Mozambique RRIP/AFCAP Back Analysis Research Project (TRL/ANE)

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This presentation comprises...

1. Characteristics of Mozambique – the challenge
2. The study
3. Methodology
4. Overall performance of test sections
5. Performance of surfacings and binder quality tests
6. Observations – anomalies
7. Conclusions
8. Recommendations
Key characteristics of Mozambique

1. Mozambique is a very large country < 10% of low volume roads are sealed.
2. Costs: Cost of construction and maintenance is very high.
3. Materials: Good materials are very scarce, vast areas covered in fine coastal sands.
4. Rainfall: very low to high rainfall (with more frequent tropical storms and cyclones).
5. Temperatures: generally very high – up to 45°C in some places.
6. Terrain: generally very flat – makes drainage design difficult.
The study

Analysing the performance of some existing sealed roads known to have been constructed using materials which don not meet current specifications.

Selection of road sections: 8 roads, 22 test sections

a) Traffic (ADT= 55 – 1000 vpd).
b) Materials (cement stabilised and unstabilised laterites, emulsion treated sands, gravel, basalts, decomposed granite, rhyolite).
c) Condition (good, fair, poor, very poor).
d) Type of surfacing (surface dressing, sand seals, Otta seals, hot sand asphalt).
Field investigations
Overall performance of the sections

Overall performance - measured from an overall index of deterioration - a combination of the Rut Depth, Cracking, Potholing and Patching:

\[ DI = RdI + CrI + PPI \]

Where

\( DI \) = deterioration index
\( RdI \) = average rut depth in mm
\( CrI \) = cracking intensity x extent
\( PPI \) = Pothole/patching area (m) x extent
Overall Performance of the Sections

- DI $\leq 40$ is indicative of a surfacing in good condition.
- DI $> 40$ not satisfactory.
- 6 sections out of 22 were considered unsatisfactory, but 2 were only marginally so.
- Low values of rut depth indicate very little if any structural failures.
- Cracking, potholes (and their patching) were the main reasons for deterioration.
Deterioration Index

- Boane Libomboks (BELS)
- Pambara Rio Save (PARE)
- Rio Zambezi Nicoadala (RINA)
- Nametil Angoche
- Oasse Mocimboa (OEMA)
- Lichinga Mandimba
- Metangula Maniamba (MAMA)
- Maniamba Lichinga (MALA)

Deterioration index (DI)
Performance variances

Performance variance for all sites (40-DI)

<table>
<thead>
<tr>
<th>Site</th>
<th>Performance Variance (40-DI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boane Libombos</td>
<td>4+700 - 5+100</td>
</tr>
<tr>
<td>Pambara Rio Save</td>
<td>5+300 - 5+700</td>
</tr>
<tr>
<td>Rio Zambezi</td>
<td>8+000 - 8+400</td>
</tr>
<tr>
<td>Nicoadala</td>
<td>8+400 - 8+700</td>
</tr>
<tr>
<td>Nameitil Angoche</td>
<td>8+700 - 9+000</td>
</tr>
<tr>
<td>Oasse Mocimba</td>
<td>9+050 - 9+350</td>
</tr>
<tr>
<td>da Praia</td>
<td>22+600 - 22+900</td>
</tr>
<tr>
<td>Lichinga Mandimba</td>
<td>140+700 - 141+000</td>
</tr>
<tr>
<td>Metangala Maniamba</td>
<td>141+050 - 141+350</td>
</tr>
<tr>
<td>Maniamba</td>
<td>141+350 - 142+000</td>
</tr>
<tr>
<td>Lichinga</td>
<td>22+600 - 22+900</td>
</tr>
<tr>
<td>Boane Libombos</td>
<td>140+700 - 141+000</td>
</tr>
<tr>
<td>Pambara Rio Save</td>
<td>141+050 - 141+350</td>
</tr>
<tr>
<td>Rio Zambezi</td>
<td>141+350 - 142+000</td>
</tr>
<tr>
<td>Nicoadala</td>
<td>142+000 - 142+750</td>
</tr>
<tr>
<td>Nameitil Angoche</td>
<td>14+900 - 15+100</td>
</tr>
<tr>
<td>Oasse Mocimba</td>
<td>27+100 - 27+400</td>
</tr>
<tr>
<td>da Praia</td>
<td>27+400 - 27+500</td>
</tr>
<tr>
<td>Lichinga Mandimba</td>
<td>0+000 - 0+300</td>
</tr>
<tr>
<td>Metangala Maniamba</td>
<td>0+150 - 0+450</td>
</tr>
<tr>
<td>Maniamba</td>
<td>0+800 - 2+100</td>
</tr>
<tr>
<td>Lichinga</td>
<td>2+800 - 3+100</td>
</tr>
<tr>
<td>Boane Libombos</td>
<td>32+600 - 32+900</td>
</tr>
</tbody>
</table>

Note: The graph shows the performance variance for different sites with specific ranges.
<table>
<thead>
<tr>
<th>ROAD NAME</th>
<th>Age of Road</th>
<th>Age of Surface</th>
<th>Daily Traffic</th>
<th>Cumulative mesas on surfacing</th>
<th>Cumulative mesas on pavement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boane-Libombos</td>
<td>13</td>
<td>13</td>
<td>315 171</td>
<td>1.7</td>
<td>1.7</td>
</tr>
<tr>
<td>Pambarra-Rio Save</td>
<td>30</td>
<td>4</td>
<td>450 222</td>
<td>1.0</td>
<td>~ 3</td>
</tr>
<tr>
<td>Oasse-Mocimboa da Praia</td>
<td>13</td>
<td>13</td>
<td>709 284</td>
<td>2.7</td>
<td>2.7</td>
</tr>
<tr>
<td>Metangula-Maniamba</td>
<td>5</td>
<td>5</td>
<td>108 58</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>Maniamba-Lichinga</td>
<td>41</td>
<td>4</td>
<td>108 58</td>
<td>0.2</td>
<td>~ 0.7</td>
</tr>
<tr>
<td>Lichinga-Mandimba</td>
<td>8</td>
<td>8</td>
<td>191 100</td>
<td>0.6</td>
<td>0.6</td>
</tr>
<tr>
<td>Nametil-Angoche</td>
<td>5</td>
<td>5</td>
<td>125 105</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>Rio Zambezi-Nicoadala</td>
<td>30</td>
<td>4</td>
<td>445 419</td>
<td>1.3</td>
<td>~ 4.5</td>
</tr>
</tbody>
</table>
Analysis – key issues

1. Performance of a road depends on a large number of parameters including:
   a) Properties of surfacing, roadbase, sub-base, subgrade
   b) Traffic factors
   c) Drainage
   d) Environmental factors
   e) Quality of construction

2. For roadbase: Grading, PI, Soaked CBR, in situ CBR, field moisture content (FMC), OMC.

3. There are also important interactions e.g. PI might only be important if the amount of fines is high hence the Plasticity Modulus (PM) rather than PI alone might be critical.

4. Surfacing: Quality and ageing of bitumen
In situ Roadbase CBR

Deterioration Index

In situ CBR

Normal minimum
Road base - in-situ strengths

1. 40% of the road bases had in-situ CBR > 90%.
2. 20% of the road bases had in-situ CBR < 55%.
3. 10% of road bases had in-situ CBR < 40%.

No structural failures were noted.
Soaked Roadbase CBR

Soaked CBR

Deterioration Index

Normal minimum
Road base - soaked CBR

1. 20% of the road bases had soaked CBR > 80% CBR, the basic conventional specification.

2. 40% of the road bases had soaked CBR < 50% CBR, a value frequently used for LVRs

3. 3 road bases had soaked CBRs < 30%

No structural failures were noted
Road base – Plasticity Index (PI)

![Graph showing Plasticity Index (PI) vs. Deterioration Index. The graph includes a normal upper limit for PI.](image-url)
Road base – Plasticity Modulus (PM)

![Diagram showing Plasticity Modulus (PM) vs Deterioration Index with a normal upper limit indicated.](image-url)
Road base – Grading Modulus (GM)

GM

Deterioration Index

Normal specification range

GM vs. Deterioration Index
Road base - Field MC/Optimum MC

![Graph showing relationship between FMC/OMC and Deterioration Index.]

- **Y-axis**: Deterioration Index
- **X-axis**: FMC/OMC

The graph illustrates the distribution of Field MC (FM) and Optimum Moisture Content (OMC) values based on their impact on the deterioration index. The points on the graph represent the observed values, with a clear concentration at certain FMC/OMC ratios.
The surfacings

1. The ageing of bitumen is identified by the changing viscosity which can be measured in various ways.
   a) Penetration
   b) Softening Point
   c) Viscosity

2. Summary of results

   Penetration on fresh bitumen from Mozambique was 58dmm instead of the expected 80/100.

   Penetration on extracted samples mostly <5dmm and only a few > 10dmm, maximum 35dmm

   Oxidation and loss of volatile is the main causes of deterioration
## Ageing of bitumen – Field vs Lab.

<table>
<thead>
<tr>
<th>Site</th>
<th>Parameter</th>
<th>Actual aging in-service</th>
<th>Simulated aging in laboratory (RTFOT)</th>
<th>Deterioration factor</th>
<th>Age of surfacing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pambara</td>
<td>Ductility</td>
<td>373</td>
<td>&gt;1000</td>
<td>&gt; 2.7</td>
<td>4</td>
</tr>
<tr>
<td>Rio Save</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Viscosity (Pas) @120°C</td>
<td>2.4</td>
<td>1.2</td>
<td>2.0</td>
<td></td>
</tr>
<tr>
<td>Nametil</td>
<td>Ductility</td>
<td>481</td>
<td>&gt;1000</td>
<td>&gt; 2.1</td>
<td>5</td>
</tr>
<tr>
<td>Angoche</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Viscosity (Pas) @120°C</td>
<td>2.1</td>
<td>1.2</td>
<td>1.7</td>
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</tr>
<tr>
<td>Nametil</td>
<td>Ductility</td>
<td>475</td>
<td>&gt;1000</td>
<td>&gt; 2.1</td>
<td>5</td>
</tr>
<tr>
<td>Angoche</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>2.4</td>
<td>1.2</td>
<td>2.0</td>
<td></td>
</tr>
</tbody>
</table>
Unusual observations

Rio Zambezi Nicoadala Site, N1 North South Highway with Heavy Trucks - 4.5mesas.
Roadbase - Clayey soil: PI = 20, Soaked CBR = 5%, moist in-situ.
Yet No Failures Observed

Maniamba Lichinga Site, built in the 70s by the army, on high embankment. Laterite base: very dry and hard upper part and wet and soft lower part Red silt subgrade: very dry and hard upper part, wet and soft lower part
No failure. Sandwiched moisture?
Unusual observations

Oasse Mocimboa da Pria Site, upgrade to sealed road 13yrs before. Sand seal, ETB, imported sand subbase (wet), in-situ grey sand subgrade (dry)
DCP failed to penetrate grey in-situ sand subgrade – consolidation!!!
Unusual observations

Nametil - Angoche Site, upgraded to sealed road 5yrs before.
Otta seal, laterite base, grey in-situ sand subgrade.
DCP failed to penetrate grey in-situ sand subgrade – consolidation!!!

Pambara - Rio Save Site, cement stabilised base > 40yrs old.
Hot sand asphalt, CTB, imported red sand subbase, red silt subgrade.
In-situ red silt stabilised with cement.
No cracks!!! No trace of cement???
100% Carbonation of cement???
Conclusions (pavements and materials)

1. Results demonstrate that good performance can be obtained from materials that do not fully meet current specifications. Materials in-service are generally drier giving higher strength and performance. Crown height had no effect on performance within the range studied.

3. Consolidation on existing roads leads to increased capacity to carry higher traffic loading. Need to take advantage of consolidation in the design for upgrading existing roads to sealed road standards (follow existing alignment as much as possible)
Conclusions - (surfacings)

1. The performance of surfacings is dependent on the content, quality and durability of the binder.

2. A large number of samples of binder extracted from surfacings had penetrations below 5dmm and only a few above 10dmm – Binders had become brittle after a relatively short in-service life.

3. Binders were deteriorating more than twice as fast as the anticipated rate obtained from simulation (Rolling thin film over tests, RTFOT). Rapid binder deterioration attributed to hot climate in Mozambique.
Recommendations - 1

1. Review specifications for materials for LVRs to accommodated materials excluded under current specifications. **Redefine upper and lower limit specs.**

2. Review the impact of traffic on the performance of LVRs (>4 mesas but no failure).

3. Review design methodologies for low volume roads to allow for consolidation on existing roads and secondary consolidation after construction. The latter is more critical.

4. Incorporate effect of environmental factors in the design of surfacings *(binder deterioration factors)* for selection of best binders and surfacing types (Inc. QA in construction).
Thank you
Obrigado
Mazvita

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