Comparitive Scaled MMLS3 Tests vs MLS10 full-scale tests in Mozambique

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Administracao Nacional de Estradas (ANE)
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The University of Texas & MLS Mozambique JV

Location: Stellenbosch and Mozambique
Project Background

- *ANE* embarked on an APT program as most cost effective means to:
  - Evaluate construction techniques
  - Determine most economical use of available “sub-standard” materials
  - Develop a m-e design system best suited for its needs with due regard to
    - materials and
    - environment

Topics to be covered

- Field distress
- Laboratory model pavement testing
- Field construction
- Field APT with MMLS3 and MLS10
- Results
Pavement Composition

Mozambican Pavement Structure
Actual Performance
# MMLS3

MOBILE MODEL LOAD SIMULATOR TESTING

## Lab test matrix

<table>
<thead>
<tr>
<th>Sand type</th>
<th>Base thickness, mm</th>
<th>Binder %</th>
<th>CEM2.5 II: Lime</th>
<th>Surfacing</th>
<th>Conditions</th>
<th>No of Tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Palmesra Red</td>
<td>50</td>
<td>5</td>
<td>100:0</td>
<td>50:50</td>
<td>AC</td>
<td>2</td>
</tr>
<tr>
<td>Palmesra Red</td>
<td>50</td>
<td>7</td>
<td>100:0</td>
<td>50:50</td>
<td>Seal AC</td>
<td>3</td>
</tr>
<tr>
<td>Palmesra Red</td>
<td>50</td>
<td>3</td>
<td>100:0</td>
<td></td>
<td>Seal AC</td>
<td>2</td>
</tr>
<tr>
<td>Palmesra Red</td>
<td>150 (F)</td>
<td>5</td>
<td>100:0</td>
<td>Seal*</td>
<td>*26/50 °C Wet/Dry</td>
<td>1</td>
</tr>
<tr>
<td>Palmesra Red</td>
<td>150 (F)</td>
<td>5</td>
<td>ETB + CEM</td>
<td>ETB</td>
<td>Seal</td>
<td>4</td>
</tr>
<tr>
<td>Palmesra Yellow</td>
<td>50</td>
<td>7</td>
<td>100:0</td>
<td>Seal*</td>
<td>AC</td>
<td>2</td>
</tr>
<tr>
<td>Core Red</td>
<td>100</td>
<td>5</td>
<td>100:0</td>
<td>Seal</td>
<td>20-50 °C Wet/Dry</td>
<td>1</td>
</tr>
</tbody>
</table>

*50°C dry only

20-50°C equals wet temperature vs. heated trafficking temperature

(F) equals MMLS3 Field tests

ETB – Emulsion Treated Base, SS60 Emulsion was used - Beyond the scope of this paper
Third Scale Construction in Laboratory

Laboratory Construction
Two MMLS3s at ITT in SA

Sand Subbase and CTB
Portable Seismic Pavement Analyzer

APT PERFORMANCE MONITORING IN LABORATORY with PSPA
SEAL construction

Laboratory Test Conditioning

• Hot air used for heating surface to 55 C

• Recirculated water on surface at 20 C

• Trafficking alternated between 200 000 heated load applications and 50 000 wet load applications

• Protocol selected to simulate critical field conditions
Distress in 7% red CTB with HMA
Longitudinal crack – loss of micro structure
3.1 m axles

Crack manifestation at bottom of core
MLS10
FULL SCALE PAVEMENT TESTING

Construction of Full-Scale Test Sections
MONITORING OF TRIAL SECTION
STIFFNESS AFTER CONSTRUCTION
in Mozambique

Layout of Test Site
MLS10 design unique

- Based on MMLS3 scaled up x3
  - 14 already produced past 8 years
- Curved rails have variable radius
  - no jerk
- Driven by contactless linear induction motors
  - no gearbox, thus no wear or fatigue of drive system
- Pneumatic-hydraulic suspension with low spring constant (0.2%/cm)
  - constant load
  - integrated damping

Perspective of a Single Bogie

Aluminium reaction plates
MLS10 design unique (cont)

- Frame Hydraulic components
  - 4 corner cylinders
  - 4 lifting cylinders
  - 2 Lateral displacement cylinders
  - 1 Steering cylinder
  - 1 Hydraulic motor

Various lengths available 3.5, 6.6m

Front View of the MLS10
From Ground Level
Long haulage of the MLS10

MLS10 on weighbridge
WIM calibration in Komatipoort

MLS10 wheel on the WIM pad
MLS10 on WIM-bridge for measuring transient wheel load
(click to start video clip)

Remote travel of the MLS10 on site in Mozambique
(click to start video clip)
### Some of the Features of the MLS3

**Technical Specifications – MLS3**

<table>
<thead>
<tr>
<th>Item</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of bogies</td>
<td>4</td>
</tr>
<tr>
<td>No. of axles per bogle</td>
<td>1</td>
</tr>
<tr>
<td>Wheels per axle</td>
<td>1</td>
</tr>
<tr>
<td>Wheel diameter</td>
<td>300 mm</td>
</tr>
<tr>
<td>Tyre width</td>
<td>80 mm</td>
</tr>
<tr>
<td>Lateral spread of tracks from centreline</td>
<td>0 to 80 mm</td>
</tr>
<tr>
<td>Maximum tracking width</td>
<td>240 mm</td>
</tr>
<tr>
<td>Tyre footprint area</td>
<td>34 cm²</td>
</tr>
<tr>
<td>Tyre contact pressure</td>
<td>560 – 800 kPa</td>
</tr>
<tr>
<td>Load cell per wheel</td>
<td>1,900 N (@ 560 kPa)</td>
</tr>
<tr>
<td>Load cell calibration</td>
<td>Automatic</td>
</tr>
<tr>
<td>Nominal speed</td>
<td>2.5 m/s</td>
</tr>
<tr>
<td>Nominal wheel load applications per hour</td>
<td>7,200</td>
</tr>
<tr>
<td>Nominal motor supply voltage</td>
<td>220 VAC single phase</td>
</tr>
<tr>
<td>Power consumption</td>
<td>1,500 W max.</td>
</tr>
<tr>
<td><strong>Dimensions:</strong></td>
<td></td>
</tr>
<tr>
<td>Length</td>
<td>2,400 mm</td>
</tr>
<tr>
<td>Width</td>
<td>600 mm</td>
</tr>
<tr>
<td>Height</td>
<td>1,150 mm</td>
</tr>
<tr>
<td>Weight</td>
<td>500 kg</td>
</tr>
</tbody>
</table>

### Some of the Features of the MLS10

**MLS10 APT Machine Parameters**

<table>
<thead>
<tr>
<th>Item</th>
<th>Standard MLS10</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Wheel configuration</td>
<td>Single/Dual</td>
</tr>
<tr>
<td>2 Wheel load</td>
<td>30 – 75 kN</td>
</tr>
<tr>
<td>3 Wheel suspension</td>
<td>Pneumatic Hydraulic</td>
</tr>
<tr>
<td>4 Wheel velocity</td>
<td>7.2 m/s</td>
</tr>
<tr>
<td>5 Trolley (carriage) description</td>
<td>Four bogie pneumatic hydraulic suspension units</td>
</tr>
<tr>
<td>6 Load setting and control</td>
<td>Force applied through inflation of Nitrogen Accumulators</td>
</tr>
<tr>
<td>7 Load propulsion</td>
<td>Linear Induction Electric Motors (LIM)</td>
</tr>
<tr>
<td>8 Drive and power systems</td>
<td>24.3 kVA Linear Induction Motors</td>
</tr>
<tr>
<td>9 Diesel generator capacity</td>
<td>175 kVA diesel generator comprising, Volvo model TAD720C E, six cylinder diesel drive engine and 175 kVA 12 pole brushless three-phase alternator</td>
</tr>
<tr>
<td>10 Mass</td>
<td>30 t</td>
</tr>
<tr>
<td>11 Vehicle dimensions</td>
<td>L * B * H = 10.7 x 2.4 x 3.1 (can rotate 1 meter for access below)</td>
</tr>
<tr>
<td>12 No. of wheels</td>
<td>4 dual/super single</td>
</tr>
<tr>
<td>13 Tyres</td>
<td>Continental R22, 255/65 and super single 355/65</td>
</tr>
</tbody>
</table>
Some of the Features of the MLS10 (cont)

<table>
<thead>
<tr>
<th>Item</th>
<th>Standard MLS10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed of operation Kph</td>
<td>76</td>
</tr>
<tr>
<td>Rut depth (mm)</td>
<td>50</td>
</tr>
<tr>
<td>Load repetitions #</td>
<td>7000</td>
</tr>
<tr>
<td>Trafficking conditions</td>
<td>Dry/Wet Heated</td>
</tr>
<tr>
<td>Trafficked width mm</td>
<td>580 – 1,600 (optional)</td>
</tr>
<tr>
<td>Lateral Traffic Load Distribution</td>
<td>Gaussian or channelized Programmable</td>
</tr>
<tr>
<td>Testing length m</td>
<td>3</td>
</tr>
<tr>
<td>Wheel path width mm</td>
<td>1.58 m</td>
</tr>
<tr>
<td>Site of test section m</td>
<td>5m x 1.5</td>
</tr>
<tr>
<td>Temperature control</td>
<td>Heating feasible</td>
</tr>
<tr>
<td>Data acquisition system</td>
<td>Digital Electrical</td>
</tr>
</tbody>
</table>

Trafficking @ time of paper

<table>
<thead>
<tr>
<th>Section</th>
<th>8</th>
<th>4</th>
<th>5a</th>
<th>5b</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stab</td>
<td>7% Cem</td>
<td>5% Cem</td>
<td>2.5%C/2.5%L</td>
<td>2.5%C/2.5%L</td>
</tr>
<tr>
<td>Binder</td>
<td>5% Cem</td>
<td>5% Cem</td>
<td>2.5%C/2.5%L</td>
<td>2.5%C/2.5%L</td>
</tr>
<tr>
<td>Sand 150mm</td>
<td>Red</td>
<td>Red</td>
<td>Red</td>
<td>Red</td>
</tr>
<tr>
<td>Surfacing</td>
<td>HMA</td>
<td>HMA</td>
<td>HMA</td>
<td>HMA</td>
</tr>
<tr>
<td>Load appl 60kN</td>
<td>84.5k</td>
<td>330k</td>
<td>100k</td>
<td>1080k</td>
</tr>
</tbody>
</table>
Response and Performance monitoring

- P SPA Stiffnesses/-ratios
- Dynamic Surface deflections
- Surface deformation
- Crack manifestation
- Diagnostic trenching

Typical Seismic Stiffness Profiles

FIGURE 7: Typical Seismic Stiffness Profiles with Axle Load Application at a specific point relative to the wheel track.
Typical Seismic Stiffness Profiles

Relative Stiffness ratios for MMLS3 and MLS10 – 7% CTB in lab and field
Extracted pavement section 4

Response and Performance monitoring

- P SPA Stiffnesses/-ratios
- Dynamic Surface deflections
- Surface deformation
- Crack manifestation
- Diagnostic trenching
Full-scale wet trafficking
(click for video clip)

Distress of the 7% Scaled pavement
Cracks after HMA debonding from CTB base full-scale section 4

Pumping due to debonding under the surfacing
Cracking due to lateral shear of the surfacing

Pumping due to failure of the HMA surfacing
Pumping due to failure of the HMA surfacing and underlying CTB

Overview of typical diagnostic trenching

Underside of HMA

Isometric view of section
Conclusions

- MMLS3 testing of scaled CTB sand pavements feasible
- MMLS3 and MLS10 trafficking results compatible in terms of distress, response & performance
- P SPA stiffness ratios monitored distress development successfully
- Distress mechanisms good replication of field performance
- Distress modes differed depending upon
  - structure and material strength
- Wet trafficking was feasible and contributed to distress development

Conclusions (cont)

Noteworthy response relationships that were found:

- Dynamic deflection progressively increased relative to initial deflection trending towards two

- Concurrently P SPA stiffness ratio progressively decreased reaching 50% when significant distress had manifested
Off-loading trailer used for carting the MMLS3 to site in Mozambique

MMLS3 testing full-scale pavement surface layers
MMLS3 CONTACT STRESS PROFILE
@ 862 kPa tire pressure –
(Epps et al, Westrack)

4-80X6 Tire (MMLS)
Inflation Pressure: 862 kPa
Temperature: 7°C
Test Vehicle Speed: 2.4 m/s
Max Stress: 867 kPa

MMLS3 on the SIM for measuring contact stress
MMLS3 on the SIM for measuring contact stress

MMLS3 SIM measurements of contact stresses by De Beer et al (2006)
MMLS3 SIM measurements of contact stresses by De Beer et al (2006)

**MMLS3 TEST TYRE: Diamond Pattern, Tyre no. 01**

- Inflation Pressure = 700 kPa
- Actual Wheel speed (MMLS3) = 0.285 m/s (1.03 kph)
- Vertical Load (MMLS3) = 2.7 kN
- Measured Resultant Lateral Load (SIM) = 0.0783 kN

**Stress Values (MPa)**

- Max Stress = 0.0799 MPa
- Min Stress = -0.04 MPa

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**MMLS3 TEST TYRE: Diamond Pattern, Tyre no. 01**

- Inflation Pressure = 700 kPa
- Actual Wheel speed (MMLS3) = 0.285 m/s (1.03 kph)
- Vertical Load (MMLS3) = 2.7 kN
- Measured Resultant Longitudinal Load (SIM) = 0.026 kN

**Stress Values (MPa)**

- Max Stress = 0.0479 MPa
- Min Stress = -0.028 MPa
RELATIVE SEISMIC STIFFNESS RATIO vs AXLE LOAD APPLICATIONS FOR SCALED 7% CEMENT STABILIZED PAVEMENT LONGITUDINAL DIRECTION

$R^2 = 0.6873$

$R^2 = 0.7774$