Environmentally Optimised Design for Low Volume District Roads in Tanzania

Authors/Presenters: Salehe Juma and Kieran Kelly

11th International Conference on Low-Volume Roads, 12-15 July 2015, Pittsburgh
Presentation Outline

- Introduction
- Environmentally optimised design (EOD)
- Pavement Design
- Findings
- Discussion
- Conclusions
Introduction

- Tanzania district roads network comprises of about 56,000 km of unpaved roads.
- Lightly trafficked and most frequently used by cyclists, motorbikes and cars.
- We wanted to implement low-cost solutions for surfacing district roads to allow year-round access.
- We only pave short lengths focusing on the problematic areas to maximise impact of limited funds.
- We built short trial sections on two roads in Tanzania – in Bagomoyo and Siha.
Project Location
Environmentally Optimised Design
ENVIRONMENTALLY OPTIMISED DESIGN (EOD)
Design Stage
Design Focus

- Roads mostly used by bicycles, motorbikes, cars and other light traffic.
- Designing for low design traffic loading <200,000 equivalent standard axles.
- Some heavy trucks during pineapple harvesting season in Bagomoyo – low volume not always low axle load!
- **Year-round access** is the critical focus not speed of travel.
- Try to use local materials and labour-based construction as much as possible.

(11th International Conference on Low-Volume Roads, 12-15 July 2015, Pittsburgh)
Pavement Design

- Initially based on Tanzanian Pavement and Materials Design Manual.
- Adjustments made based on local experience to fit with the concept of low-volume roads.
- Marly limestone used in Bagomoyo because it was a local material and reduced costs.
- In Siha the DCP design approach was used for bituminous surfaces/flexible pavement design.
- DCP design optimised these designs and made savings.
Trial Sections

**Bagomoyo**
- Single Otta seal with sand seal
- Double surface dressing
- Double sand seal
- Slurry seal
- Concrete strips
- Concrete geocells
- Hand packed stone
- Gravel wearing course

**Siha**
- Penetration macadam
- Double surface dressing
- Concrete geocells
- Concrete strips
- Concrete slabs - lightly reinforced and unreinforced
- Gravel wearing course

- Only short lengths ranging from 140m to 1,100m long.
Findings
Bituminous Seals

- Double surface dressing, double sand seal, Otta seal and penetration macadam performing well with only minor defects.
- Marly limestone used in Bagomoyo. Would not comply with a conventional base specification.
- Minor rutting of 5-10mm – likely due to lack of compaction during construction and/or overloaded agricultural vehicles.
- May ultimately have an impact on the life of the pavement.
- DCP CBR indicate adequate strength at in-situ density and moisture content.
Bituminous Seals

- CBR reduced in Siha under the macadam.
- Thought to be a result of moisture ingress.
- Only section performing badly is the slurry seal surface in Bagomoyo.

- Surface failing due to poor construction.
- Good serviceability even on slurry sealed section.
- All sections provide year-round access.

11th International Conference on Low-Volume Roads, 12-15 July 2015, Pittsburgh
Concrete Pavements

- Lightly reinforced concrete sections are performing well.
- This includes slabs and concrete strips.

- Concrete geocells (above) also performing very well.
- Only minor deterioration around cell edges.

11th International Conference on Low-Volume Roads, 12-15 July 2015, Pittsburgh
Concrete Pavements

- Concrete strips not liked by local boda boda drivers.
- They cannot overtake cyclists and motorcyclists easily.
- Problems with the unreinforced concrete sections.
- Longitudinal cracking on many slabs.
Concrete Pavements

- Combination of issues:
  - Pavement cross-section too thin for an unreinforced slab.
  - Laid on weak subgrade soils.
  - Poor construction and material quality.
  - Possible early-trafficking by the Contractor.
- Issue more prevalent in Siha than in Bagomoyo.
- Construction quality better in Bagomoyo.
Hand Packed Stone

- Laid on a short section with weak subgrade soils.
- Ensures access but is a very rough surface.
- Flooding has made the surface much worse.
- Strongly disliked by local road users.
Hand Packed Stone

- Safety issues for cyclists.
- Potential for damage to vehicles.
- Identical issues on a similar project in Lao PDR.
- Road users actively avoided the surface by driving on the shoulders.

Condition after flooding

11th International Conference on Low-Volume Roads, 12-15 July 2015, Pittsburgh
Concrete Paving Blocks

- Located in Lawate village (Siha)
- Very durable. Ideal where there is turning traffic and steep grades.
- Excellent performance since construction.
- Construction is labour intensive.
- Can be maintained locally.
Construction and Whole Life Costs

- Gravel wearing course has the cheapest capital cost.
- This is why most countries re-gravel road networks.
- Cheap up-front cost allows many km’s to be re-surfaced but it needs frequent maintenance:
  - High gravel losses observed in Bagomoyo and Siha of >50mm/year.
- Gravel is also a non-renewable resource and it should only be used where suitable.
- Whole life costing (WLC) showed gravel can be more expensive than a paved alternative.
Construction and Whole Life Costs

- Otta seal with sand seal is more cost effective in flat areas than re-gravelling – Bagomoyo.
- In hilly areas double surface dressing, concrete strips and concrete paving blocks also came out cheaper than re-gravelling.
- All of these pavements also performed very well.
- They incorporate local materials and local labour.
- They ensure year-round access – something gravel does not if used in unsuitable locations.
Discussion and Conclusions

Bituminous Pavements

- With the exception of slurry seal, all bituminous sections are performing very well in Bagomoyo and Siha.
- Some minor issues – could be attributed to lack of compaction or over-loaded agricultural trucks.
- Good performance from local materials.

Conclusions

- They can provide cost-effective alternatives to re-gravelling.
- Provide year-round access and high levels of serviceability.
- Need for maintenance and local capacity to undertake it.
Discussion and Conclusions

Concrete Pavements

- They are expensive but perform very well.
- Only exception was the unreinforced slabs and strips.

Conclusion

- Likely to be difficult to justify economically except in the most high stress or problematic areas.
- Light reinforcement recommended in any future pavements.
- Minimal additional cost overall and creates a stronger structure – particularly if using relatively thin slabs.
Discussion and Conclusions

Hand Packed Stone

- Did what it was supposed to do – ensured year-round access even under difficult conditions.
- But it is a very rough surface and is disliked by road users.
- It is reported to have caused damage to vehicles and resulted in accidents, particularly for cyclists.
- Similar feedback from Lao PDR – cyclists and motorcyclists actively avoid it by driving on the shoulder.

Conclusion

- Limit all future use unless no other viable alternatives.
## Discussion and Conclusions

<table>
<thead>
<tr>
<th>Surface Type</th>
<th>Adequate Level of Service</th>
<th>Cost Effective</th>
<th>Maintenance Requirements</th>
<th>Buildable by Local Contractors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bituminous Surfaces</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Double Surface Dressing</td>
<td>Yes</td>
<td>Yes</td>
<td>Medium</td>
<td>Yes</td>
</tr>
<tr>
<td>Double Sand Seal</td>
<td>Yes</td>
<td>No</td>
<td>Usually High - Bagomoyo seems an exception</td>
<td>Yes</td>
</tr>
<tr>
<td>Single Otta Seal with Sand Cover Seal</td>
<td>Yes</td>
<td>Yes</td>
<td>Medium</td>
<td>Yes</td>
</tr>
<tr>
<td>Single Slurry Seal</td>
<td>Yes</td>
<td>No</td>
<td>High</td>
<td>Yes</td>
</tr>
<tr>
<td>Penetration Macadam</td>
<td>Yes</td>
<td>Yes</td>
<td>Medium</td>
<td>Yes</td>
</tr>
<tr>
<td>Concrete Surfaces</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concrete Strips (Reinforced)</td>
<td>Yes</td>
<td>Yes</td>
<td>Medium</td>
<td>Yes</td>
</tr>
<tr>
<td>Concrete Strips (Unreinforced)</td>
<td>Yes</td>
<td>Yes</td>
<td>Medium</td>
<td>Yes</td>
</tr>
<tr>
<td>Unreinforced Concrete Slab</td>
<td>Yes</td>
<td>Yes in high stress areas</td>
<td>Low</td>
<td>Yes</td>
</tr>
<tr>
<td>Lightly Reinforced Concrete Slab</td>
<td>Yes</td>
<td>Yes in high stress areas</td>
<td>Low</td>
<td>Yes</td>
</tr>
<tr>
<td>Geocells</td>
<td>Yes</td>
<td>No</td>
<td>Low</td>
<td>Yes</td>
</tr>
<tr>
<td>Segmental and Stone Surfaces</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concrete Paving Blocks</td>
<td>Yes</td>
<td>Yes in high stress areas</td>
<td>Low</td>
<td>Yes</td>
</tr>
<tr>
<td>Hand Packed Stone</td>
<td>No</td>
<td>No</td>
<td>Medium</td>
<td>Yes</td>
</tr>
<tr>
<td>Gravel</td>
<td>Not Always</td>
<td>No</td>
<td>High</td>
<td>Yes</td>
</tr>
</tbody>
</table>

11th International Conference on Low-Volume Roads, 12-15 July 2015, Pittsburgh