INNOVATIVE INITIATIVES IN ROAD PAVEMENT DESIGN AND CONSTRUCTION

By

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ABSTRACT

Innovative Initiatives in Road Design, Construction and Maintenance, in the Province of KwaZulu-Natal, South Africa

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 provinces' largely rural communities have increased.

As many parts of the province also lack suitable gravel sources resulting in high re-gravelling costs, due to long haul distances and accelerated gravel loss from poor materials.

The application of Innovative Initiatives in Road Design, Construction and Maintenance 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.

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

This paper also indicates the benefits of using available insitu materials, 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 service to some of the 70% of the road network, carrying less than 25% of the traffic.

This 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 constructed and maintained 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.

1. 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.

Faced with these problems, road engineers are 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.

2. 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, Construction and Maintenance have been applied, which has resulted in the provision of water proof gravel roads and the provision of low volume surfaced roads at 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 [2] Pavement Design Manual, using the Standard South African TRH 14 [1] 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 available materials, and in combination with conventional and new stabilising agents and compaction aids, together with conventional and new surfacing techniques, to deliver appropriate service to some of the 70% of the road network, carrying less than 25% of the traffic are considered.

The use of Innovative Initiatives to match the public's service delivery requests to match the budget allocations given. Comparative cases of actual roads constructed and maintained 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.

3. PROJECT BUDGET DILEMIA

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, and apply the standard design techniques that you have always used.

3.2) Then be totally innovative and see what you can change without compromising the design.

3.3) Use innovative techniques to solve the problem within the budget.

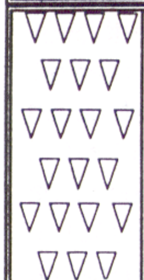
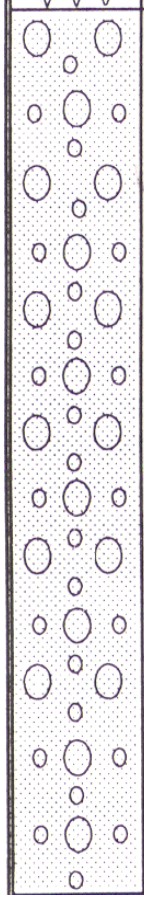
3.4) Test and verify the innovative ideas and new binders, compaction aids or stabiliser additives with the proposed insitu or recommended quarry materials in the laboratory before specifying them on site. What works in the laboratory will work on site if the standard tests are applied to the materials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

3.5) 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 change at a time.

4. SOUTH AFRICAN STANDARDS

In South Africa we use the TRH 14 [1] Road Materials Standards.

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[1] 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, [8] 1979, Method A 14)

***** ITS Indirect Tensile Strength (SABITA Manual 14, [11] 1993)

****** Durability (TMH 1, [8] 1979 Method A 19)

Use TRH 4 [(2)] Road Pavement Design Techniques.

TABLE A : CUMULATIVE E80 CALCULATION - TRH4 [(2)] (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, and use the TRH 4 pavement catalogue alternatives to select an appropriate pavement design for you project.

Pavement Alternatives — Road Category A — 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							
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

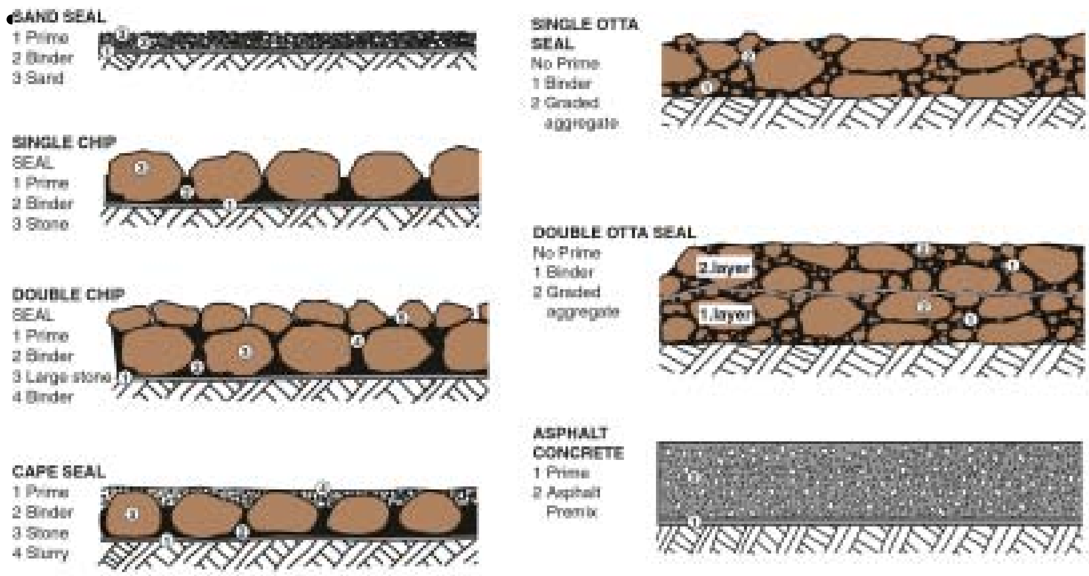
Pavement Alternatives — Road Category D — WET REGION

	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

- Use standard COLTO [3] estimating rates to determine 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 20 and 40% possible

5. INNOVATIVE INITIATIVES IN ROAD PAVEMENT DESIGN AND CONSTRUCTION

- Apply a Sand Seal an Otta Seal or a Grav. Seal Surface treatment.
- Eliminate prime coat applications.



- Manipulate recommended TRH 4 road pavement designs, and pavement layer thicknesses.
- Apply various stabilisers or chemical compaction aids to enhance pavement material performance.
- Mix available materials & additives to achieve the required pavement material performance.

6. SOME RECENT EXAMPLES OR CASE STUDIES IN KWAZULU - NATAL

- **The Waterproof Gravel Road**
  – D 425 Alverstone
  – P 28/1 Draycote - Giants Castle
  – D119 Monte Aux Sources – Cavern Resort
- **The Low Volume Surfaced Road**
  – D 887 Elsinkelweni
  – P 50/2 Nkandla
  – P 16/2 Kranskop
  – D 348 Mount Elias

7. THE WATERPROOF GRAVEL ROAD – A RECENT EXAMPLE OR CASE STUDY IN KWAZULU - NATAL

D425 Alverstone (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)

TRH 4		ACTUAL PAVEMENT BUILT
S2	**surfacing**	Otta Seal @ R 8.36/m2 = $ 1.05/m2 (Annex.A)
150mm G5	**base**	G7+SPP@100ml/m3 = G5 treated base @ 98%
150mm G7	**sub-base**	G7 insitu sub base @ 95% modified AASHTO
150 mmG9	**selected**	G9 selected insitu @ 93% modified AASHTO
G10 insitu	**sub-grade**	G10 insitu sub grade @ 90% mod. AASHTO

D425 Alverston – Waterproof Gravel just after construction

D425 Alverston – Waterproof Gravel 8 months after construction

8. THE LOW COST SURFACED ROAD - SOME RECENT EXAMPLES OR CASE STUDIES IN KWAZULU - NATAL

D887 Esinkleweni (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)

TRH 4		ACTUAL PAVEMENT BUILT
S2	**surfacing**	Otta Seal @ R 8.36/m2 = $1.05/m2
150 G4	**base**	G5 + SPP@125ml/m3 = G4 treated@98% (25km haul)
150 G6	**sub-base**	G8 sand+50mmBerea red + SPP125ml/m3 = G6 @ 95%
150 G9	**sub-grade**	G8 insitu sand @ 100% modified AASHTO
G10 insitu		G10 insitu material

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.

P 50/2 Nkandla (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)

TRH 4		ACTUAL PAVEMENT BUILT
S2	**surfacing**	Otta Seal @ R 8.36/m2 = $ 1.05/m2 (Annex A)
150mm G5	**base**	G5 Natural gravel base @ 98% (25km Haul)
150mm G7	**sub-base**	G9 insitu+SPP125ml/m3 = G7@ 95%
150mm G9	**sub-grade**	G9 insitu material @ 93% mod. AASHTO
G10 insitu material		G 10 insitu material

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.

9. LOW COST SURFACED ROAD PAVEMENT DESIGN COMPARISONS

9.1) **P 16/2 Kranskop** (9.5 km = 6 miles long project)

19mm Seal+Prime @ R9.65 m2 + R1.35/m2	vs **surfacing**	Gravseal @ R9.60/m2 or Otta Seal @ R8.36/m2
100 mm 4%ETB (BES) @R13.57m2	vs **base**	150 mm 4% lime = C4 @ R 7.05/m2

Same: 150 mm G8+SPP=G7 **sub-base** @ 95% mod. AASHTO.

" 250 mm G9 insitu material **sub-grade** @ 93% mod. AASHTO

(R2.22 m = R33.38/m2) vs (R 1.78m = R26.82/m2) = **- 20% Cheaper**

SOME RECENT EXAMPLES OR CASE STUDIES IN KWAZULU - NATAL

- The low Cost Surfaced Road

P 16/2 Kranskop (R 9.5 km cost R 3.0 million) => (R 315 700/km = R 45.10/m2)
(9.5 km = 6miles cost $ 375 000) => ($ 39 475 /km = $63 158 /mile = $ 5.64 /m2)

TRH 4		ACTUAL PAVEMENT BUILT
S2	**surfacing**	Gravseal @ R 9.60/m2
150mm C4	**base**	G7+4% lime=C4 base @ 98%
150mm G6	**sub-base**	G8 insitu+SPP@125ml/m3=G7@ 95%
150mm G9	**sub-grade**	G9 insitu material @ 93%
G10 insitu		G 10 insitu

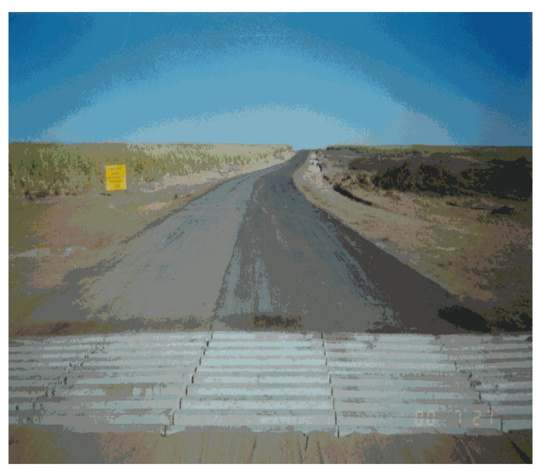
P 16/2 Kranskop - Application of the cutback 150/200 penetration grade Bitumen binder for the Gravseal on the lime stabilised base layer.

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

9.2) **D 348 Mount Elias** (3.5 km = 2.2 miles long project)

40mm Asphalt plus Prime	vs **surfacing**	8mm Slurry Seal plus Prime
150 mm 4% lime = C4	**base**	100 mm 4%ETB
150 mm imported G5 @ 95% mod. AASHTO .	**sub-base**	200 mm insitu G7 + SPP @ 125ml/m3 compacted @ 98% m.AASHTO = G5.
250 mm G9 insitu material @93% mod. AASHTO	**sub-grade**	250 mm G9 insitu material @ 93% mod.AASHTO
(R1 118 000 = R45.63/m2) ($ 139 750 = $ 5.70/m2)	vs	(R 700 000 = R28.57/m2) = -37.5% ($ 87 500 = $ 3.57/m2) = - 37.5%

D 348 Mount Elias – Before upgrading.



D 348 Mount Elias – After upgrading

10. COST COMPRISONS FOR DIFFERENT ROAD TYPES

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

NB: 1) Maintenance costs are assumed to be the same over the life of the road, and are currently set at the budget figure of R 3 000 per km per year.

2) Cost escalation over the years is assumed equal for the different activities, and therefore can be ignored in the comparison table.

Time Scale (Life)	Gravel Cost	Waterproof Gravel	Low Cost Surfaced	Full Standard Surfaced	Quarries Required
Year 0	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	Regravel Q2 75	Reseal CS1 50	Reseal CS1 50	Reseal CS1 50	Yes Q2 or CS1
Year 12	Regravel Q3 75	Reseal CS1 50	Reseal CS1 50	Reseal CS1 50	Yes Q3 or CS1
Year 18	Regravel Q4 75	Reseal CS1 50	Reseal CS1 50	Reseal CS1 50	Yes Q4 or CS1
Year 24	Regravel Q5 75	Reseal CS1 50	Reseal CS1 50	Reseal CS1 50	Yes Q5 or CS1
Initial Life Costs.	**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.

11. 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.) Hence the development of the Waterproof Gravel, and the Low Volume Surfaced Road pavement design concept, together with the various examples successfully constructed in the province, based on the Standard South African TRH 4 (2) Pavement Design Manual, and using the Standard South African TRH 14 (1) Road Building Materials Standards, on roads carrying less than 400 vehicles per day, are now too numerous not to be considered as a viable 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 10 (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 and maintained 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.

    In the examples quoted above, savings of 20% to 37.5% have been achieved by applying innovative initiative techniques, to the TRH 4 (2) catalog pavement designs. In all cases we have provided a cost effective alternative, 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 here in KwaZulu-Natal, South Africa, why can this technology not be applied in the rest of Africa, in accordance with the African Renaissance initiative.

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EXACT COST OF THE OTTA SEAL AT D887. **ANNEXURE A:**

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