Present Value), the most cost-effective life-cyclestrategy could be selected.

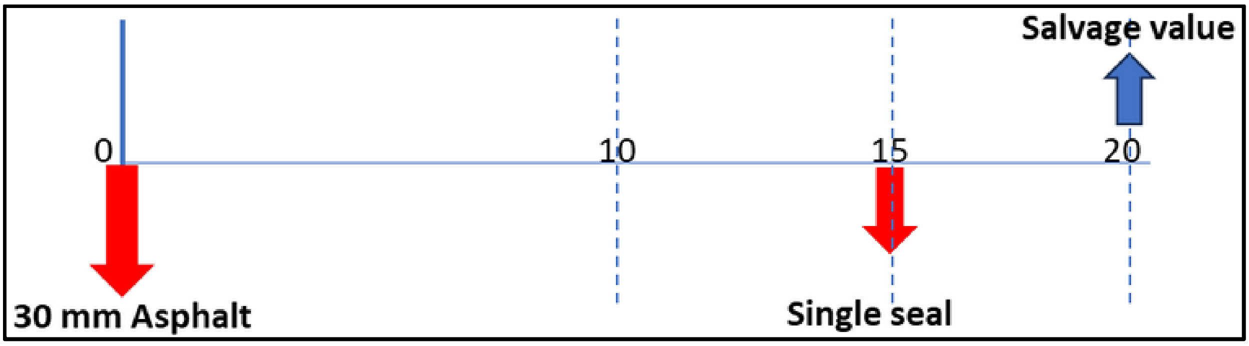


Figure H 7 Maintenance strategy A: Asphalt

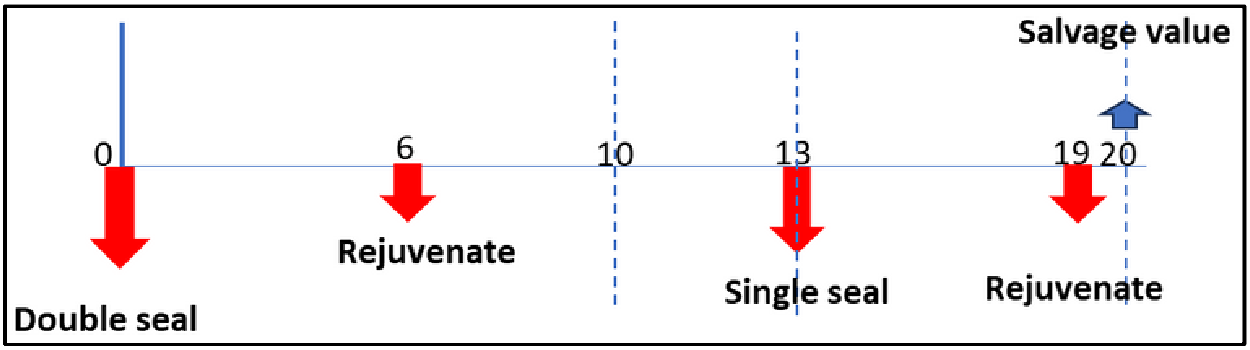


Figure H 8 Maintenance strategy B: Double seal

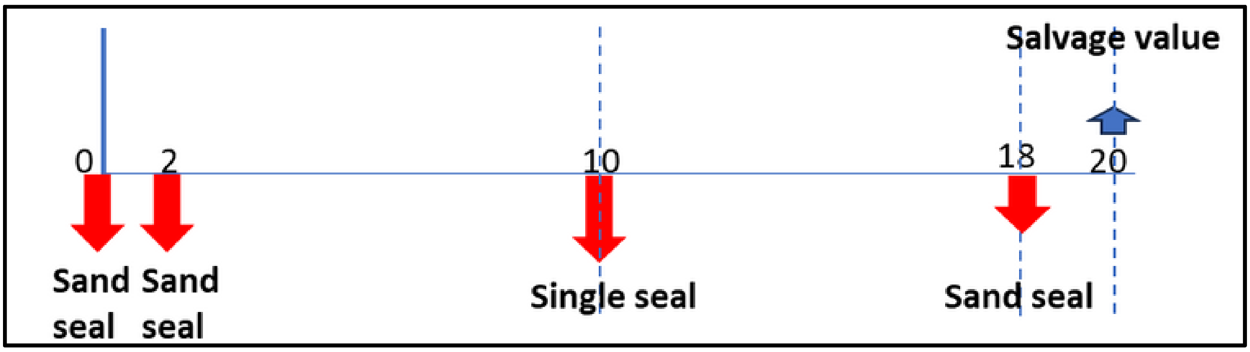


Figure H 9 Maintenance strategy C: Sand seal

Risk of poor maintenance

Even with adequate funding, poor maintenance strategies, planning and operational procedures will result in the objectives not being achieved (Figure H 9).

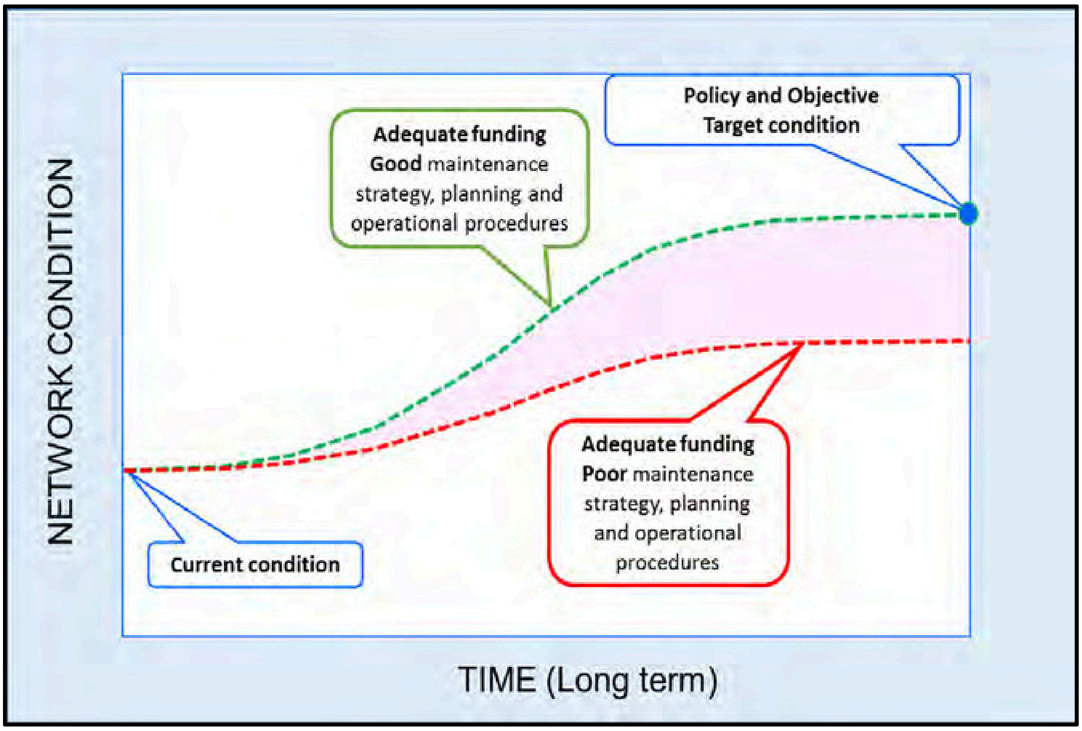


Figure H 10 Impactofpoormaintenanceplanning and execution

The consequencesofpoormaintenancecouldbe summarised as follows:

- Lossofassets:theresultinglossinvalue of road assets due to neglect in maintenance:
- Accordingtoa1988WorldBankstudy, allocations over twenty years for road maintenance in developingcountriesweresolowthatnearly 15 per cent of the capital invested in main roads - roughlyUS$43billionequivalentto2per cent of these countries' GNP - had eroded due to lack of maintenance.Thesamestudydemonstrated that reconstructing these roads - costing US$ 40 to US$45billionworldwide-couldhavebeen avoided by spending US$ 12 billion on maintenance. Thisisaratioofabout3.5to1,nottaking into consideration the time value of money;
- Lossofagriculturaloutputs:Sensitiveagricultural produce e.g., soft fruit, eggs;
- Lossoftimeandaccess:Moreworkingtime is lost as a result of poor or inadequate maintenance whichwillcausedelaysorpreventaccess to work, services like schools, medical facilities, and placesofworship,andgenerallycanisolate communities for long periods; Increasedrehabilitationcost;
- Experiencehasshownthatneglectofmaintenance at the right time could lead to the complete loss of
- theasset.AnexampleisshowninFigure H 10, where "not resealing" at the right time at a cost of Rxresultsintheneedtorehabilitateat six to eighteen times the cost of the reseal. To apply the resealattheoptimumtime,theneedfor reseal be identified at an early stage to allow sufficient timefortherequiredprocessesbeforeconstruction. This emphasises the need for regular condition assessments,and

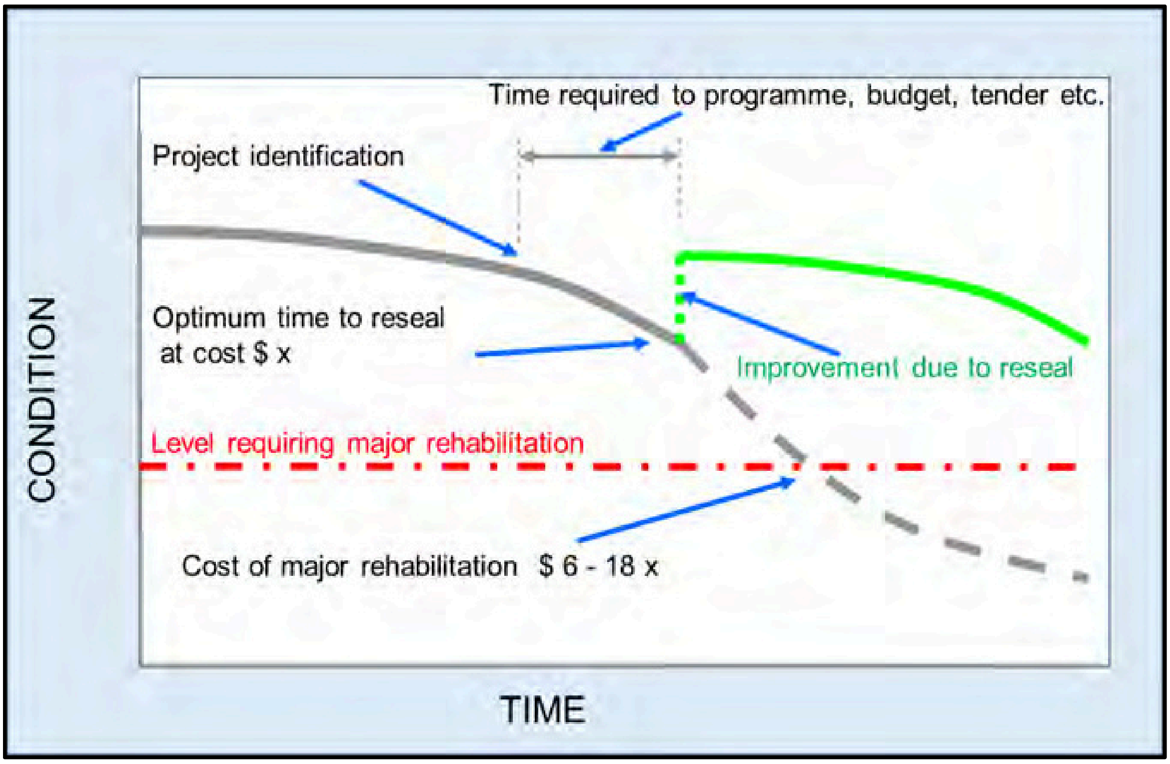


Figure H 11 Early identification of need required and impact of deferment

- Vehicle deterioration and vehicle operating cost: Not only do roads deteriorate due to lack of maintenance, but the vehicles using the road also get damaged, break down and often cause accidents.