



2009 Convention on Rural Roads Arusha, Tanzania

Overview of Gravel Road Performance Studies in the
Western Cape

Presenter:
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Presentation Outline

- Gravel Study
 - Introduction
 - Improvement Procedures
 - Existing Performance Models
 - Monitoring Sections
 - Study Results
 - Impact of Improved Performance
 - Conclusion
- Additives Study
 - Background Information
 - Experimental Design
 - Construction
 - Performance Monitoring
 - Interesting Observations
 - Study Results
 - Economic Analysis
 - Conclusions

Gravel Study: Introduction

- WCPG is dedicated to improve all aspects of gravel road construction and maintenance
- After the improvements was introduced, better performance was noted since 2001
- Performance monitoring since 2003: deterioration models
- Selection criteria for monitoring sections was based on the following: age, climate, material properties and traffic
- Background summary of the improved processes
- Brief summary of the experimental design
- More emphasis on gravel loss than road roughness
- Maintenance strategies and benefits

Western Cape

WESTERN CAPE PROVINCIAL GOVERNMENT

Road Length for Provincial Network

Status Description	Surfaced Roads	Gravel Roads	Total (km)
Trunk Roads	3,019.23	131.24	3,150.47
Main Roads	2,460.07	1,980.62	4,440.69
Divisional Roads	1,094.75	8,142.44	9,237.19
Minor Roads*	233.86	9,988.68	10,222.54
*Minor Roads incomplete (±5,500km)	6,807.91	20,242.98	27,050.89

Improvement Procedures

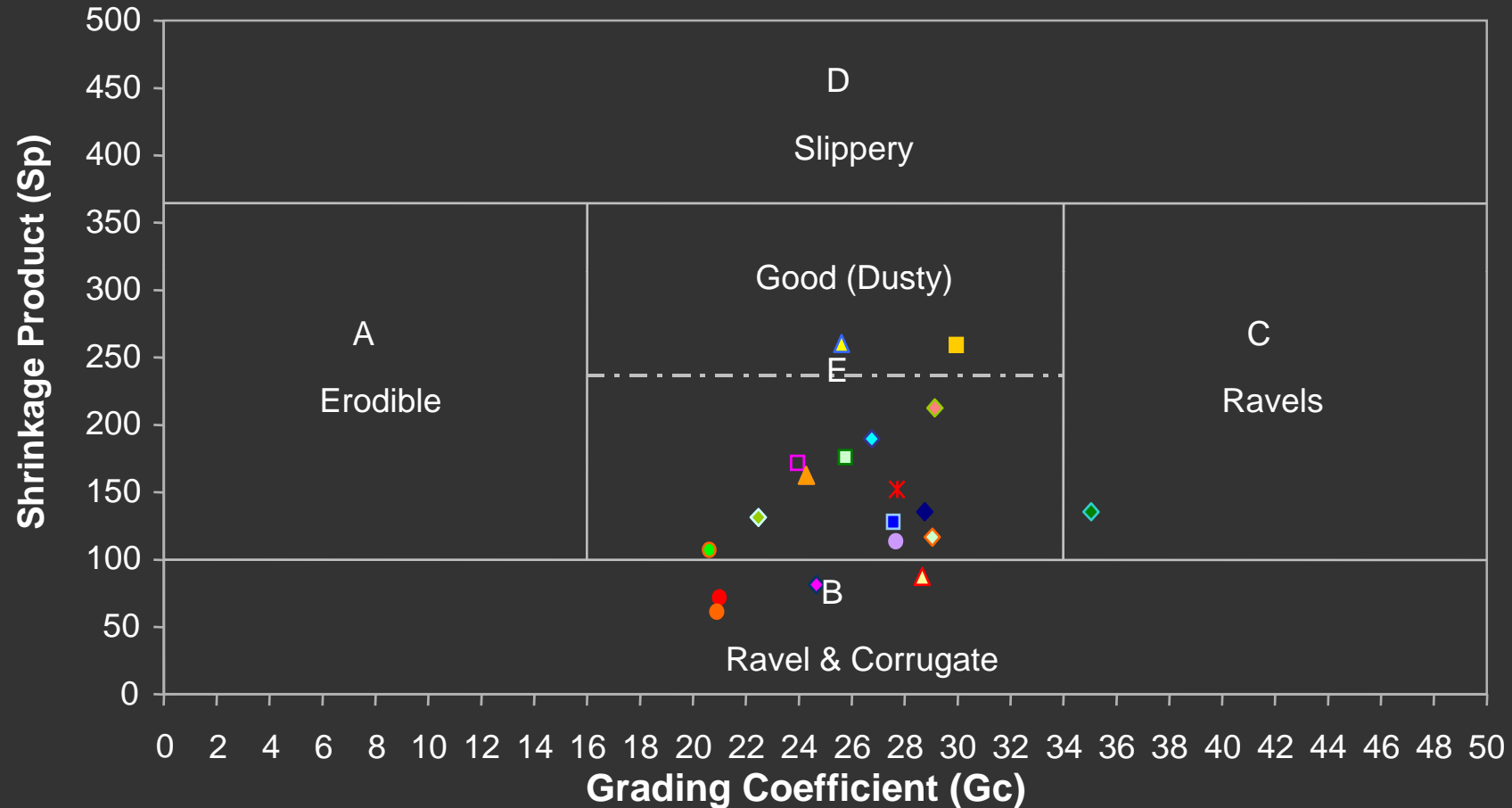
- Assistance: Appointed 5 Consultants for 5 different regions
- Management
 - Upgrading of Gravel Road Management System
 - Developed a Gravel Management System
 - Keeping track of productivity and cost
- Road and Material Design
 - Borrow pit Investigation
 - Formal Design and Approval
- Construction
 - Training of Staff
 - Proper Quality Control
 - Implementation of Trial Sections
 - Processes and Equipment

Existing Performance Models

- Two aspects of performance modelling:-
 - Gravel Loss
 - Road Roughness
- International models used for gravel loss:-
 - ‘draft’ Technical Recommendations for Highways Manual 20 (TRH20)
 - World Bank Highway Development and Management (HDM4)
 - Australian Road Research Board (ARRB) model
 - Brazil model
 - Kenya model
- International models used for roughness:-
 - ‘draft’ TRH20
 - HDM4
- Both HDM4 and TRH20 models currently used in South Africa

Monitoring Sections: Material Classification

TRH20 Parameters



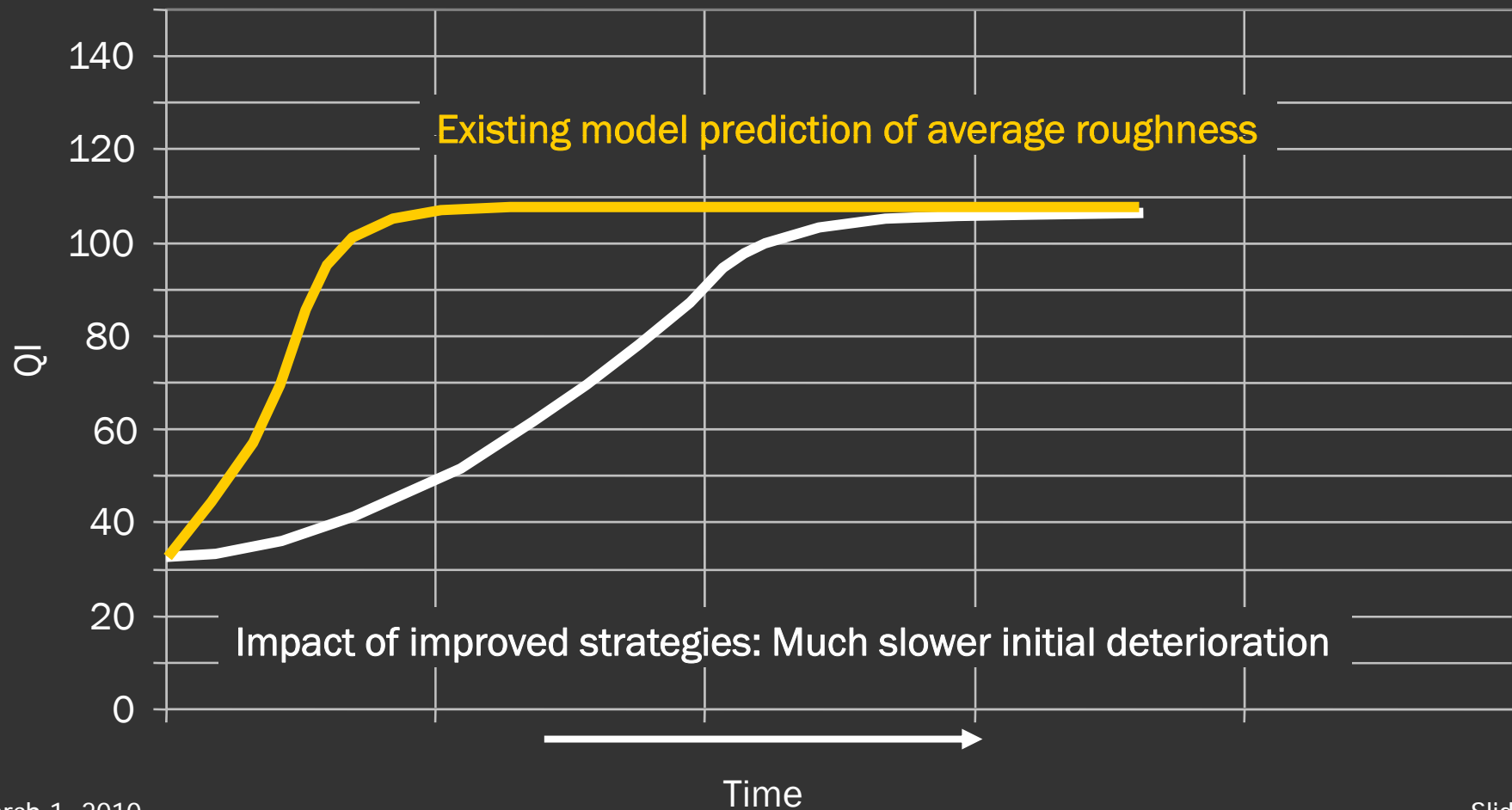
Shrinkage Product (Sp) = Linear Shrinkage x % passing 0,425 mm sieve

Grading Coefficient (Gc)

= ([% passing 26,5 mm – % passing 2,0 mm] x % passing 4,75 mm) / 100

Study Results

- Much slower initial rate of deterioration than predicted by existing deterioration models



Study Results

Comparison of Actual vs Predicted Gravel Loss (AADT<150)

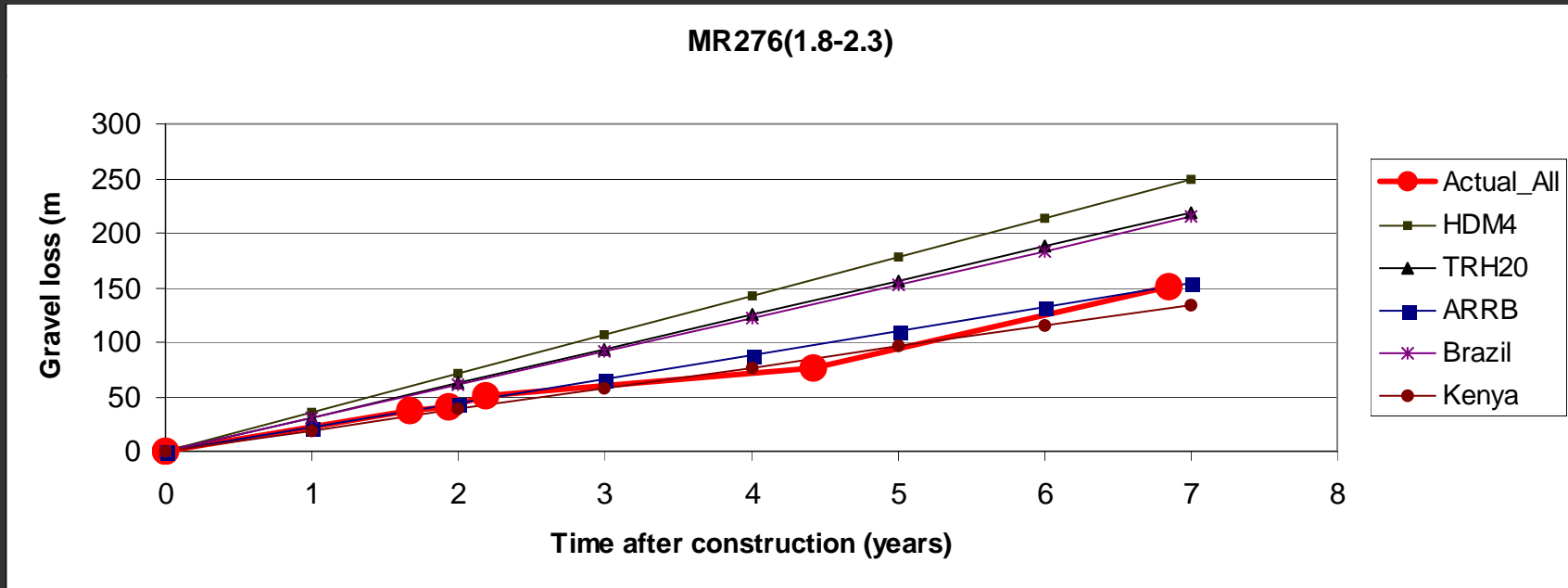
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Study Results

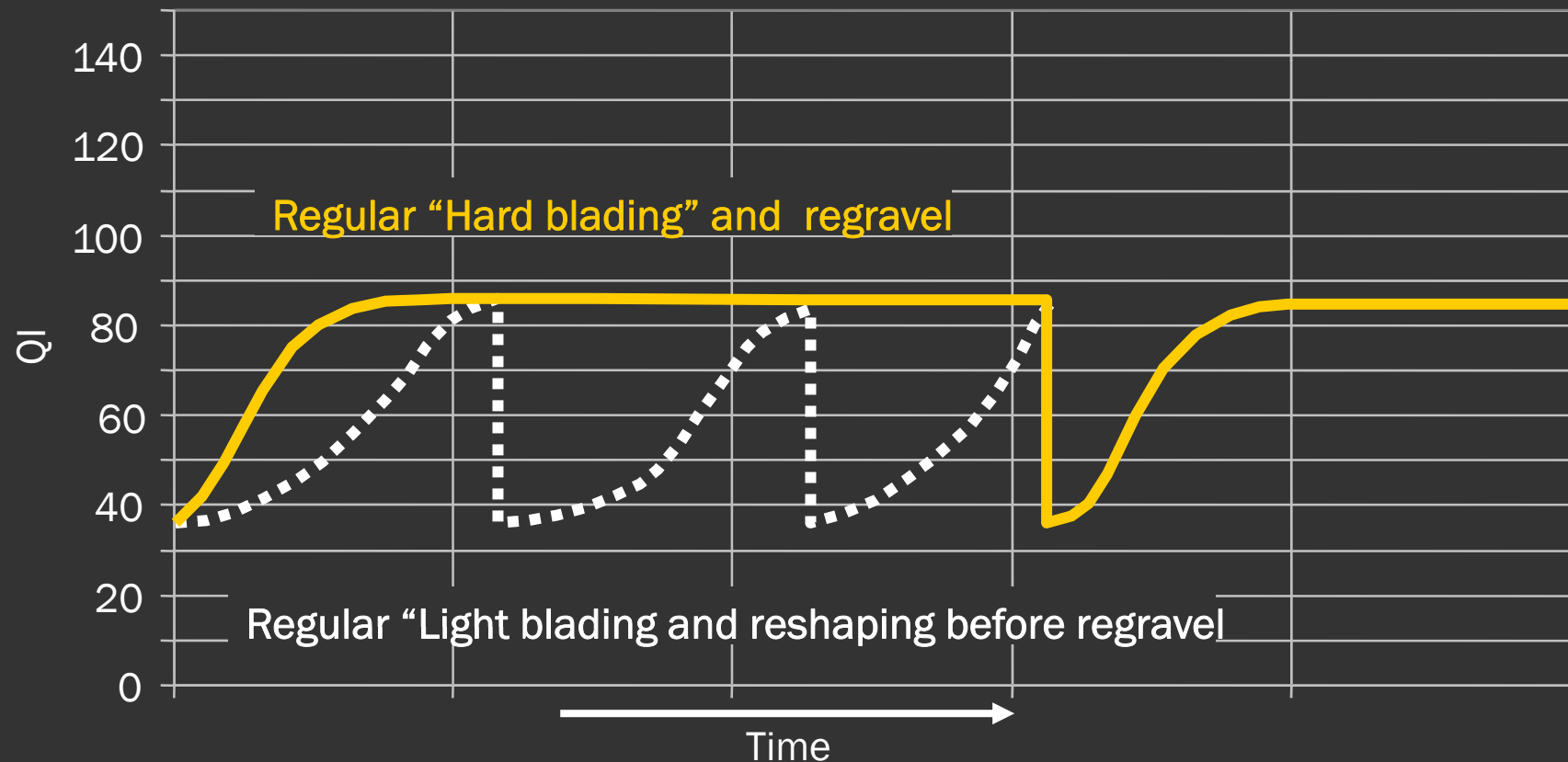
Comparison of Actual vs Predicted Gravel Loss (AADT=350)

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Impact of Improved Performance

- Huge savings in Road user cost
- Potential savings in Road Agency maintenance cost
- Surfacing only warranted at much higher traffic levels
- Huge saving in available material resources

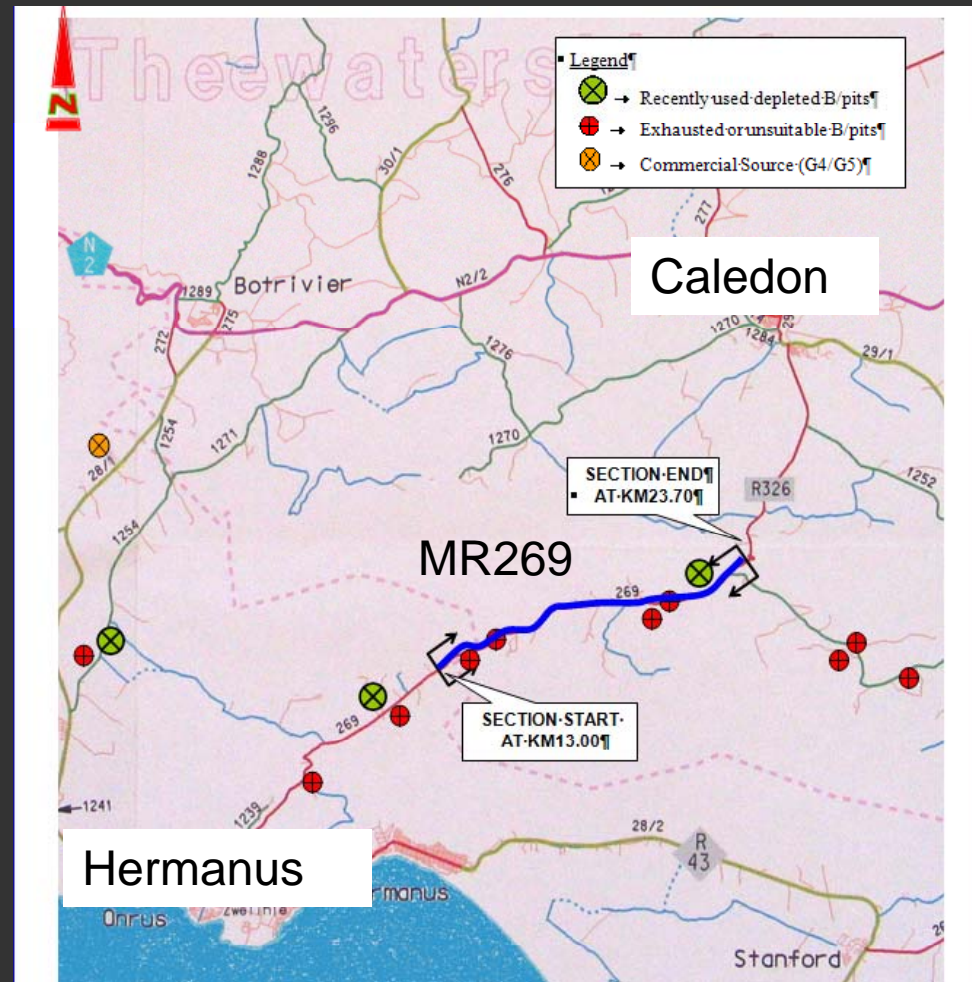


Conclusions

- Rate of deterioration for both roughness and gravel loss slower than predicted, especially on higher traffic volume roads, high percentage of heavy vehicles and non-favourable environmental conditions
- Attributed to improved construction, better material selection and more stringent quality control
- Result of the study could lead to changes to future maintenance strategies (periodic and routine maintenance strategies)
- Consider adjustment to current deterioration models

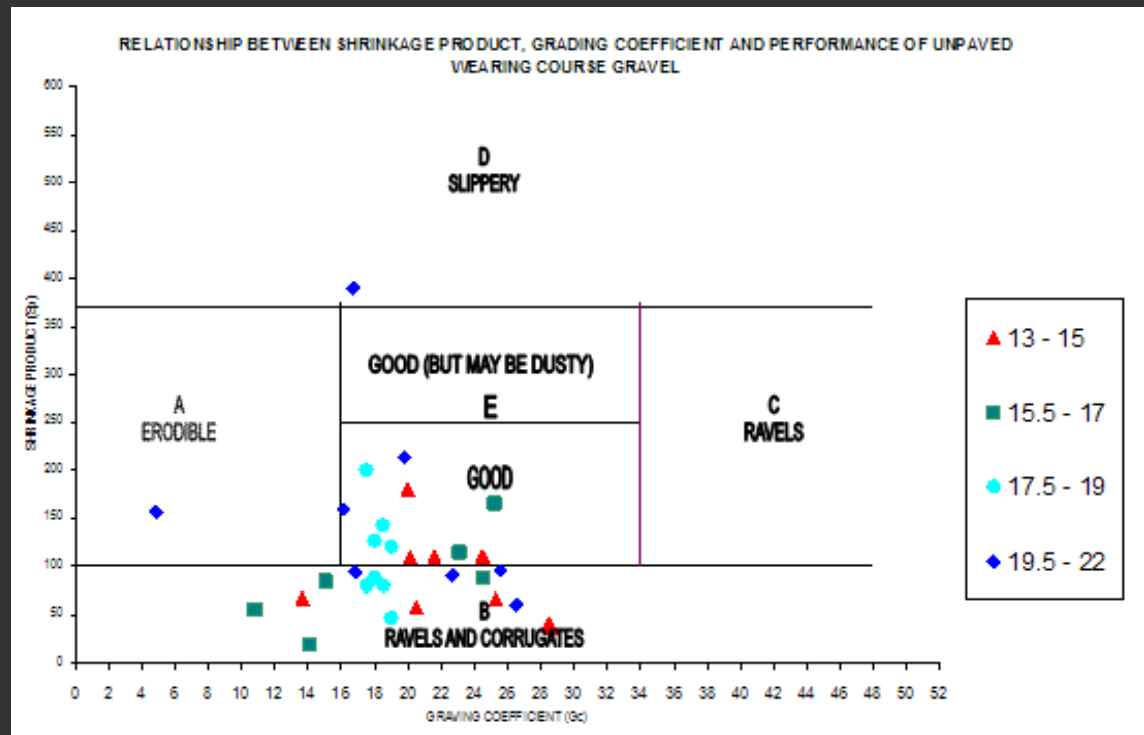
Additive Study: Background Information

- To be upgraded in 3 years
- Traffic volume: 2001 (355 AADT, 45 heavies)
- Limited budget (less than R1,5 million)
- Ideal opportunity to investigate different additives as a holding action



Background Information

- Situation
 - Rolling to mountainous
 - Annual rainfall: 450 – 500 mm (Weinert N : 2)
 - Traffic volumes: 2005; Light: 454; Heavies: 53
 - Geology: sandstone, mudstone, shale
 - Material properties:
 - GM: 1.3 – 2.1
 - PI: 3 – 6
 - LS: 2 - 4



Experimental Design

- Control section
- Unsealed sections with additives
 - Enzymes
 - Natural polymer (Lignosulphonates)
 - Bitumen Emulsion
 - Synthetic polymer
 - Combination of polymer and bituminous binder
 - Traditional stabilizer (cement)
- Sealed sections
 - Cement stabilized
 - Combination of polymer and bituminous binder
 - Electro-chemical (ionic)

Experimental Design

- Variations on unsealed sections
 - Enzymes (2 types; 2 application rates)
 - Natural polymer (2 application rates, combined with emulsion)
 - Bitumen Emulsion
 - Synthetic polymer (2 application rates)
 - Combination of polymer and bituminous binder (2 application rates)
 - Traditional stabilizer (cement)

Construction

- Same construction process
- 125 mm rip, mix-in and compact
- Basic equipment (app R40,000/km)
 - Motor grader
 - Water bowser
 - Vibratory roller
 - LDV
 - 2 operators, 2 flagmen

Ease of Construction

Product	Construct	Add Cost
Control section	Easy	Slight
Enzyme	Easy	None
Natural Polymer	Moderate	Slight
Synthetic Polymer	Moderate	Slight
Synthetic Polymer/Bit Bind	Difficult	High
Cement	Moderate	Slight

Performance Monitoring

- Gravel loss (initial, 3 monthly intervals)
- Road roughness (2 – 5 times)
- Visual assessment (2 – 5 times)
- DCP (initial, 3 months)

- Additional Testing
 - Sieve Analysis
 - Atterburg Limits
 - OMC/MDD
 - CBR/UCS
 - Abrasion/Erosion Resistance

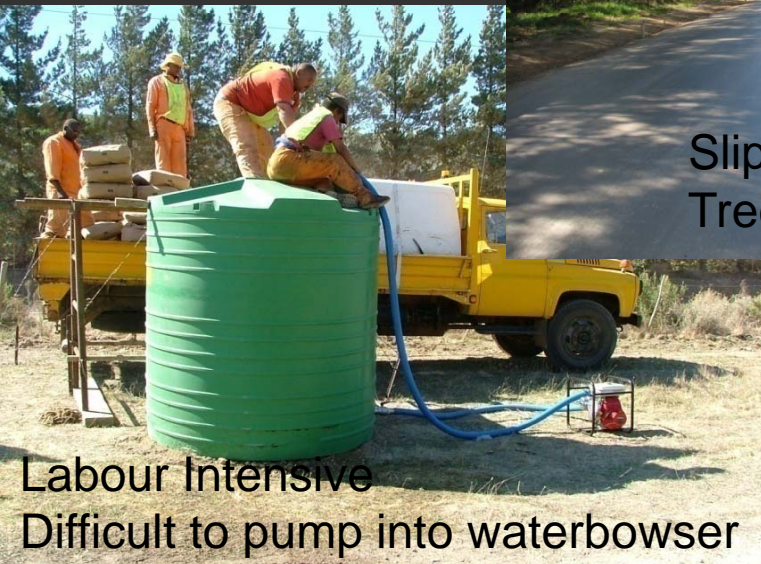
Interesting Observations



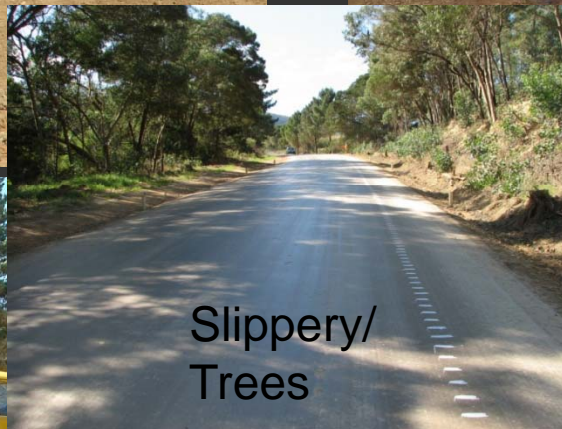
Difficult to Control
Mixing/Application



Messy
Environmental Impact



Labour Intensive
Difficult to pump into waterbowser



Slippery/
Trees



False Sense of
Safety : Speeding

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Interesting Observations



Effective initial
dust control
(Enzyme)



Transverse Erosion
(Synthetic Polymer)



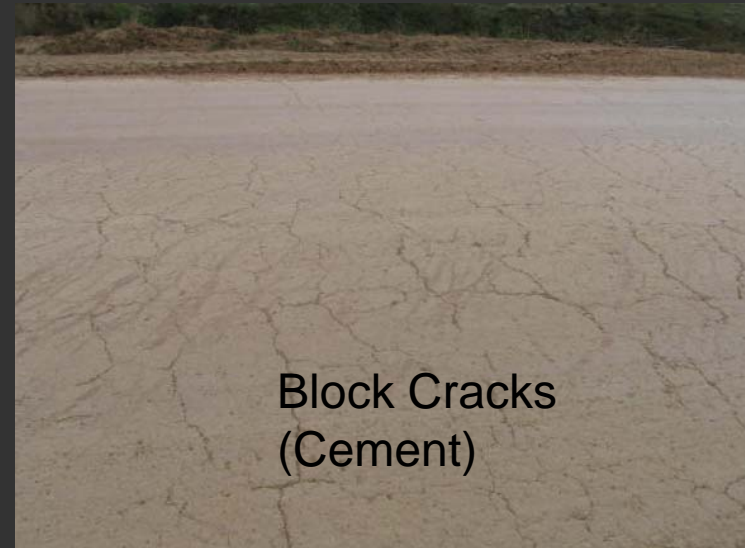
Pothole Development
(Natural Polymer)



Potholes
(Natural Polymer)

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Interesting Observations



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Interesting Observations

- Maintainability ???



March 1, 2010

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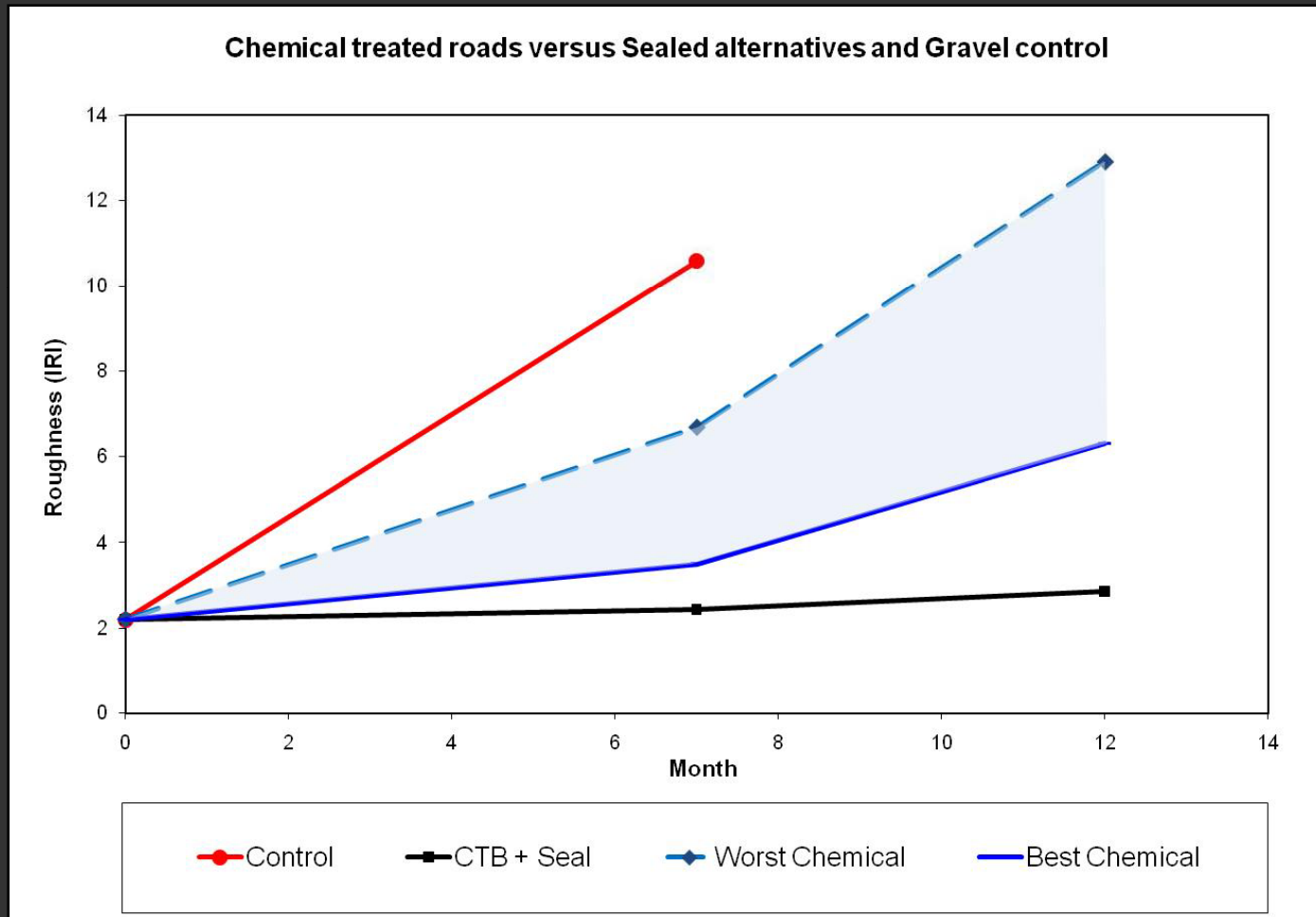
Study Results

MR269 : RESULTS MATRIX

CBR @ 95%
Untreated/Treated

Sect	Action	Laboratory Monitoring																Performance Monitoring										Financial Monitoring								
		From (k)	To (km)	GM	PI	OMC	MDD	CBR (95%)		UCS	Abrasion Resistance		Erosion Resistance		Moisture Sensitivity		Depth (mm)	Compaction	DCP (start)	DCP (3 months)	Gravel Loss (annual)	HDM-4 (annual)	TRH20 (annual)	ARRB (annual)	Brazil (annual)	Kenya (annual)	Period	Riding Quality (start)	Riding Quality (end)	Period	VCI start	VCI end	Period	Construction	Rejuvenation	Life Cycle
		Untreated	Treated	Treated	Untreated	Treated	Untreated	Treated	Untreated	Treated	Untreated	Treated	Untreated	Treated	Untreated	Treated	Untreated	Treated	Untreated	Treated	Untreated	Treated	Untreated	Treated	Untreated	Treated	Untreated	Treated	Untreated	Treated	Untreated	Treated	Untreated	Treated	Untreated	Treated
1	Rip and Recompact	13.1	13.2	1.7	4.2	8.1	2086	18	-	-	-	-	-	-	-	125	-	X	X	45	43	22	35	36	31	1.16	2	13.28	0.88	63.2	64.0	1.16	X	X		
2	Rip and Recompact	13.6	13.7	1.4	4.6	9.7	2039	13	-	-	-	-	-	-	-	125	-	X	X	28	44	21	36	39	14	1.16	2	13.28	0.88	65.6	52.3	1.14	X	X		
3	Cement and Seal	14.7	15.3	1.6	5.0	7.8	2049	23	53	0.80	-	-	-	-	-	125	98.6	-	-	-	-	-	-	-	-	2	2.9	14.7	0.87	85.0	80.0	2.08	X	X		
4	Stabilize: Cement	15.35	15.45	1.7	5.2	7.7	2121	25	84	1.00	-	-	-	-	-	125	100.8	X	X	28	41	23	29	31	19	0.81	2	14.23	0.91	93.0	63.1	0.83	X	X	X	
5	Stabilize: Cement	15.55	15.65	1.6	5.2	8.7	2035	7	55	1.02	-	-	-	-	-	125	100.3	X	X	25	46	21	48	45	16	0.82	2	14.23	0.91	93.0	62.4	0.83	X	X	X	
6	Additive: Polymer	15.775	15.875	1.5	4.4	7.9	2075	5	6	0.73	-	-	-	-	-	125	98.8	X	X	24	45	20	36	39	13	0.82	2	12.91	0.91	93.0	72.9	0.83	X	X	X	
7	Additive: Polymer	16	16.1	1.5	4.4	7.9	2075	5	6	0.73	-	-	-	-	-	125	98.8	X	X	22	45	20	38	41	9	0.81	2	12.91	0.90	93.0	61.9	0.83	X	X	X	
8	Additive: Polymer	16.3	16.4	1.4	5.6	10.6	2044	6	15	0.74	-	-	-	-	-	125	99.5	X	X	50	46	19	36	41	10	0.84	2	8.76	0.96	83.6	48.1	0.91	X	X	X	
9	Additive: Polymer	16.45	16.55	1.4	5.6	10.6	2044	6	15	0.74	-	-	-	-	-	125	99.5	X	X	46	46	19	36	41	9	0.84	2	8.76	0.96	83.6	66.5	0.83	X	X	X	
10	Additive: Lignosulphonate	17.05	17.15	1.5	4.5	9.1	2057	4	5	0.71	-	-	-	-	-	125	98.9	X	X	17	45	18	34	40	22	0.85	2	8.4	0.96	93.0	58.9	0.91	X	X	X	
11	Additive: Lignosulphonate	17.4	17.5	1.2	4.6	10.4	2029	3	4	0.70	-	-	-	-	-	125	100.8	X	X	43	48	18	41	45	11	0.86	2	8.4	0.96	61.5	66.7	0.91	X	X	X	
12	Additive: Lignosulphonate	17.9	18	1.5	4.8	8.8	2141	3	3	0.64	-	-	-	-	-	125	101.5	X	X	14	44	20	26	35	21	0.86	2	9	0.99	93.0	46.5	0.91	X	X	X	
13	Additive: Lignosulphonate	18.4	18.5	1.3	5.5	9.3	2112	3	4	0.72	-	-	-	-	-	125	99.6	X	X	17	45	19	29	37	6	0.86	2	8	0.99	87.9	64.5	0.91	X	X	X	
14	Additive: Enzyme	19.55	19.65	1.5	8.0	8.7	2086	7	4	1.06	X	X	X	X	X	125	101.8	X	X	22	43	19	36	36	9	0.94	2	11.8	0.68	85.0	51.2	0.69	X	X	X	
15	Additive: Enzyme	20.4	20.5	1.6	5.4	9.2	2095	20	28	1.06	X	X	X	X	X	125	101.3	X	X	55	45	20	48	44	4	0.71	2	11.8	0.68	85.0	60.9	0.69	X	X	X	
16	Additive: Enzyme	21.4	21.5	1.7	5.4	9.2	2118	11	11	1.06	X	X	X	X	X	125	99.9	X	X	44	42	22	36	36	15	0.65	2	11.6	0.30	87.9	60.6	0.54	X	X	X	
17	Additive: Enzyme	23.35	23.7	1.7	5.4	9.2	2118	11	11	1.06	X	X	X	X	X	125	99.9	X	X	44	42	22	36	36	15	0.65	2	11.6	0.30	87.9	60.6	0.55	X	X	X	
18	Additive: Enzyme	23.35	23.7	1.7	5.4	9.2	2118	11	11	1.06	X	X	X	X	X	125	99.9	X	X	44	42	22	36	36	15	0.65	2	11.6	0.30	87.9	60.6	0.55	X	X	X	
19	Additive: Enzyme	23.35	23.7	1.7	5.4	9.2	2118	11	11	1.06	X	X	X	X	X	125	99.9	X	X	44	42	22	36	36	15	0.65	2	11.6	0.30	87.9	60.6	0.55	X	X	X	
20	Additive: Enzyme	23.35	23.7	1.7	5.4	9.2	2118	11	11	1.06	X	X	X	X	X	125	99.9	X	X	44	42	22	36	36	15	0.65	2	11.6	0.30	87.9	60.6	0.55	X	X	X	
21	Additive: Enzyme	23.35	23.7	1.7	5.4	9.2	2118	11	11	1.06	X	X	X	X	X	125	99.9	X	X	44	42	22	36	36	15	0.65	2	11.6	0.30	87.9	60.6	0.55	X	X	X	
22	Additive: Enzyme	23.35	23.7	1.7	5.4	9.2	2118	11	11	1.06	X	X	X	X	X	125	99.9	X	X	44	42	22	36	36	15	0.65	2	11.6	0.30	87.9	60.6	0.55	X	X	X	
23	Additive: Enzyme	23.35	23.7	1.7	5.4	9.2	2118	11	11	1.06	X	X	X	X	X	125	99.9	X	X	44	42	22	36	36	15	0.65	2	11.6	0.30	87.9	60.6	0.55	X	X	X	
24	Additive: Enzyme	23.35	23.7	1.7	5.4	9.2	2118	11	11	1.06	X	X	X	X	X	125	99.9	X	X	44	42	22	36	36	15	0.65	2	11.6	0.30	87.9	60.6	0.55	X	X	X	
25	Additive: Enzyme	23.35	23.7	1.7	5.4	9.2	2118	11	11	1.06	X	X	X	X	X	125	99.9	X	X	44	42	22	36	36	15	0.65	2	11.6	0.30	87.9	60.6	0.55	X	X	X	
26	Additive: Enzyme	23.35	23.7	1.7	5.4	9.2	2118	11	11	1.06	X	X	X	X	X	125	99.9	X	X	44	42	22	36	36	15	0.65	2	11.6	0.30	87.9	60.6	0.55	X	X	X	
27	Additive: Enzyme	23.35	23.7	1.7	5.4	9.2	2118	11	11	1.06	X	X	X	X	X	125	99.9	X	X	44	42	22	36	36	15	0.65	2	11.6	0.30	87.9	60.6	0.55	X	X	X	
28	Additive: Enzyme	23.35	23.7	1.7	5.4	9.2	2118	11	11	1.06	X	X	X	X	X	125	99.9	X	X	44	42	22	36	36	15	0.65	2	11.6	0.30	87.9	60.6	0.55	X	X	X	
29	Additive: Enzyme	23.35	23.7	1.7	5.4	9.2	2118	11	11	1.06	X	X	X	X	X	125	99.9	X	X	44	42	22	36	36	15	0.65	2	11.6	0.30	87.9	60.6	0.55	X	X	X	
30	Additive: Enzyme	23.35	23.7	1.7	5.4	9.2	2118	11	11	1.06	X	X	X	X	X	125	99.9	X	X	44	42	22	36	36	15	0.65	2	11.6	0.30	87.9	60.6	0.55	X	X	X	
31	Additive: Enzyme	23.35	23.7	1.7	5.4	9.2	2118	11	11	1.06	X	X	X	X	X	125	99.9	X	X	44	42	22	36	36	15	0.65	2	11.6	0.30	87.9	60.6	0.55	X	X	X	
32	Additive: Enzyme	23.35	23.7	1.7	5.4	9.2	2118	11	11	1.06	X	X	X	X	X	125	99.9	X	X	44	42	22	36	36	15	0.65	2	11.6	0.30	87.9	60.6	0.55	X	X	X	
33	Additive: Enzyme	23.35	23.7	1.7	5.4	9.2	2118	11	11	1.06	X	X	X	X	X	125	99.9	X	X	44	42	22	36	36	15	0.65	2	11.6	0.30	87.9	60.6	0.55	X	X	X	
34	Additive: Enzyme	23.35	23.7	1.7	5.4	9.2	2118	11	11	1.06	X	X	X	X	X	125	99.9	X	X	44	42	22	36	36	15	0.65	2	11.6	0.30	87.9	60.6	0.55	X	X	X	
35	Additive: Enzyme	23.35	23.7	1.7	5.4	9.2	2118	11	11	1.06	X	X	X	X	X	125	99.9	X	X	44	42	22	36	36	15	0.65	2	11.6	0.30	87.9	60.6	0.55	X	X	X	
36	Additive: Enzyme	23.35	23.7	1.7	5.4	9.2	2118	11	11	1.06	X	X	X	X	X	125	99.9	X	X	44	42	22	36	36	15	0.65	2	11.6	0.30	87.9	60.6	0.55	X	X	X	
37	Additive: Enzyme	23.35	23.7	1.7	5.4	9.2	2118	11	11	1.06	X	X	X	X	X	125	99.9	X	X	44	42	22	36	36	15	0.65	2	11.6	0.30	87.9	60.6	0.55	X	X	X	
38	Additive: Enzyme	23.35	23.7	1.7	5.4	9.2	2118	11	11	1.06	X	X	X	X	X	125	99.9	X	X	44	42	22	36	36	15	0.65	2	11.6	0.30	87.9	60.6	0.55	X	X	X	
39	Additive: Enzyme	23.35	23.7	1.7	5.4	9.2	2118	11	11	1.06	X	X	X	X	X	125	99.9	X	X	44	42	22	36	36	15	0.65	2	11.6	0.30	87.9	60.6	0.55	X	X	X	
40	Additive: Enzyme	23.35	23.7	1.7	5.4	9.2	2118	11	11	1.06	X	X	X	X	X	125	99.9	X	X	44	42	22	36	36	15	0.65	2	11.6	0.30	87.9	60.6	0.55	X	X	X	
41	Additive: Enzyme	23.35	23.7	1.7	5.4	9.2	2118	11	11	1.06	X	X	X	X	X	125	99.9	X	X	44	42	22	36	36	15	0.65	2	11.6	0.30	87.9	60.6	0.55	X	X	X	
42	Additive: Enzyme	23.35	23.7	1.7	5.4	9.2	2118	11	11	1.06	X	X	X	X	X	125	99.9	X	X	44	42	22	36	36	15	0.65	2	11.6	0.30	87.9	60.6	0.55	X	X	X	
43	Additive: Enzyme	23.35	23.7	1.7	5.4	9.2	2118	11	11	1.06	X	X	X	X	X	125	99.9	X	X	44	42	22	36	36	15	0.65	2	11.6	0.30	87.9	60.6	0.55	X	X	X	
44	Additive: Enzyme	23.35	23.7	1.7	5.4	9.2	2118	11	11	1.06	X	X	X	X	X	125	99.9	X	X	44	42	22	36	36	15	0.65	2	11.6	0.30	87.9</						

Study Results



Costs

Product	Cost(R)/M2 (2006 rates) (Exchange \$1 = R8)
Enzymes	R6.00 – R9.00
Emulsion	R11.00
Natural Polymer/Emulsion	R17.00
Natural Polymer	R9.00 – R12.00
Synthetic Polymer	R24.00 – R30.00
Polymer/ Bit Binder	R32.00 – R34.00
Cement	R10.00
Control Section (Rip & Recompact)	R7.00
Seal/Cement	R25.00
Seal/Electro-chemical	R22.00
Seal/Polymer/Bit Binder	R37.00

Costs

Section	Action	From (km)	To (km)	Life Cycle (IRI=8)	Light vehicles	Heavy vehicles	Gravel		Paved		VOC (life)	Lyfe Cycle Cost (900 days)	Total Cost
							VOC (L)	VOC (H)	VOC (L)	VOC (H)			
1	Rip and Recompact	13	14.7	0.466	454	53	3.020	11.23			R 1,769,643	R 230,450	R 2,000,093
2	Cement and Seal	14.7	15.3	2.466	454	53			2.686	9.39	R 1,545,403	R 174,925	R 1,720,328
3	Stabilize: Cement	15.3	15.5	0.658	454	53	3.020	11.23			R 1,769,643	R 262,219	R 2,031,862
4	Stabilize: Cement	15.5	15.75	0.658	454	53	3.020	11.23			R 1,769,643	R 262,219	R 2,031,862
5	Additive: Polymer	15.75	16	0.658	454	53	3.020	11.23			R 1,769,643	R 843,108	R 2,612,751
6	Additive: Polymer	16	16.25	0.658	454	53	3.020	11.23			R 1,769,643	R 898,714	R 2,668,357
7	Additive: Polymer	16.25	16.5	0.548	454	53	3.020	11.23			R 1,769,643	R 770,625	R 2,540,268
8	Additive: Polymer	16.5	16.7	0.548	454	53	3.020	11.23			R 1,769,643	R 967,500	R 2,737,143
9	Additive: Lignosulphonate	16.7	17.2	0.932	454	53	3.020	11.23			R 1,769,643	R 174,256	R 1,943,899
10	Additive: Lignosulphonate	17.2	17.7	0.932	454	53	3.020	11.23			R 1,769,643	R 217,059	R 1,986,702
11	Additive: Lignosulphonate	17.7	18.2	0.932	454	53	3.020	11.23			R 1,769,643	R 309,706	R 2,079,349
12	Additive: Lignosulphonate	18.2	18.7	0.986	454	53	3.020	11.23			R 1,769,643	R 187,500	R 1,957,143
13	Additive: Enzyme	18.7	20	0.411	454	53	3.020	11.23			R 1,769,643	R 283,750	R 2,053,393
14	Additive: Enzyme	20	21	0.411	454	53	3.020	11.23			R 1,769,643	R 279,773	R 2,049,416
15	Additive: Enzyme	21	22	0.164	454	53	3.020	11.23			R 1,769,643	R 950,000	R 2,719,643
16	Additive: Enzyme	22	23	0.164	454	53	3.020	11.23			R 1,769,643	R 918,182	R 2,687,825
17	Electrochemical stabilisation and Seal	23	23.35	2.466	454	53			2.856	10.503	R 1,667,955	R 154,625	R 1,822,580
18	Additive: Polymer and Seal	23.35	23.7	2.466	454	53			2.743	9.906	R 1,593,306	R 255,284	R 1,848,590

Conclusions

- Treated materials perform better than untreated sections
- Performance of sealed sections (treated) far superior to unsealed sections
- Additives can improve performance of marginal materials
- Each product may have a place in the market, but:
- Consider the following first:
 - Rejuvenation frequency (life cycle cost)
 - Maintenance strategy (ease of blading)
 - Ease of construction
 - Traffic volumes
 - Material properties
 - Environmental properties

Thank You



PS: Remember less than 200 days
to the 2010 FIFA world cup



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