LIFE-CYCLE COST COMPARISON OF ALTERNATIVE SURFACING FOR STEEP SLOPES ON LOW-VOLUME ROADS IN GHANA

8TH AFRICA TRANSPORTATION TECHNOLOGY TRANSFER CONFERENCE – 2017

Joseph Anochie-Boateng
CSIR Built Environment, South Africa

10 May 2017
ACKNOWLEDGEMENTS

DFID is the sponsor of the project

This study was carried out under the terms of a contract between Cardno Emerging Markets (UK) Ltd (the AfCAP/ReCAP Managers) and CSIR in partnership with BRRI, as part of the DFID-funded AfCAP Research in Community Access Partnership (ReCAP) programme. The Project Team comprised Joseph Anochie-Boateng (Team Leader); Edmund Debrah (Local Civil Engineer). The valuable support and technical advice of Les Sampson and Paulina Agyekum is gratefully acknowledged. The Department of Feeder Roads (DFR) provided office space for the project team, relevant information on feeder roads in Ghana, and all land transport for site visits.

Co-authors of the paper – Les Sampson & Paulina Agyekum (Cardno UK Ltd), K Osafo Ampadu (DFR, Ghana)
SCOPE OF THE PROJECT

• Project is a two-phase study on alternative surfacing (gravel wearing course) for steep slopes on low-volume (feeder) roads in Ghana

  – **Phase 1:** involved a desk study, preliminary site evaluation and scoping for the phase 2 study (GHA2065A)
    • CSIR/BRRI partnership (Jan 2016 – May 2016)

  – **Phase 2:** involves design, construction and monitoring of selected pavement options identified in the phase 1 study (GHA2065B)
    • CSIR/BRRI partnership (Feb 2017 – Feb 2020)
MOTIVATION / NEED

High Annual Rainfall in Ghana
- 780mm - 2160mm
- Highest rainfall (Western, Eastern & Ashanti Regions)
- Two rainy seasons (Apr–Jun; Sep – Nov)

Steep Gradients Sections on Feeder Roads
- More roads located on hilly / rolling terrains (Eastern & Volta Regions)
- Drainage problems, erosion; slopes >12%

Gravel Wearing Course Surfacing
- Inappropriate drainage structures
- Loss of a 100-200 mm thick gravel wearing course

DFR
THE SITUATION

- Erosion and drainage
THE SITUATION

• Erosion and drainage
CURRENT SOLUTIONS

• Appropriate?
CURRENT SOLUTIONS

- Appropriate?
MAIN OUTCOME OF PHASE 1

1. Bituminous surfacings
   - lateritic gravel modified with sand/quarry dust + AC10 binder
   - Otta seal (1x) lateritic gravel modified with sand/quarry dust + emulsion
   - 2x surface dressing (seal)

2. Concrete surfacings
   - concrete block paving (interlocking)
   - ultra-thin reinforced concrete
   - roller compacted concrete

3. Cobblestone/stone setts
   - granite
   - quartzite
   - sandstone

Mechanical stabilisation (1. lateritic gravel + crushed stone/quarry dust; 2. lateritic gravel + sand/ pozzolana)
OBJECTIVE OF PAPER

To present a life-cycle cost comparison of six pavement options proposed for steep slopes on feeder roads in Ghana

1. 70 mm ultra-thin reinforced concrete on mechanically stabilised laterite base [crushed stone and quarry dust]

2. 50 mm thin hot mix asphalt on mechanically stabilised laterite base

3. Interlocking concrete paving blocks on mechanically stabilised laterite

4. Screened gravel single Otta seal [14mm-25mm aggregates] on 100mm and 150mm mechanically stabilised base and subbase layers

5. Stone setts / cobbles [100 mm-250 mm] arranged on spread sand/quarry dust blinding of average depth 25 mm on 100 mm stabilised laterite

6. Double seal [10 mm and 19 mm] on 100 mm stabilised base and 150 mm stabilised sub-base
SURFACING OPTIONS

Ultra-thin reinforced concrete

Thin hot mix asphalt
SURFACING OPTIONS

Interlocking concrete paving blocks

Screened gravel single Otta seal
SURFACING OPTIONS

Stone setts / cobbles

Double seal
## INITIAL CONSTRUCTION COSTS

<table>
<thead>
<tr>
<th>Option #</th>
<th>Pavement structure</th>
<th>Provisional Sum Cost GBP</th>
<th>Lined Side Drains Cost GBP</th>
<th>Pavement Layers Cost GBP</th>
<th>Culvert Cost GBP</th>
<th>Estimated Total Cost GBP</th>
<th>Cost Per Sq. Metre GBP</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>70 mm ultra-thin rein. concrete on 200 mm mechanically stabilised laterite base</td>
<td>12 450.00</td>
<td>28 636.00</td>
<td>53 340.00</td>
<td>6000.00</td>
<td>100 426.00</td>
<td>66.95</td>
</tr>
<tr>
<td>2</td>
<td>50 mm hot-mix asphalt with processed lateritic gravel and AC-10 bitumen on 200 mm mechanically stabilised base</td>
<td>12 450.00</td>
<td>28 636.00</td>
<td>89 100.00</td>
<td>6000.00</td>
<td>136 186.00</td>
<td>90.79</td>
</tr>
<tr>
<td>3</td>
<td>Interlocking concrete paving blocks on 150 mm stabilised laterite [crushed stone and quarry dust]</td>
<td>12 450.00</td>
<td>28 636.00</td>
<td>84 696.00</td>
<td>6000.00</td>
<td>131 782.00</td>
<td>87.85</td>
</tr>
<tr>
<td>4</td>
<td>Screened gravel single Otta seal [14mm-25mm aggregates] on 100mm mechanically stabilised base and 150mm mechanically stabilised subbase</td>
<td>12 450.00</td>
<td>28 636.00</td>
<td>55 200.00</td>
<td>6000.00</td>
<td>102 286.00</td>
<td>68.19</td>
</tr>
<tr>
<td>5</td>
<td>Stone setts / cobbles [100 mm-250 mm] arranged on spread sand/quarry dust blinding of average depth 25 mm on 100 mm stabilised laterite</td>
<td>12 450.00</td>
<td>28 636.00</td>
<td>74 646.00</td>
<td>6000.00</td>
<td>121 732.00</td>
<td>81.15</td>
</tr>
<tr>
<td>6</td>
<td>Double seal [10 mm and 14 mm] on 100 mm stabilised base and 150 mm stabilised sub-base</td>
<td>12 450.00</td>
<td>28 636.00</td>
<td>85 200.00</td>
<td>6000.00</td>
<td>132 286.00</td>
<td>88.19</td>
</tr>
</tbody>
</table>
# LIFE-CYCLE COST ANALYSIS

\[ PWOC = C + M \downarrow 1 (1+r)^{\uparrow x} \downarrow 1 + \cdots + M \downarrow j (1+r)^{\uparrow x} \downarrow j - S(1+r)^{\uparrow z} \]

<table>
<thead>
<tr>
<th>Surfacing</th>
<th>Surfacing Life (Years)</th>
<th>Structural Maintenance</th>
<th>Initial Cost / m² (GBP)</th>
<th>Maintenance Cost / m² (GBP)</th>
<th>Life-Cycle Cost / m² (GBP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>70 mm UTRC</td>
<td>30-50</td>
<td>Repairs</td>
<td>20</td>
<td>66.95</td>
<td>0.37</td>
</tr>
<tr>
<td>50 mm HMA</td>
<td>15-20</td>
<td>overlay</td>
<td>15</td>
<td>90.79</td>
<td>5.24</td>
</tr>
<tr>
<td>Paving Blocks</td>
<td>30-50</td>
<td>Repairs</td>
<td>10</td>
<td>87.85</td>
<td>4.40</td>
</tr>
<tr>
<td>Gravel Single Otta Seal</td>
<td>5-8</td>
<td>Reseal</td>
<td>3</td>
<td>68.19</td>
<td>4.20</td>
</tr>
<tr>
<td>Stone Setts / Cobbles</td>
<td>20-30</td>
<td>Repairs</td>
<td>20</td>
<td>81.15</td>
<td>9.44</td>
</tr>
<tr>
<td>Double Seal</td>
<td>10-15</td>
<td>Fog spray</td>
<td>3</td>
<td>88.19</td>
<td>0.52</td>
</tr>
<tr>
<td></td>
<td>Fog spray</td>
<td>10</td>
<td>88.19</td>
<td>0.52</td>
<td>89.27</td>
</tr>
<tr>
<td></td>
<td>Reseal</td>
<td>12</td>
<td>88.19</td>
<td>1.05</td>
<td>89.27</td>
</tr>
</tbody>
</table>
LIFE-CYCLE COST ANALYSIS

Life Cycle Cost (GBP/m²)

- 70 mm UTRC
- 50 mm HMA
- Paving Blocks
- Single Otta Seal
- Stone setts / Cobbles
- Double Seal

r = 8% 10% 12%
CONCLUSIONS

• Cost difference between the initial construction and the total life-cycle insignificant for all six pavement options selected for this study

• All six pavement options identified through this project are feasible for the current and future studies

• LCCA of gravel wearing course on the steep sections of the feeder roads in Ghana (GBP 106.07 per square metre) > the three relatively expensive options (i.e. double seal, paving blocks, thin HMA)

• Current policies of the DFR may influence the final decision on which particular pavement options to adopt for the steep gradients on feeder roads in Ghana
RECOMMENDATIONS

• Four pavement options proposed for Phase 2

1. 70 mm ultra-thin reinforced concrete on mechanically stabilised laterite base [crushed stone and quarry dust]

2. 50 mm thin hot mix asphalt on mechanically stabilised laterite base

3. Stone setts / cobbles [100 mm-250 mm] arranged on spread sand/quarry dust blinding of average depth 25 mm on 100 mm stabilised laterite

4. Interlocking concrete paving blocks on mechanically stabilised laterite

• Introduce mechanical stabilisation of lateritic soils as the common materials for the base/subbase layers of all pavement options on steep sections of feeder roads in Ghana
ULTIMATELY…

To enable experience to be gained with a range of alternative surfacing that better utilise local resources in a sustainable way, minimising whole-life-costs and supporting the socio-economic activities of the community. The overall goal is to complement national standards with cost-effective surfacing options for steep gradient sections on feeder roads in Ghana.
Thank You

Joseph Anochie-Boateng (janochieboateng@csir.co.za)