Unsealed and Sealed Low Volume Road Technology in South Africa

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Introduction

• South Africa still has many kilometers of unsealed road (>75% of proclaimed road network)
• Many of these are “low volume”
• Their condition and passability have significant impact on local economic development
• Earth and gravel roads are environmentally unsustainable
• Cost of traditional paved roads makes upgrading uneconomic
• Need to be more innovative
Scope

• Summarise recent developments

• Unsealed roads
  • Specification
  • Performance modelling
  • Implementation

• Sealed low volume roads
  • Effect of environment
  • Specification and design
  • Warrants for upgrading
  • Construction issues

• Seals covered in next presentation
Unsealed roads

• Mostly start as earth roads
• Imported selected gravel is first improvement
• Must comply with certain requirements
  • Have sufficient cohesion to resist raveling and erosion;
  • Have a particle size distribution that facilitates a tight interlock of the individual material particles, and
  • Have sufficient strength to support the applied traffic loads without significant plastic deformation
• Deficiencies result in
  • Increased maintenance costs
  • Poorer functionality
  • Higher road user costs
• During the 1980s and 1990’s, we developed performance-related specifications
## Specifications

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum size (mm)</td>
<td>37,5</td>
</tr>
<tr>
<td>Oversize index ($I_0$)</td>
<td>&lt; 5 %</td>
</tr>
<tr>
<td>Shrinkage product (Sp)</td>
<td>100 - 365</td>
</tr>
<tr>
<td>Grading coefficient (Gc)</td>
<td>16 - 34</td>
</tr>
<tr>
<td>CBR (at 95 % AASHTO T180)</td>
<td>&gt; 15 %</td>
</tr>
<tr>
<td>Treton impact value (%)</td>
<td>20 – 65</td>
</tr>
</tbody>
</table>
Grading Coefficient

Shrinkage Product

A  Erodible
B  Corrugates and ravels
C  Ravels
D  Slippery
E  Good
MODELLING AND PREDICTION

Deterioration models have been developed for South Africa:

Gravel Loss = f (time, traffic, materials, climate)

Rate of Roughness progression = f (time, traffic, materials, climate and season)

Roughness after blading = f (traffic, materials and roughness before blading)
PLOTS OF ACTUAL (A) AND PREDICTED (*) GRAVEL LOSS
MEASURED AND PREDICTED ROUGHNESS
Change in roughness between maintenance:
- grid-rolled section
- rock-busted section

Average roughness over 1.5 years:
- grid-rolled section
- rock-busted section
Unsealed road materials

- Specs implemented slowly
- Generally successful
- Performance greatly improved
- Good material selection and construction
Slow Roughness Deterioration
(No Maintenance section)

MR270: km32 - 32.5: Roughness Deterioration (Model vs. Actual)

Riding Quality (QI)

Years since construction

AADT = 66, 17% heavy
Other important issues

- Proper compaction
  - Wet
  - Refusal
- Quality control
  - More not less
- Material loss
  - Dust
  - Erosion
- Proprietary stabilizers
- Sustainability
Sealed low volume roads

- Irrespective of material and maintenance quality, unsealed roads are not sustainable
- We can’t keep replacing material indefinitely
- Many local (even in situ) materials are suitable as structural layers in paved roads
- Require a protective seal
- Usually bituminous – could be concrete or blocks
Environment

- Various research projects in SA carried out recently
- Performance dictated by environment more than traffic
  - Moisture regimes
  - Material moisture susceptibility
  - Drainage conditions
Pavement structure for sealed roads

- Gravel wearing course material is seldom suitable for road base.
- Look at in situ materials - may be suitable for base (not wearing course).
- Traffic moulding must not be underestimated.
- Minimise disturbance of existing road structure.
South African experience

- Investigated and monitored 57 light pavement structures between 1989 and 1994
- Material properties, environment, traffic, performance
- Typical example
Example

Road in the Eastern Cape sealed in 1977 and had the following base properties (in 1991)

PI = 9 – 10
P075 = 14 – 16
CBR @ 100%Mod = 56 – 67
300 vpd (6 ESALs / d)

Now (2006) 29 years old – 3.2 m light and 60 000 ESALs
Dynamic Cone Penetrometer (DCP) profiles

IWT (DSN 800 = 85)
General Findings from Investigation

- Existing specification requirements far too strict
- Especially CBR and PI
Design using in situ strength

- Determined using DCP \(^7\) “CBR”
- Must consider in situ density and moisture content
- Also, moisture content seasonally variable
- Compare with pavement design diagram (in situ)
Understand the materials

- Need to understand moisture/density/strength relationships
- Results obtained from MDD/OMC testing
Structural adequacy

- We typically use linear elastic theory in mechanistic analyses
- In practice non linear ($y = (mx + a)(1 - e^{-bx})$)
- Rutting functional more than structural problem on LVR
- Cumulative deformation – not forever?
- Contact stresses of 300 kPa more common on LVR than normal 700 - 1000 kPa used in design
HVS testing

- “Superlight” pavement (150 mm weathered granite or ferricrete on in situ) with bituminous/tar surface spray
- Various layers of old wearing course
- 9 test sections
  - Dual wheel load 20 – 70 kN
  - Tire inflation pressure 420 – 720 kPa
  - Moisture (4.5 to 1.0 % below OMC)
  - Repetitions 2000 – 800 000
  - Wandering and channelized trafficking
Relatively Dry Test Conditions, Except at the end of Sections 2 and 4.
WET

Load change

Relatively Wet Test Conditions

PERMANENT SURFACE DETERIORATION [mm]

LOAD APPLICATIONS [millions] AT LOADING CONDITIONS INDICATED IN TABLE 3

Section 5  Section 8  Section 9
HVS testing

- Fitting of non-linear model produced $r^2$ of 0.8 to 0.99
- However, water was critical
Priming

- Very important
- Use a low viscosity prime
- Penetration increases strength of upper portion
Drainage

• Critical
• Unsealed shoulders
  • Good shape
  • Regular maintenance
• Sealed shoulders
  • Optimum
  • Beware “attracted” traffic
• Side drains
  • 450 mm below crown
  • Good mitre drains
  • NB Maintenance
Economic analysis

• Useful to confirm viability of upgrade
• Full life cycle cost analyses
• Financial
  • Construction
  • Maintenance
• Economic
  • Vehicle operating costs
  • Time
  • Safety
  • Environmental
  • Social
  • Sustainability
• Environmental, social and sustainability costs/benefits difficult to quantify
  • Breakeven
Conclusions

• We have made significant recent advances in unsealed road design and construction
• Unsealed roads are not sustainable in the long term
• We have to make their upgrading to low volume sealed roads more affordable
• Many innovations are available for this
• However, these roads probably need more engineering input (experience and judgment) than for a “recipe” design
• Attempted to provide some “food for thought” based on recent experiences in southern Africa
THANK YOU