INNOVATIVE INITIATIVES IN ROAD DESIGN AND CONSTRUCTION, IN THE PROVINCE OF KWAZULU-NATAL, SOUTH AFRICA

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ABSTRACT

Many parts of the Province KwaZulu-Natal lack suitable gravel sources, resulting in high re-gravelling costs. The use of poor materials results in accelerated gravel loss, and poor serviceability. The application of Innovative Initiatives in Road Design and Construction have been applied, which has resulted in the provision of water proof gravel roads and the provision of low volume surfaced roads as alternatives to the conventional poor gravel road.

This paper compares various actual Waterproof Gravel and Low Volume Surfaced Road pavement design cases constructed, based on the Standard South African TRH 4[1] Pavement Design Manual, using the Standard South African TRH 14[2] Road Building Materials Standards, on roads carrying less than 400 vehicles per day.

The paper indicates the benefits of using available insitu materials, mixed together with other economically available borrow materials, in combination with conventional and new stabilising agents and compaction aids. This together with conventional and new surfacing techniques, has resulted in the delivery of very cost-effective roads, to the rural communities inspite of the relatively low traffic, by applying appropriate engineering technology to match the project to the budget available.

The paper suggests the use of Innovative Initiatives to match the public's service delivery requests to the budget allocations given. Comparative cases of actual roads designed and constructed in KwaZulu-Natal are used to illustrate the benefit of applying innovative initiatives in road pavement technology to attempt to solve the provision of appropriate roads for rural communities on the African Continent, in all Developing Countries and possibly World wide.

FOREWORD

Today, almost world-wide, there is a general shortage of the resources required to provide appropriate road networks. This is mostly as a result of cuts in government funding for roads as other infrastructure facilities gain higher priorities, especially housing, schools and hospitals. At the same time, the cost of obtaining good road construction materials is increasing and these materials are becoming scarcer as existing sources are being depleted, necessitating long haul distances. This situation is forcing a re-evaluation of conventional road design, materials and construction methods.

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Faced with these problems, the road engineer is having to investigate and consider the use of sub-standard materials on many roads where normally specified or preferred materials are not economically available.

This however, leads to additional problems, particularly on earth or gravel roads, such as;

- Safety, health and environmental problems related to dust or loose surface material.
- Maintenance problems related to the surface durability under wet and dry conditions.
- Level of service problems related to general surface deterioration such as rutting and pot holing caused by poor materials, high traffic volumes and heavy loads.

Frequent maintenance by experienced and good grader operators can limit the level of service problem to a significant extent, but frequent maintenance is costly and disruptive to traffic flow with serious road safety implications.

INTRODUCTION

As about 30% of the Provincial Road network carries 75% of the Provincial traffic, that means that the remaining 70% of the Provincial Road network carries only 25% of the Provincial traffic.

Since about 70 percent of the declared road network in the Province of KwaZulu-Natal in the Republic of South Africa, is of gravel standard, this majority part of the network needs to be properly maintained. In 1985 the Province was moving 1,5 million cubic meters of gravel material to re-gravel the gravel road network. Budgets for this re-graveling work have continued to decline, however the needs of the largely rural communities have increased.

As many parts of the province also lack suitable gravel sources resulting in high re-graveling costs, due to long haul distances and accelerated gravel loss from poor materials. In an endeavour to overcome some of these problems, road engineers in the province of KwaZulu-Natal, South Africa, have embarked on a series of innovative initiatives, which has resulted in the construction of a series of alternative pavement trials from 1986. These trials have since been evaluated, and new innovative and cost effective pavement designs have been introduced based on the initial trial work. The application of Innovative Initiatives in Road Design and Construction have been applied, which has resulted in the provision of water proof gravel roads and the provision of low volume surfaced roads as alternatives to the conventional gravel road.This has resulted in the service delivery of very cost-effective roads, to the rural communities inspite of the relatively low traffic, by applying appropriate engineering technology to match the project to the budget available.

Comparisons between some actual Waterproof Gravel and Low Volume Surfaced Road pavement design cases constructed, based on the Standard South African TRH 4[(1)] Pavement Design Manual, using the Standard South African TRH 14[(2)] Road Building Materials Standards, on roads carrying less than 400 vehicles per day are undertaken.

The benefits of using available insitu materials mixed together with other economically available borrow materials in combination with conventional and new stabilising agents and compaction aids, together with conventional and new surfacing techniques are considered. This is done to deliver appropriate service to some of the 70% of the road network, carrying less than 25% of the traffic, in the province of KwaZulu-Natal.

The use of Innovative Initiatives to match the public's service delivery requests and to match the budget allocations given. Comparative cases of actual roads designed and constructed in KwaZulu-Natal are used to illustrate the benefit of applying innovative initiatives in road pavement technology to attempt to solve the provision of appropriate roads for rural communities on the African Continent, and possibly now World wide.

3. PROJECT BUDGET DILEMMA

The road project estimate normally exceeds the clients' project budget.

- How do you solve the problem, without compromising the road pavement design?
- or compromising the construction phase?

Never throw away your engineering knowledge or experience, when dealing with a problem.

3.1) Go back to basics, & apply the standard design techniques that you have always used.

3.2) One needs to assess the maintenance capability of the Client or Road Authority for which you are designing the road pavement. If this capability is low or almost zero, the pavement designer needs to seriously consider adjusting the proposed pavement design to cater for the low or zero maintenance criteria. The use of a more robust design in this situation is normally recommended with a higher TRH 4[1] Road Category Rating, ie:(Less probability of failure). However this may result in the estimated project cost totally exceeding the project budget so this dilemma of **construction cost** versus **maintenance capability** needs to be discussed and potential risks verified and approved with the Client, before the final pavement design is completed and approved. A lighter and cheaper pavement will present the Client with an affordable project but with a higher potential failure risk later, and the Client must be made aware of these facts before the final pavement design is presented and approved.

3.3) Then be totally innovative and see what you can change without compromising the design and while staying within the project budget.

3.4) Use innovative techniques to solve the problem within the Client's budget restraints.

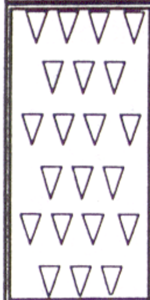
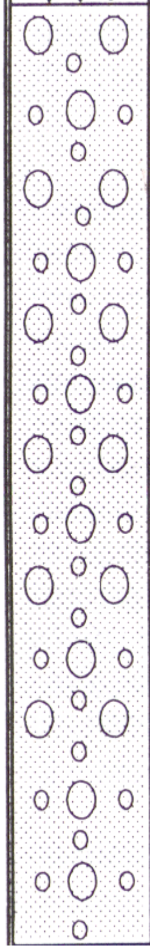
3.5) Test and verify the innovative ideas and new binders, compaction aids or stabiliser additives with the proposed insitu or recommended quarry materials in the laboratory before specifying them on site. What works in the laboratory will work on site if the standard tests are applied to the materials in the procedurally correct manner

3.6) Apply the new technology and techniques using the standard tried and tested construction procedures to produce the new pavement design on site. It is recommended that new technology and techniques be applied in a one step or in a one change at a time

4. SOUTH AFRICAN ROAD MATERIALS STANDARDS

In South Africa we use the TRH 14[2] Road Materials Standards and apply them in the Catalogue Designs listed in the TRH 4[1] Structural Design of Flexible Pavements for Interurban and Rural Roads as a Road Pavement Design Standard.

Material symbols and abbreviated specifications used in the Catalogue designs

SYMBOL	CODE	MATERIAL	ABBREVIATED SPECIFICATIONS
	G1	Graded crushed stone	Dense - graded unweathered crushed stone; Maximum size 37,5 mm; 86 - 88 % apparent relative density; Soil fines PI < 4
	G2	Graded crushed stone	Dense - graded crushed stone; Maximum size 37,5 mm;100 - 102 % Mod. AASHTO or 85 % bulk relative density; Soil fines PI < 6
	G3	Graded crushed stone	Dense - graded stone and soil binder; Maximum size 37,5 mm; 98 - 100 % Mod. AASHTO ; Soil fines PI < 6
	G4	Crushed or natural gravel	Minimum CBR = 80 % @ 98 % Mod. AASHTO; Maximum size 37,5 mm; 98 - 100 % Mod. AASHTO; PI < 6; Maximum Swell 0,2 % @ 100 % Mod. AASHTO. For calcrete PI ≤ 8
	G5	Natural gravel	Minimum CBR = 45 % @ 95 % Mod. AASHTO; Maximum size 63 mm or 2/3 of layer thickness; Density as per prescribed layer usage; PI < 10; Maximum swell 0,5 % @ 100 % Mod. AASHTO *
	G6	Natural gravel	Minimum CBR = 25 % @ 95 % Mod. AASHTO; Maximum size 63 mm or 2/3 of layer thickness; Density as per prescribed layer usage; PI < 12; Maximum swell 1,0 % @ 100 % Mod. AASHTO *
	G7	Gravel / Soil	Minimum CBR = 15 % @ 93 % Mod. AASHTO; Maximum size 2/3 of layer thickness; Density as per prescribed layer usage; PI < 12 or 3GM** + 10; Maximum swell 1,5 % @ 100 % Mod. AASHTO ***
	G8	Gravel / Soil	Minimum CBR = 10 % @ 93 % Mod. AASHTO; Maximum size 2/3 of layer thickness; Density as per prescribed layer usage; PI < 12 or 3GM** + 10; Maximum swell 1,5 % @ 100 % Mod. AASHTO ***
	G9	Gravel / Soil	Minimum CBR = 7 % @ 93 % Mod. AASHTO; Maximum size 2/3 of layer thickness; Density as per prescribed layer usage; PI < 12 or 3GM** + 10; Maximum swell 1,5 % @ 100 % Mod. AASHTO ***
	G10	Gravel / Soil	Minimum CBR = 3 % @ 93 % Mod. AASHTO; Maximum size 2/3 of layer thickness; Density as per prescribed layer usage; or 90% Mod. AASHTO

* For calcrete PI< 15 on condition that the Linear Shrinkage (LS) does not exceed 6%.

** GM – Grading Modulus (TRH 14[2] 1985) = $\frac{300 - (P_{2.00mm} + P_{0.425mm} + P_{0.075mm})}{100}$
where $P_{2.00mm}$ etc. denotes the percentage passing through the sieve size.

*** For calcrete PI < 17 on condition that the Linear Shrinkage (LS) does not exceed 7%.

Material symbols and abbreviated specifications used in the Catalogue designs

SYMBOL	CODE	MATERIAL	ABBREVIATED SPECIFICATIONS
	C1	Cemented crushed stone or gravel	UCS**** : 6,0 to 12,0 MPa at 100 % Mod. AASHTO; Specification at least G2 before treatment; Dense - graded ; Maximum aggregate 37,5 mm
	C2	Cemented crushed stone or gravel	UCS : 3,5 to 6,0 MPa at 100 % Mod. AASHTO; Minimum ITS ***** = 400 kPa at 95 - 97 % Mod. AASHTO compaction; Specification at least G2 or G4 before treatment; Dense - graded; Max. aggregate 37,5 mm; Max. fines loss = 5 %******
	C3	Cemented natural gravel	UCS : 1,5 to 3,5 MPa at 100 % Mod. AASHTO; Minimum ITS***** = 250 kPa at 95 - 97 % Mod. AASHTO compaction; Maximum aggregate 63 mm; 5 % Maximum PI = 6 after stabilization; Max. fines loss = 20 %
	C4	Cemented natural gravel	UCS : 0,75 to 1,5 MPa at 100 % Mod. AASHTO; Minimum ITS***** = 200 kPa at 95 - 97 % Mod. AASHTO compaction; Maximum aggregate 63 mm; 5 % Maximum PI = 6 after stabilization; Max. fines loss = 30 %
	BEM	Bitumen emulsion Modified gravel	Residual bitumen: 0,6 - 1,5 % (SABITA, manual 14, 1993); Minimum CBR = 45 and Minimum UCS = 500 kPa @ 95 % Mod. AASHTO. Compaction: 100 - 102 % Mod. AASHTO
	BES	Bitumen emulsion Stabilized gravel	Residual bitumen 1,5 - 5,0 % (SABITA, manual 14, 1993); Minimum ITS***** = 100 kPa; Minimum resilient modulus 1000 kPa. Compaction: 100 - 102% Mod. AASHTO
	BC1	Hot - mix asphalt	LAMBS; Max. size 53 mm (SABITA, manual 13, 1993)
	BC2	Hot - mix asphalt	Continuously graded; Max. size 37,5 mm
	BC3	Hot - mix asphalt	Continuously graded; Max. size 26,5 mm
	BS	Hot - mix asphalt	Semi - gap graded; Max. size 37,5 mm
	AG	Asphalt surfacing	Gap graded (TRH 8, 1987)
	AC	Asphalt surfacing	Continuously graded (TRH 8, 1987)
	AS	Asphalt surfacing	Semi - gap graded (TRH 8, 1987)
	AO	Asphalt surfacing	Open graded (TRH 8, 1987)
	AP	Asphalt surfacing	Porous (Drainage) asphalt (SABITA, manual 17, 1994)
	S1	Surface treatment	Single seal (TRH 3, 1996)
	S2	Surface treatment	Multiple seal (TRH 3, 1996)
	S3	Sand seal	See TRH 3, 1996
	S4	Cape seal	See TRH 3, 1996
	S5	Slurry	Fine grading
	S6	Slurry	Medium grading
	S7	Slurry	Coarse grading
	S8	Surface renewal	Rejuvenator
	S9	Surface renewal	Diluted emulsion
	WM1	Waterbound macadam	Max. size 75 mm; Max.PI of fines = 6; 88 - 90 % apparent relative density
	WM2	Waterbound macadam	Max. size 75 mm; Max.PI of fines = 6; 86 - 88 % apparent relative density
	PM	Penetration macadam	Coarse stone + keystone + bitumen
	DR	Dumprock	Upgraded waste rock, maximum size 2/3 layer thickness

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**** UCS Unconfined Compression Strength (TMH 1, [3] 1979, Method A 14)

***** ITS Indirect Tensile Strength (SABITA Manual 14, [4] 1993)

****** Durability (TMH 1, [3] 1979 Method A 19)

SOUTH AFRICAN ROAD PAVEMENT DESIGN STANDARDS

In South Africa we use the TRH 4 [(1)] Structural Design of Flexible Pavements for Interurban and Rural Roads as a Road Pavement Design Standard. This involves the conversion of the Annual Average Daily Traffic (ADDT) counts to Equivalent 80 KN Axles (E80's)

An Example of a TRH 4[(1)] calculation and catalogue pavement design is shown below:

TABLE A : CUMULATIVE E80 CALCULATION - TRH4 [(1)] 1996)

Road Number **P 16/2**

Traffic Count Station Number Near Kranskop

Road Category **D**

Enter the Design Period; AADT ; % Heavies and Time to open road (YRS).
Excel will then perform the necessary sensitivity analysis's!

Design Period **10**

Calculation of number of heavy vehicles per direction in design year 1

AADT	**% Heavy**	**Heavies**	**No. of years to opening road**			**5**
(in 1995)	(in 1995)	(in 1995)	Growth % - Table 11			
			2	4	6	8
200	25	23.4	26	29	32	35
Note : A 50:50 directional split is assumed						

Calculation of cumulative E80's

Low Traffic Volume = 26

		Expected annual growth(%) in E80's			
E80/Heavy:Table5		**2**	**4**	**6**	**8**
		Million E80's			
0.6		0.06	0.07	0.08	0.09
1.2		0.13	0.14	0.16	0.18
2		0.21	0.24	0.27	0.30

Expected % in E80's	
2	**4**
Pavement Class	
ES0.3	ES0.3
ES0.3	ES0.3
ES0.3	ES0.3

High Traffic Volume = 35

		Expected annual growth(%) in E80's			
E80/Heavy:Table5		**2**	**4**	**6**	**8**
		Million E80's			
0.6		0.09	0.10	0.11	0.12
1.2		0.17	0.19	0.21	0.24
2		0.29	0.32	0.36	0.40

Expected % in E80's	
2	**4**
Pavement Class	
ES0.3	ES0.3
ES0.3	ES0.3
ES0.3	ES1

NOTE: Categorise your road category into a pavement class, of A, B, C or D and use the TRH 4 pavement Catalogue alternatives to select an appropriate pavement design for your project.

Pavement Alternatives Road Category A WET REGION

	Low Class ES0.3			High Class ES1			
	0.1 - 0.3 x 10^6 E80			0.3 - 1.0 x 10^6 E80			Proposed by ….
BASE	***Granular***	***Cemented***	***Hot-mix***	***Granular***	***Cemented***	***Hot-mix***	
Surface							
Base							
Subbase1							
Subbase2							
Upper Sel							
Lower Sel							
Subgrade							

Pavement Alternatives Road Category B WET REGION

	Low Class ES0.3			HighClass ES1			
	0.1 - 0.3 x 10^6 E80			0.3 - 1.0 x 10^6 E80			Proposed by……
BASE	***Granular***	***Cemented***	***Hot-mix***	***Granular***	***Cemented***	***Hot-mix***	
Surface				S 2	S 2		S 2
Base				150 G2	125 C3		150 G2
Subbase1				200 G5/C4	150 C4		200 G5/ 150C4
Subbase2							
Upper Sel				150 G7	150 G7		150 G7
Lower Sel				150 G9	150 G9		150 G9
Subgrade				G 10	G 10		G10

Pavement Alternatives Road Category C WET REGION

	Low Class ES0.3			HighClass ES1			
	0.1 - 0.3 x 10^6 E80			0.3 - 1.0 x 10^6 E80			Proposed by……
BASE	***Granular***	***Cemented***	***Combined***	***Granular***	***Cemented***	***Combined***	
Surface	S 2	S 2	S 2	S 2	S2	S2	S2
Base	150 G4	200 C3	125 G5/C4	150 G2	125 C3	125 G2	150 G4/150 C4
Subbase1	150 G6		125 C4/G6	150 G5	125 C4	150 C4	150 G6
Subbase2							
Upper Sel	150 G7	150 G7	150 G7	150 G7	150 G7	150 G7	150 G7
Lower Sel	150 G9	150 G9	150 G9	150 G9	150 G9	150 G9	150 G9
Subgrade	G 10	G 10	G 10	G 10	G 10	G 10	G 10

Pavement Alternatives Road Category D WET REGION

	Low Class ES0.3			HighClass ES1			
	0.1 - 0.3 x 10^6 E80			0.3 - 1.0 x 10^6 E80			Proposed by……
BASE	***Granular***	***Cemented***	***Combined***	***Granular***	***Cemented***	***Combined***	
Surface	S 2	S 2	S 2	S 2	S 2	S 2	S2
Base	125 G4	125 C4	100 G5	150 G4	125 C4	125 G5	150 G4/125 C4
Subbase1	125 G6	125 G6	125 C4	150 G6	150 G6	150 C4	150 G6
Subbase2							
Upper Sel	150 G9	150 G9	150 G9	150 G9	150 G9	150 G9	150 G9
Lower Sel							
Subgrade	G 10	G 10	G 10	G 10	G 10	G 10	G 10

Comparing the four catalogue TRH 4[1] pavement designs suggested above for the project on Main road P 16/2 near Kranskop in KwaZulu-Natal, no pavement design is recommended for a Road Category A Pavement Design.

The Pavement design differences between the Road Categories B, C and D refer to variations between the support conditions in the Subbase1 in the pavement design categories B and C.

The differences between Road Categories C and D refer to a fairly major variation between the support conditions in the upper selected 1 layer where the G7 layer is totally removed.

- Use standard COTO [5] estimating rates to determine comparable project costs.
- Compare project costs to project budget and apply innovative initiatives to bring the project costs down to meet the project budget. Savings of between 15% and 45% are possible, but the potential variation in pavement failure risk must also be considered in terms of the Client's or Road Authorities ability to maintain the road pavement being designed.
- If the maintenance capability of the Road Authority is low or almost zero, the pavement designer needs to seriously consider adjusting the proposed pavement design to cater for the low or zero maintenance criteria. The replacement of an S2 – Double Surface Treatment Seal with an Asphalt Concrete Treatment is recommended, as it is considered as a low maintenance surfacing treatment. The project construction budget may then be exceeded, and therefore the dilemma of construction cost versus maintenance capability needs to be discussed and potential risks verified and approved with the Client.

The final pavement design chosen for the project will depend on the Client's maintenance capability and willingness to accept pavement failure risk versus initial construction cost.

INNOVATIVE INITIATIVES IN ROAD PAVEMENT DESIGN AND CONSTRUCTION

- If one applies TRH 4[1] and TRH 14[2] to your project, you achieve a Catalogue Pavement Design appropriate for the information applicable to the facts appropriate to your project.
- Compare the materials results from the project site to the materials requirement in accordance with the TRH 4[1] Catalogue Pavement Design.
  This could include considering the following questions:
  1) Manipulate recommended TRH 4[1] road pavement designs, and pavement layer thicknesses.
  2) Apply various stabilisers or chemical compaction aids to enhance pavement material performance.
  3) Mix available materials and additives to achieve the required pavement material performance.

- Try as far as possible to be innovative and use the insitu materials from the project site, and consider any materials, which are economically viable.
- Then apply a range of available additives to the available materials to match the materials required in accordance with the TRH 4[1] Catalogue Pavement Design.
  These could include:
  1. Lime
  2. Cement
  3. Hot Bitumen or Bitumen emulsion
  4. Suphonated Petroleum Products (SPP's)
  5. Polymers or Polymer Emulsions
  6. Enzymes

to name but a few.

Although numerous conventional stabilisers and compaction aids have been tried and tested during the 15 years of research conducted since 1986, the group of chemical stabilisers or compaction aids called the Sulphonated Petroleum Products (SPP's) additives have been particularly successfully used, in a wide range of natural gravel's in KwaZulu-Natal.

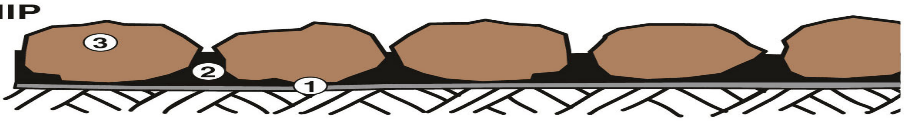
Examples of their use and performance in KwaZulu-Natal are quoted later in this paper.

- In accordance with Bennett and Paige-Green [5] the TRH 14[2] "**G**" classification of a material can be adjusted by between at least one (1) and up to two (2) "**G**" classifications by the application at the correct dosage of an appropriate Suphonated Petroleum Product (SPP)
- The dosage of the SPP is critical, and must be pre-tested to match the material being treated. Over dosage will result in the deterioration or complete collapse of the structure of the material, with the resultant reduction of bearing capacity and strength.
- The correct dosage of the material will however result in a significant increase in the bearing capacity and strength of the material, et al Bennett and Paige-Green[5]
- The correct method to identify the SPP product dosage and the resulting increase in CBR value is explained in the example in **Annexure A.**
- Examples of some natural material and SPP treated material test results confirming the testing process is attached in **Annexure A.**
- The overriding concept is to utilise the insitu and existing materials as far as possible on a project. Where the insitu or existing materials available on the project, are only suitable for some pavement layers, the balance of the materials required must first be sourced from the conversion of insitu and existing materials, by mixing and or using material enhancement additives. There after alternative and normally more expensive borrow or commercial sources can be located and compared before the final pavement design and the materials required are finalised.
- Then interrogate the Catalogue Pavement Design or the adjusted pavement design that you have modified from the Catalogue Pavement Design based on the materials available to ensure you have a balanced design and you can economically sourced all the materials, but the project pavement design still confirms with the pavement design criteria and input data as required and defined in TRH 4[1]
- Then consider the surfacing requirement of your project, and see if you can apply alternative more economically surface treatments, which are appropriate and still ensure the integrity of the road, and the maintenance implications are considered.
  This could include considering the following questions:
  1. What are the Maintenance Capabilities of the Road Authority responsibility for the project.
  2. Would a coarse graded Sand Seal, an Otta Seal, or a modified even graded Otta Seal Surface treatment be appropriate, in terms of the project and the Road Authorities Maintenance capabilities.
  3. Would a combination of the above with a conventional surface treatment be appropriate in terms of the project and the Road Authorities Maintenance capabilities.
  4. Eliminate prime coat applications.
  5. Ensure that the first bitumen binder applied to any new construction is applied hot.
  6. Ensure that the total bitumen applied to any new construction project is a minimum of 2.0 litres/m^2 to ensure the seal is waterproof.

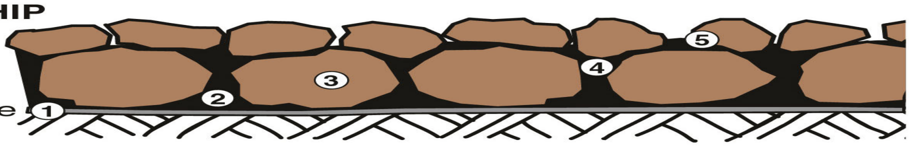
A table of some conventional and innovative surface treatment seals is shown below for ease of reference and to confirm uniform definition of these surface treatment seal names.

SAND SEAL
1 Prime
2 Binder
3 Sand

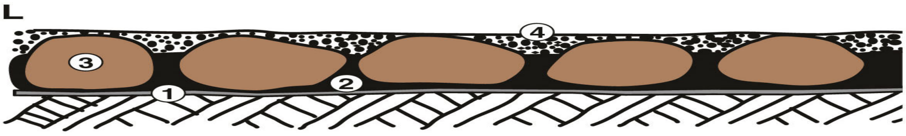
SINGLE CHIP SEAL
1 Prime
2 Binder
3 Stone



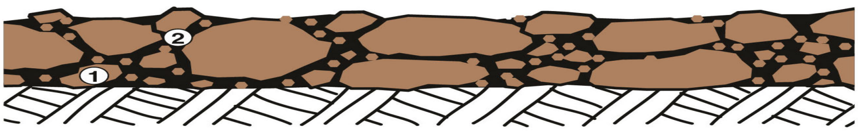
DOUBLE CHIP SEAL
1 Prime
2 Binder
3 Large stone
4 Binder



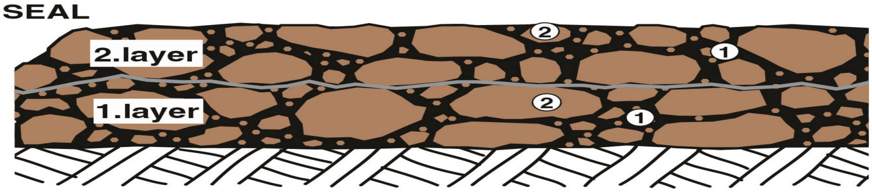
CAPE SEAL
1 Prime
2 Binder
3 Stone
4 Slurry



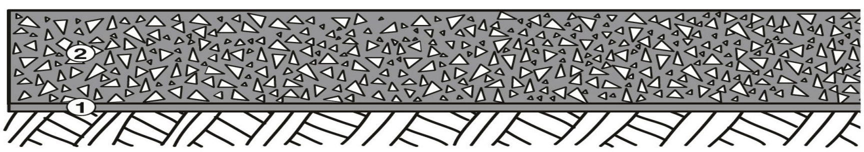
SINGLE OTTA SEAL
No Prime
1 Binder
2 Graded aggregate



DOUBLE OTTA SEAL
No Prime
1 Binder
2 Graded aggregate



ASPHALT CONCRETE
1 Prime
2 Asphalt Premix



Often a combination of seals is applied or a modification of a surface treatment seal is applied

For Example:
1) A modified graded single Otta Seal is applied.
2) An inverted surface treatment is applied.
3) A modified binder is applied.
4) A modified aggregate grading is applied.
5) A combination of some of the above is applied.

SOME RECENT EXAMPLES OR CASE STUDIES IN KWAZULU - NATAL

THE WATERPROOF GRAVEL ROAD – (TRH 4[1] Road Category D)

D425 Alverstone (Conversion Rate Used: R 8.00 => US $ 1.00)

(2 km cost R 376 000) => (R 188 000 /km = R 26.85 /m2)
(2km = 1.25 miles cost $ 47 000) => ($ 23 500 /km = $ 37 600 /mile = $ 3.36 /m2)

(All Prices quoted are at April 2000 rates and are likely to have increase by 2002.)

LAYER	TRH 4 CATALOGUE	**ACTUAL PAVEMENT BUILT**
Surface Treatment	S2 => 19mm + 9.5mm Double Seal	Single 19mm Otta Seal @ R 8.36/m2 => $ 1.05/m2 (Annexure C)
Base Course	150mm G5 Natural Gravel. CBR = 45 @ 98% mod. AASHTO	150mm G7 Sub Base + SPP @ 100ml/m^3 CBR > 45 @ 98% => G5 treated base @ 98% mod. AASHTO
Sub Base	150mm G7 Natural Gravel @ 95% modified AASHTO	150mm G7 Insitu Sub Base @ 95% modified AASHTO
Selected	150 mm G9 Insitu Natural Gravel @ 93% mod. AASHTO	150mm G9 Insitu Natural Gravel @ 93% modified AASHTO Compaction
Sub Grade	G10 insitu sub grade @ 90% modified AASHTO	G10 insitu sub grade @ 90% modified AASHTO Compaction

D425 Alverston – Waterproof Gravel just after construction

D425 Alverston – Waterproof Gravel 8 months after construction

THE LOW VOLUME SURFACED ROAD - (TRH 4[1] Road Category C or D)

D 887 Esinkelweni (Conversion Rate Used: R 8.00 => US $ 1.00)

(9.5 km cost R 2.6 million) => (R 274 000 / km = R 39.10 / m2)
(9.5 km = 6miles cost $ 325 000) => ($ 34 210 /km = $54 200 /mile = $ 4.90 /m2)

(All Prices quoted are at April 2000 rates and are likely to have increase by 2002.)

LAYER	TRH 4 CATALOGUE	ACTUAL PAVERMENT BUILT
Surface Treatment	S2 = 19mm + 9.5mm Double Seal	Single Otta Seal @ R 8.36/m2 = $1.05/m2 (Annex. A)
Base Course	150mm G4 Natural Gravel CBR = 80 @ 98% modified AASHTO	150mm G5 + SPP @ 125ml/m3 @ 98% CBR > 80 => G4 treated base @ 98% mod. AASHTO (G5 hauled 25 km)
Sub Base	150mm G6 Natural Gravel CBR = 25 @ 95% modified AASHTO	150mm G8 sand + 50mm Berea red + SPP @ 125ml/m3 @ 95% CBR > 25 => G6 treated base @ 95% mod. AASHTO
Selected	150mm G9 Insitu Natural Gravel @ 93% mod. AASHTO	150mm G8 Insitu Sand @ 100% modified AASHTO
Sub Grade	G10 Insitu sub grade @ 90% modified AASHTO	G10 Insitu sub grade material @ 90% modified AASHTO

D 887 Before Upgrading – A poor sandy gravel road serving a large rural community and black sugar cane farmers.

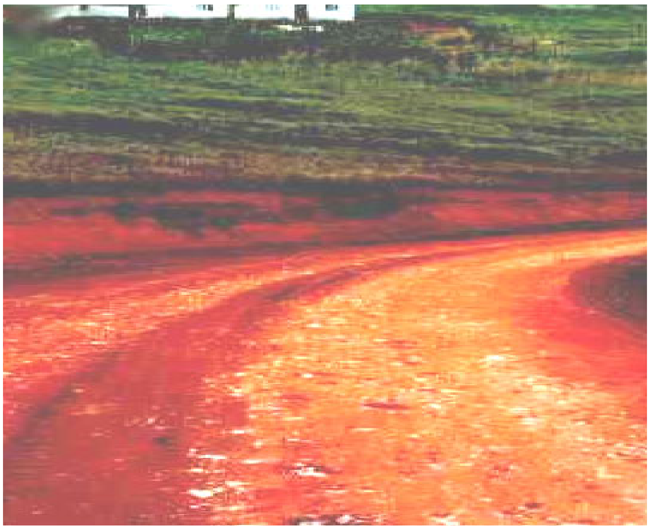
D 887 After Upgrading –
A low cost all weather road to serve the large rural community and black sugar cane farmers.

<u>P 50/2 Nkandla</u> (Conversion Rate Used: R 8.00 => US $ 1.00)

(14 km cost R 3.2 million) => (R 228.572 /km = R 32.65 /m2)
(14 km = 8.75miles cost $ 400 000) => ($ 28 572 /km = $ 45 715 /mile = $ 4.08 /m2)

(All Prices quoted are at April 2000 rates and are likely to have increase by 2002.)

LAYER	TRH 4 CATALOGUE	ACTUAL PAVEMENT BUILT
Surface Treatment	S2 = 19mm + 9.5mm Double Seal	Single Otta Seal @ R 8.36/m2 = $ 1.05/m2 (Annexure B)
Base Course	150mm G5 Natural Gravel @ 98% modified AASHTO	150mm G5 Natural gravel base @ 98% modified AASHTO (G5 hauled 25 km)
Sub Base	150mm G7 Natural Gravel CBR = 25 @ 95% modified AASHTO	150mm G9 insitu + SPP @ 125ml/m3 CBR > 25 @ 95% modified AASHTO => G7 @ 95% modified AASHTO
Selected	150mm G9 Insitu material @ 93% mod. AASHTO	150mm G9 Insitu material @ 93% mod. AASHTO
Sub Grade	G 10 insitu material @ 90% modified AASHTO	G 10 insitu material @ 90% modified AASHTO



P50-2 NKANDLA, Before upgrading – A very poor gravel road serving a large rural community and giving assess to Nkandla.

P50-2 NKANDLA; After Upgrading
A low cost all weather road to serve the large rural community and give access to Nkandla.

<u>P 16/2 Kranskop</u> (Conversion Rate Used: R 8.00 => US $ 1.00)

(R 9.5 km cost R 3.0 million) => (R 315 700/km = R 45.10/m^2)
(9.5 km = 6miles cost $ 375 000) => ($ 39 475 /km = $63 158 /mile = $ 5.64 /m^2)

(All Prices quoted are at April 2000 rates and are likely to have increase by 2002.)

LAYER	TRH 4 CATALOGUE	FIRST PAVEMENT DESIGN	ACTUAL PAVEMENT BUILT
Surface Treatment	S2 = 19mm + 9.5mm Double Seal + Prime @ R 18.65/m^2	19mm Single Seal @ R9.65m^2 + Prime @ R1.35/m^2 = R11.00/m^2	Single modified Otta Seal @ R9.60/m^2 or (Single Otta Seal @ R8.36/m^2) alternative
Base Course	150mm C4 Lime Stabilised Base G7 + 4% Lime = C4 @ R 7.05/m^2	100 mm G7 Natural Gravel + 4% Bitumen Emulsion = (BES) @ R13.57/m^2	150 mm G7 Natural Gravel + 4% lime = C4 Stabilised Base @ R 7.05/m^2
Sub Base	150mm imported G6 Natural Gravel CBR = 25 @ 95% modified AASHTO @ R 8.81/m2	150 mm imported G6 Natural Gravel CBR = 25 @ 95% modified AASHTO @ R 8.81/m^2	150 mm G8 Natural Gravel + SPP@ 125ml/m3 @ 98% CBR > 25 => G6@ 95% modified AASHTO @ R 5.40/m^2
Selected	150 mm G9 insitu material CBR = 7 @ 93% mod. AASHTO	150 mm G9 insitu material CBR = 7 @ 93% mod. AASHTO	150 mm G9 insitu material CBR = 7 @ 93% modified AASHTO (all 3 designs the same)
Sub Grade	G10 insitu material CBR = 3 @ 90% modified AASHTO	G10 insitu material CBR = 3 @ 90% modified AASHTO	G10 insitu material CBR = 3 @ 90% modified AASHTO (all 3 Designs the same)
Cost Comparison	R 2.295 million =R 34.51/m^2	R2.22 million =R33.38/m^2	R 1.78million = R26.82/m^2 = 20% to 22% Saving

P 16/2 Kranskop – The C4 lime stabilised base preparation before the application of the cutback 150/200 penetration grade bitumen binder for the rural seal on the lime stabilised base layer.

P 16/2 Kranskop - Application of the cutback 150/200 penetration grade bitumen binder for the modified Otta seal on the lime stabilised base layer.

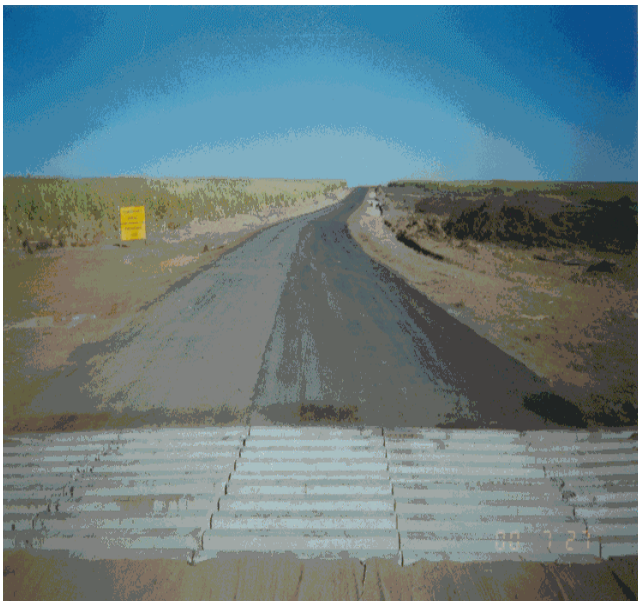
P 16/2 Kranskop - Application of half the cutback 150/200 penetration grade bitumen binder and the graded aggregate for the modified Otta seal. Note the exposed binder for the center joint overlap.

<u>D 348 Mount Elias</u> (3.5 km = 2.2 miles long project)

(All Prices quoted are at April 2000 rates and are likely to have increase by 2002.)

LAYER	**TRH 4 CATALOGUE**	**FIRST PAVEMENT DESIGN**	**ACTUAL PAVEMENT BUILT**
Surface Treatment	S2 = 19mm + 9.5mm Double Seal + Prime @ R18.65/m^2	40mm Asphalt + Tack Coat @ R 29.77/m^2	Single modified Otta Seal @ R9.60/m^2 or (Single Otta Seal @ R8.36/m^2) alternative
Base Course	150mm G4 Nataural Gravel Base or C4 Lime Stabilised Base G7 + 4% Lime = C4 @ R 7.05/m^2	150 mm G7 Natural Gravel + 4% lime = C4 Stabilised Base @ R 7.05/m^2	100 mm G7 Natural Gravel + 4% Bitumen Emulsion = (BES) @ R13.57/m^2
Sub Base	150mm imported G6 Natural Gravel CBR = 25 @ 95% modified AASHTO @ R 8.81/m^2	150 mm imported G5 Natural Gravel CBR = 35 @ 95% modified AASHTO @ R 8.81/m^2	200 mm insitu G7 Natural Gravel + SPP @ 125ml/m3 @ 98% CBR > 35 => G5 @ 95% modified AASHTO @ R5.40/m^2
Selected	150 mm G9 insitu material CBR = 7 @ 93% mod. AASHTO	150 mm G9 insitu material CBR = 7 @ 93% mod. AASHTO	150 mm G9 insitu material CBR = 7 @ 93% modified AASHTO (All 3 designs the same)
Sub Grade	G10 insitu material CBR = 3 @ 90% modified AASHTO	G10 insitu material CBR = 3 @ 90% modified AASHTO	G10 insitu material CBR = 3 @ 90% modified AASHTO (All 3 designs the same)
Cost Comparison	R 845 495 => R 34.51/m^2 US$ 105 687 => US$ 4.31/m^2	R1 118 000 => R45.63/m^2 US $ 139 750 => US $ 5.70/m^2	R 700 000 => R28.57/m^2 => US$ 87 500 =>US$ 3.57/m^2 => **17% to 37.5%** Saving

D 348 Mount Elias – Before upgrading to low volume surfaced standard.



D 348 Mount Elias – After upgrading to low volume surfaced standard.

<u>D 1132 Sweetwaters</u> (2.2 km = 1.375 miles long project)

Total Project Cost = R 400 000 ➔ R 25.98 /m2

(All Prices quoted are at April 2000 rates and are likely to have increase by 2002.)

LAYER	TRH 4 CATALOGUE	FIRST PAVEMENT DESIGN	ACTUAL PAVEMENT BUILT
Surface Treatment	S2 = 19mm + 9.5mm Double Seal + Prime @ R18.65/m^2	40mm Asphalt + Tack Coat @ R 29.77/m^2	Single modified Otta Seal over 8mm Slurry Seal + Prime @ R 17.96/m^2
Base Course	150mm G4 Nataural Gravel Base or C4 Lime Stabilised Base G7 + 4% Lime = C4 @ R 7.05/m^2	150 mm G7 Natural Gravel + 4% lime = C4 Stabilised Base @ R 7.05/m^2	150 mm milled premix rap @ 98 % modified AASHTO @ R2.62/m^2 (Spread & Compact only)
Sub Base	150mm imported G6 Natural Gravel CBR = 25 @ 95% modified AASHTO @ R 8.81/m^2	150 mm imported G5 Natural Gravel CBR = 35 @ 95% Modified AASHTO @ R 8.81/m^2	150 mm insitu G7 Natural Gravel + SPP @ 125ml/m3 @ 98% CBR > 35 => G5 @ 95% modified AASHTO @ R5.40/m^2
Selected	150 mm G9 insitu material CBR = 7 @ 93% mod. AASHTO	150 mm G9 insitu material CBR = 7 @ 93% mod. AASHTO	150 mm G9 insitu material CBR = 7 @ 93% modified AASHTO (All 3 designs the same)
Sub Grade	G10 insitu material CBR = 3 @ 90% modified AASHTO	G10 insitu material CBR = 3 @ 90% modified AASHTO	G10 insitu material CBR = 3 @ 90% modified AASHTO (All 3 designs the same)
Cost Comparison	R 531 454 => R 34.51/m^2 US$ 66 432 => US$ 4.31/m^2	R702 702 => R45.63/m^2 US $ 87 838 => US $ 5.70/m^2	R 400 000 => R25.98/m^2 => US$ 50 000 =>US$ 3.25/m^2 => 24.5% to 43% Saving

D1132 Sweetwaters – Before upgrading.

D1132 Sweetwaters – After upgrading with the application of a 150mm Rap base a hot prime and a 8mm thick slurry seal.

D1132 Sweetwaters – Official opening by Head:Transport Dr. K.B. Mbanjwa, with the Nkosi and Community Leaders.

D 1132 Sweetwaters – Note Attention to Drainage, Accesses & Surfacing. Drainage Protection to follow.

COST COMPRISONS FOR DIFFERENT ROAD TYPES

(All figures in the table are in R 1, 000 Rand Units)

- The listed maintenance cycles of 6years are based experience used in KZN for ideal re-gravelling and resealing intervals.
- Maintenance costs are assumed to be the same over the life of the road, as currently provinces only get allocations for road maintenance which are set at the budget figure of R 3 000 per km per year, and this is applied to both surfaced and gravel roads.
- Cost escalation over the years is assumed equal for the different activities, and therefore can be ignored in the comparison table

(All Prices quoted are at April 2000 rates and are likely to have increase by 2002.)

Time Scale (Life)	Gravel Cost	Waterproof Gravel	Low Cost Surfaced	Full Standard Surfaced	Quarries Required
Year 0 Initial Cost	Construct Q1 100 to 150	Construct Q1 150 to 200	Construct Q1 250 to 300	Construct Q1+ 800 to 1 000	Yes Quarry 1
Year 6 Mainten. Cost	Regravel Q2 75	Reseal CS1 50	Reseal CS1 50	Reseal CS1 50	Yes Q2 or CS1
Accumulated Costs @ Y6	175 to 225	200 to 250	300 to 350	850 to 1050	—
Year 12 Mainten. Cost	Regravel Q3 75	Reseal CS1 50	Reseal CS1 50	Reseal CS1 50	Yes Q3 or CS1
Accumulated Costs @ Y12	250 to 300	250 to 300	350 to 400	900 to 1100	—
Year 18 Mainten. Cost	Regravel Q4 75	Reseal CS1 50	Reseal CS1 50	Reseal CS1 50	Yes Q4 or CS1
Accumulated Costs @ Y18	325 to 375	300 to 350	400 to 450		
Year 24 Mainten. Cost	Regravel Q5 75	Reseal CS1 50	Reseal CS1 50	Reseal CS1 50	Yes Q5 or CS1
Initial Life Costs @ Y 24	**400 to 450**	**350 to 400**	**450 to 500**	**1 000 to 1 200**	---
Typical Traffic Volumes	**< 200 vpd**	**< 400 vpd**	**< 800 vpd**	**> 1 200 vpd**	---
Public Rating	**4th Worst**	**3rd Acceptable**	**2nd Good**	**1st Best**	---
Level of Service	**Unacceptable in dry & wet**	**Acceptable all weather**	**Acceptable all weather**	**Desired option**	---
Overall Rating	**Affordable but not Acceptable**	**Affordable and Acceptable**	**Desirable And Affordable**	**Desirable but not Affordable**	---

Therefore over the projected life of the road, the waterproof gravel and low cost surfaced options become very attractive as acceptable and affordable solutions to the Public's Level of Service (LOS) demands, versus the Client's moral responsibility, and budget restraints.

The Quarry and materials haulage requirements for the gravel and full standard road options are excessive, in comparison to the waterproof gravel or low cost surfaced options. Which only require the initial use of one quarry (Q1) and the use of one Commercial Source (CS1) of reseal aggregate during the life of the road.

CONCLUSIONS

This research has resulted in the service delivery of very cost-effective roads, to the rural communities' inspite of the relatively low traffic, by applying appropriate engineering technology to match the project to the budget available.

1. The development of the "Waterproof" Gravel, and the Low Volume Surfaced Road pavement design concept, has been applied to road projects carrying less than 400 vehicles per day. The various trials and successfully examples constructed in the province, KwaZulu-Natal using this technology, which is based on the Standard South African TRH 4 (1) Structural Design of Flexible Pavements for Interurban and Rural Roads Pavement Design Manual, and uses the

Standard South African TRH 14 [2] Guidelines for Road Building Materials, are now too numerous not to be considered as a viable and cost effective alternative to the conventional gravel, and full standard surfaced road.

If the cost comparisons of the four types of road scheduled in the table in section 8 (above) of this document are analysed, the cost benefit over the initial life, short term life, and longer term life of the road, continues to increase the longer the road life is extended. These figure don't include any cost benefit values for the savings in vehicle operating costs and the improved level of service provided by the waterproof gravel or low volume surfaced road, or the full standard surfaced road, as compared to the gravel road standard. If these values are added the full value of the waterproof gravel or low volume surfaced road pavement options become apparent.

2.) The cost savings and therefore benefit gained by using available insitu materials, from the current road prisms and or existing quarry sources, mixed together with other available materials, and combinations of conventional and new stabilising agents and compaction aids, together with conventional and new surfacing techniques, to deliver appropriate and acceptable levels of service to some of the 70% of the road network, carrying less than 25% of the traffic, (with daily vehicle counts of < 400vpd), is making an appropriate contribution to the development of a cost effective and viable all weather road network in the province, KwaZulu-Natal.

3) This paper suggests the use of Innovative Initiatives to match the public's service delivery requests and demands to the budget allocations given. Comparative cases of actual roads constructed in KwaZulu-Natal illustrate the benefit of applying innovative initiatives in road pavement technology to attempt to solve the provision of appropriate roads for rural communities on the African Continent, and now World wide.

In the examples quoted above, savings of 17% to 43% have been achieved by applying innovative initiative techniques, to the TRH 4[1] catalogue pavement designs. In all cases we have provided a cost effective alternative. The road pavement failure risk has been assessed in terms of the Road Authorities ability to maintain the road network. Yet we have achieved the same level of service and design life in the road pavement design actually built on site, and managed to do this within the project budget allocated. In this manner we are able to design and build appropriate road pavements to provide the required level of service for our rural communities in KwaZulu-Natal. And if we can do it here in KwaZulu-Natal, South Africa, why can't this technology be applied in the rest of Africa, in accordance with the African Renaissance initiative, and why not World wide to deliver appropriate road infrastructure services to rural communities.

REFERENCES AND FURTHER READ:

1. **Structural Design of Flexible Pavements for Interurban and Rural Raods** Committee of Land Transport Officials, COLTO; Draft TRH4: 1996, Pages 1-101
2. **Guidelines for Road Construction Materials** Committee of State Road Authorities: Draft TRH 14: 1985, Pages 1 – 57
3. **Standard Methods of Testing Road Construction Material** Technical Methods for Highways, TMH1: 1979, (revised 1985)
4. **The Design and Use of Granular Emulsion Mixes.** South African Bitumen Association, SABITA MANUAL 14 1993 – GEMS:
5. **The Use of Sulphonated Petroleum Products (SPP's) in Road Pavements in KwaZulu-Natal: State of the Art: by Bennett H.E. and Paige –Green Dr P.** South African Transportation Conference Proceedings: July 1993.
6. **The Structural Design, Construction and Maintenance of unpaved Roads** Committee of State Road Authorities: Draft TRH 20: February 1990, Pages 1-53

7. **Guidelines For Upgrading of Low Volume Roads:** Department of Transport: Chief Directorate National Roads RR 92/466/1; March 1993: Pages 1-1;9-2

8. **Guidelines For Upgrading of Low Volume Roads:** Department of Transport: Chief Directorate National Roads RR 92/466/2; March 1993: Pages 1-1;9-2

9\. **The Effect of A sulphonated Petroleum product on some Physical and Chemical Properties of Some Standard Clays and Minerals** Shardesh Sewlall; 1997: Pages 1-41

10. **Local Low Volume Roads and Streets:** American Society of Civil Engineers November 1992: Pages I-1; V-31

11. **Surfacing Seals for Rural and Urban Roads and compendium of Design methods for surfacing seals used in South Africa. Committee of State Road Authorities: TRH3 1996:**

12\. **Selection and Design of Hot-Mix Asphalt Surfacings for Highways.** Committee of State Road Authorities: TRH8 1987:

13\. **The Design and Use of Porous Asphalt Mixes.** South African Bitumen Association, SABITA MANUAL 17 1994:

AN EXAMPLE OF THE CORRECT METHOD OF DETERINING THE SPP DOSAGE.

LABORATORY AND FIELD DATA :

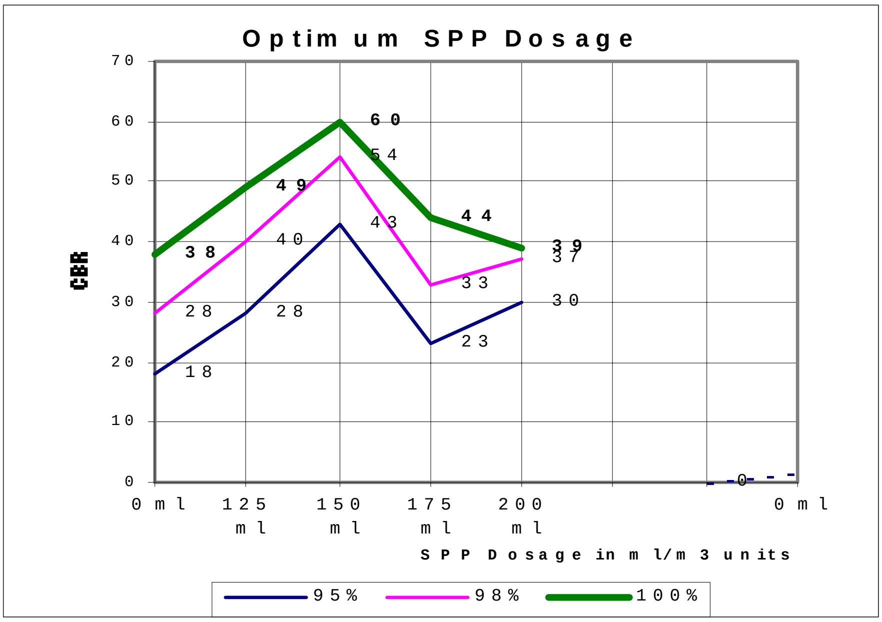
Quarry ^@ km 9+600

Laborotory Nos. 23509 23510 23511 23512 23513

km/pit No. 1+200

Layer Subbase

SIEVE ANALYSIS		MECHANICAL ANALYSIS		CBR			
Sieve Size	% Passing			SPP Only			
75.0	100	Coarse Sand	31	CURING : 4 Days			
63.0	96	Coarse fine Sand	7	ml / m^3	Mod. ASSHTO Compaction		
53.0	91	Medium fine Sand	6		95%	98%	100%
37.5	86	Fine fine Sand	5	**0 ml**	**18**	**28**	**38**
26.5	79	Silt and Clay	51	125 ml	28	40	49
19.0	72			150 ml	**43**	**54**	**60**
13.2	60	Liquid Limit	29	175 ml	23	33	44
4.75	37	Plasticity Index	9	200 ml	30	37	39
2.00	32	Linear Shrinkage	5				
0.425	22	Grading Modulus	2.29		Swell		
0.075	17	PRA Classification		**0 ml**	1.61		
		TRH 14 Classificatio	G7	125 ml	0.94		
		M.D.D. / O.M.C.	2017/11.0	150 ml	0.89		
				175 ml	0.90		
				200 ml	0.87		



The optimum SPP dosage for this project is at 150ml/m^3 which results in the highest increase in CBR value. The difference between the CBR value at 0ml/m^3 and that at 150ml/m^3 is the increase in CBR achieved by using the SPP at the specified % of mod AASHTO compaction.

EXACT COST OF THE OTTA SEAL AT D 887. **ANNEXURE B:**

(Conversion Rate Used: R 8.00 = US $ 1.00)
(All Prices quoted are at April 2000 rates and are likely to have increase by 2002.)

ITEM	UNIT	QUANTITY	No.	RATE	TOTAL (R)	TOTAL ($)
1. MATERIALS						
Aggregate	Tonne	1700		103.45	175 865.00	21 983.13
Bitumen 150/200 Shell	Tonne	112.16		795.00	89 167.20	11 145.90
Paraffin Shell	Litre	7200		2.00	14 400.00	1 800.00
2. PLANT +EQUIPMENT						
Sprayer hire-Colas	Day	9	2	3500.00	31 500.00	3 937.50
Hire of tipper trucks	Day	9	2	650.00	11 700.00	1 462.50
Chip spreader	Day	9	1	1000.00	9 000.00	1 125.00
Pneumatic roller	Day	9	2	700.00	12 600.00	1 575.00
Tractor& broom	Day	9	1	400.00	3 600.00	450.00
Payloader	Day	9	1	1000.00	9 000.00	1 125.00
Diesel	Litre	2704		2.3485	6 350.34	793.80
Consumables					500.00	62.50
3. LABOUR						
Labour units	Day	9	12	46.00	4 968.00	621.00
Overtime	Day	4	12	30.67	3312.36	414.05
Living out allow. `	Night	9	12	15.00	1 620.00	202.50
Salary – Foreman	Day	9	1	300.00	2 700.00	337.50
Overtime	Day	4	1	200.00	800.00	100.00
Living out allow.	Night	9	1	65.00	585.00	73.13
Sub-Total					**377 667.90**	**47 208.49**
4. OTHER						
Rise and fall on bitumen	Tonne	112.16		230.00	25 796.80	3 224.60
Site establishment				16 000.00	16 000.00	2 000.00
Sub-Total					**419 464.70**	**52 433 09**
VAT 14%					**58 725.06**	**7 340.63**
TOTAL					**478 189.76**	**59 773.72**

- AREA SURFACED: **62939 m^2**
- TOTAL COSTS: **R478 189.76 => $ 59 773.72**
- RATE M^2: **R7.60/m^2 => $0.95/$m^2$**
-10% for contractor head office overheads + profits: **R0.76/m^2 => $0.10/$m^2$**

TOTAL COST OF OTTA SEAL = R8.36 /m^2 = $ 1.05 /m^2.

(All Prices quoted are at April 2000 rates and are likely to have increase by 2002.)