



Targeted Interventions for Low Volume Roads in Mozambique AFCAP/MOZ/001/C

Monitoring Report
CPR 1458

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Launched in June 2008 and managed by Crown Agents, the five year-long, UK government (DFID) funded project, supports research and knowledge sharing between participating countries to enhance the uptake of low cost, proven solutions for rural access that maximise the use of local resources.

The programme is currently active in Ethiopia, Kenya, Ghana, Malawi, Mozambique, Tanzania, Zambia, South Africa, Democratic Republic of Congo and South Sudan and is developing relationships with a number of other countries and regional organisations across Africa.

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Preface

This report presents some interim findings from the monitoring data collected at intervals to measure the performance of the sites constructed under the second phase of the AFCAP project in Mozambique.

A preliminary discussion is made under each parameter sub-heading of the performance of each trial site.

A more detailed analysis of the monitoring data will be provided once the final monitoring period has been completed in February 2013.

Final recommendations will be made in the Final Report in consideration of these results and those to be obtained from the AFCAP project "Analysis of Performance of Previous Low Volume Rural Roads (AFCAP/MOZ/001/G)".

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1 Introduction

The experimental sites under the AFCAP phase 2 project in Mozambique were constructed as part of the broader programme of Targeted Interventions for Low Volume Roads in Mozambique. Construction took place at different times at each site; hence some sites have been monitored over a longer period than others, as shown in the schedule in Table 1-1.

Though the overall monitoring period has been over a relatively short time, the monitoring results will provide valuable lessons will be learnt to enable cost reduction and rapid expansion of a quality road network. The monitoring period started in February 2011 and it will be completed in February 2013 under the current TRL involvement. It will however be encouraged that the ANE team continue with long term monitoring beyond the mandate of TRL's contract.

By the end of TRL's monitoring period, the experimental sections will have been studied at the end of the dry season and as well as in the middle of the rainy season which represent the extremes of climatic conditions that affect road performance.

This report is organised by province where experimental sections have been built. Under each section, the parameters that are being monitored are discussed. Finally the report outlines what is expected to be carried out in the final monitoring round expected to take place in February 2013.

It has not been possible to include the full appendices since each site monitored includes at least 50 spread sheets. Specific data sets are available on request.

Table 1-1 Monitoring schedule

| Site | Feb – March 2011 | July - August 2011 | Nov - 2011 | March 2012 | Aug - Sept 2012 | February 2013 |
|-----------------------|-------------------------|---------------------------|-------------------|-------------------|------------------------|----------------------|
| Cumbana-Chacane | √ | √ | √ S | √ S | √ | TBC |
| Inhacufera-Machaze | | √ | | √ S | √ | TBC |
| Zero-Mopeia | | √ | √ S | √ S | √ | TBC |
| Xitaxi-Moeda | | √ | | | √ | TBC |
| Marracuene - Macaneta | | | | | √ | TBC |

√S selected parameters

2 Maputo Province: Marracuenne – Macaneta road

2.1 Description

This site is located in Maputo province about 40km North of Maputo city centre. This road leads to Macaneta beach. The experimental section on this road consists of 780m of 15mm slurry seal surfacing on top of 100mm Emulsion Stabilised Sand Base. The section starts at the edge of Marracuenne and ends at the ferry crossing.

Construction of this experimental section was delayed and was only recently completed in July 2012. Results from this section are expected to influence both city street construction as well as rural road construction where the only available naturally occurring material is sand. The design for this section was done using sand that did not exactly meet the specification requirements for Emulsion Treated Bases and, as such, it is of interest if the performance information shows it to be working well.

The road carries in excess of 300 vehicles per day, most of which are light vehicles going to Macaneta beach. The monitoring which has been undertaken so far is marking out and collecting baseline data for subsequent monitoring. This was carried out in September 2012.

2.2 Rutting

The baseline values for rutting are shown in Table 2-1 below. These values do not necessarily signify rutting since they may merely be surface irregularities during construction. This is further reinforced by the absence of any clear visible wheel tracks. These values will act as the baseline for comparison of future measurements at these points.

Table 2-1 Baseline values for rutting on Maracuenne – Macaneta road

| Chainage | Rutting Baseline Value (mm) | |
|----------|-----------------------------|---|
| | L | R |
| 0+010 | 2 | 3 |
| 0+110 | 2 | 0 |
| 0+210 | 3 | 0 |
| 0+310 | 6 | 4 |
| 0+385 | 2 | 0 |
| 0+450 | 3 | 0 |
| 0+480 | 4 | 3 |
| 0+570 | 3 | 0 |
| 0+590 | 4 | 0 |
| 0+640 | 4 | 0 |
| 0+665 | 4 | 2 |
| 0+715 | 3 | 3 |

Many road authorities consider rutting values of up to 20mm to be safe and therefore the values measured are in no way alarming at this stage.

2.3 Texture Depth

The texture depths shown in Table 2-2 appear to be low but this is normal for slurry seal surfacing. Significant change is not expected during the service life of the road.

Table 2-2 Baseline values for texture depth on Marracuene – Macaneta road

| Chainage | Test Position (offset from mark) (m) | Texture Depth (mm) |
|-----------------|---|-----------------------------------|
| 0+010 | 1.0 | 0.8 |
| 0+110 | 1.0 | 0.9 |
| 0+210 | 1.0 | 0.8 |
| 0+310 | 1.0 | 1.0 |
| 0+385 | 1.0 | 0.8 |
| 0+450 | 1.0 | 1.0 |
| 0+480 | 1.0 | 1.0 |
| 0+570 | 1.0 | 1.0 |
| 0+590 | 1.0 | 0.9 |
| 0+640 | 1.0 | 0.9 |
| 0+665 | 1.0 | 0.8 |
| 0+715 | 1.0 | 0.9 |

The limit for surfaced dressed roads for texture depths measured by the sand patch method should not normally be below 0.9mm for trunk roads. The depths shown in Table 2-4 should therefore cause no alarm.

2.4 Roughness

Roughness was measured by means of a bump integrator and is also not expected to rise significantly during the service life of the road if routine maintenance is carried out. The values are as shown in Table 2-3 below.

Table 2-3 Baseline values for roughness on Marracuenne – Macaneta road

| ROAD SECTION | CHAINAGE | Sep –2012 (m/km) |
|---------------------|-----------------|-------------------------|
| 1 | 0+000-0+300 | 3.4 |
| 2 | 0+385-0+470 | 3.7 |
| 3 | 0+470-0+581 | 3.9 |
| 4 | 0+581-0+654 | 4.7 |
| 5 | 0+654-0+715 | 3.9 |

Though the values of roughness are in the mid-range, they are perfectly acceptable for low-volume roads and city streets.

2.5 Visual condition survey

Visually the road still appears sound with no defects such as cracks, depressions, or major potholing. There is an absence of slurry seal at a few isolated spots as shown in Table 2-4 but this appears to be a construction defect rather than a performance defect.

Table 2-4 Potholing/surface loss defects on Marracuenne – Macaneta road

| Chainage | | Potholes / Surface Loss (including binder) | | | |
|-----------------|----------|---|---------------|------------------------|----------------------|
| Km | m | Position | Number | Total Area | Average Depth |
| | | L,C,R,A | | (m²) | (mm) |
| 0+385-0+450 | 65 | L | 3 | 0.0675 | 20 |
| 0+590-0+600 | 10 | L | 1 | 0.45 | 20 |

The provincial consultant has been asked to request the contractor to correct these defects while the defects liability period is still valid.

3 Inhambane Province: Cumbana - Chacane road

3.1 Description

Cumbana is a town located on the N1 trunk road about 30km South of Maxixe city in Inhambane province. The project road begins in Cumbana and extends South-Westwards to Chacane. The experimental sections are located between chainages 18+200 and 24+700. This consists of 2km of Otta Seals sections and 4.4km of blended gravel sections.

Construction was completed towards the end of 2010. The pavement structure consists of Otta Seal surfacing on a 150mm base of a blend of red sand and plastic calcrete. This same blend was also used as gravel wearing course. Neat red sand (150mm) was used as a sub-base. For the Otta Seal sections, spray rates were varied on the experimental sections to determine the performance limiting values for use with calcrete gravels. These sections are aimed at providing suitable surfacing, quality base material and longer lasting gravel road materials for use in areas of calcrete and sand abundance.

Baseline monitoring was undertaken at this section in February 2011. Since then monitoring has been carried out in July 2011, November 2011, March 2012 and in August 2012.

3.2 Traffic Counts

Traffic on this road generally travels in the morning hours and in the early afternoon hours. The levels indicate a very low volume road.

Table 3-1 Traffic count on Cumbana – Chacane road

| Vehicle Type | 5hr Count | 12hr Projection |
|---------------------|------------------|------------------------|
| Light vehicles | 6 | 14 |
| Trucks (2-axle) | 11 | 26 |
| Trucks (3-axle) | 1 | 3 |
| | | |
| Estimated vpd | | 43 |

As shown in Table 3-1, the traffic comprises mainly 2-axle trucks that ferry calcrete boulders and firewood to the city and take merchandise to the villages. These traffic levels are not sufficient to provide for rapid curing of Otta Seals.

3.3 Rutting

Rutting values for the Otta Seal sections are shown in Table 3-2 and Table 3-3. It is often difficult to measure rutting on surfaces where the final cutting to the base has not been done properly or the road has been trafficked before surfacing; which was the case at this site.

Table 3-2 Rutting values for first Otta Seal sections on Cumbana - Chacane Otta road

| Chainage | Rutting Value (mm) | | Differential Rutting Value (mm) |
|----------|--------------------|-------------|---------------------------------|
| | February 2011 | August 2012 | |
| 18+230 | 5 | 12 | 7 |
| 18+300 | 7 | 7 | 0 |
| 18+328 | 5 | 8 | 3 |
| 18+390 | 2 | 4 | 2 |
| 18+420 | 2 | 2 | 0 |
| 18+540 | 3 | 0 | 3 |
| 18+630 | 5 | 3 | 0 |
| 18+810 | 10 | 11 | 1 |
| 19+026 | 7 | 7 | 0 |
| 19+157 | 6 | 8 | 2 |

Table 3-3 Rutting values for second Otta Seal Sections on Cumbana - Chacane road

| Chainage | Rutting Value (mm) | | Differential Rutting Value (mm) |
|----------|--------------------|-------------|---------------------------------|
| | February 2011 | August 2012 | |
| 23+730 | 4 | 5 | 1 |
| 23+760 | 3 | 10 | 7 |
| 23+830 | 5 | 13 | 8 |
| 23+860 | 2 | 5 | 3 |
| 23+936 | 16 | 16 | 0 |
| 24+155 | 9 | 5 | 0 |
| 24+206 | 6 | 5 | 0 |
| 24+320 | 5 | 5 | 0 |
| 24+380 | 0 | 4 | 4 |
| 24+517 | 6 | 12 | 6 |
| 24+535 | 6 | 9 | 3 |
| 24+613 | 6 | 27 | 23 |

The absolute values of rutting are well below 20mm which is the generally accepted critical level for rutting on trunk roads. Again, these values may be construction irregularities as opposed to rutting. The differential values give a better understanding of the rutting that may have occurred, but these values are also very low and, in the absence of the visibility of channelized wheel paths, we can assume that no significant rutting has occurred.

3.4 Texture Depth

Texture depths that were measured at various points during the monitoring are shown in Table 3-4 and Table 3-5. The values are generally adequate in terms of drainage and skid resistance.

Table 3-4 Texture depth values on first Otta Seal sections on Cumbana - Chacane road

| Sections 1 | Bitumen Spray Rate (l/m ²) | Mar-11 (mm) | Jul-11 (mm) | Mar-12 (mm) | Aug-12 (mm) |
|------------|--|-------------|-------------|-------------|-------------|
| 1 | 2.82 | 2.3 | 1.8 | 1.7 | 2.3 |
| 2 | 1.54 | 1.7 | 1.1 | 1.5 | 1.6 |
| 3 | 2.10 | 1.4 | 1.4 | 1.4 | 1.9 |
| 4 | 1.24 | 1.6 | 1.4 | 1.5 | 1.7 |
| 5 | 1.71 | 1.6 | 1.3 | 1.3 | 1.7 |
| 6 | 1.88 | 2.0 | 1.4 | 1.4 | 1.8 |
| 7 | 1.29 | 1.5 | 1.6 | 1.9 | 2.3 |
| 8 | 0.60 | 1.9 | 2.0 | 2.1 | 1.8 |
| 9 | 3.12 | 1.5 | 2.6 | 1.9 | 2.3 |
| 10 | 1.58 | 2.0 | 1.3 | 2.2 | 1.9 |
| Average | 1.79 | 1.7 | 1.6 | 1.7 | 1.9 |

Table 3-5 Texture depth values on second Otta Seal sections on Cumbana – Chacane road

| Sections 2 | Bitumen Spray Rate (l/m ²) | Mar-11 (mm) | Jul-11 (mm) | Mar-12 (mm) | Aug-12 (mm) |
|------------|--|-------------|-------------|-------------|-------------|
| 1 | 2.90 | 3.0 | 2.8 | 2.6 | 2.9 |
| 2 | 2.16 | 2.9 | 1.8 | 1.9 | 2.2 |
| 3 | 1.87 | 3.2 | 2.0 | 2.7 | 3.2 |
| 4 | 1.80 | 4.3 | 2.6 | 4.9 | 2.8 |
| 5 | 1.51 | 3.2 | 1.6 | 1.5 | 2.1 |
| 6 | 1.51 | 2.0 | 1.9 | 2.9 | 3.5 |
| 7 | 1.42 | 2.7 | 2.5 | 2.0 | 2.7 |
| 8 | 1.76 | 3.1 | 2.4 | 3.2 | 1.9 |
| Average | 1.87 | 3.1 | 2.2 | 2.7 | 2.7 |

The important thing to note in both these tables is that from July 2011 no significant change occurred in the texture depths, implying that the bitumen had stopped migrating upwards on through the aggregate mix. This stresses the importance of initial rolling by pneumatic rollers as opposed to relying on traffic to do most of the compaction.

3.5 Roughness

The roughness values measured during the monitoring period are shown in Table 3-6 and in Table 3-7. The values were measured by use of a calibrated vehicle mounted bump integrator.

Table 3-6 Roughness values of first Otta Seal sections on Cumbana – Chacane road

| Sections 1 | Jul-11 (m/km) | Mar-12 (m/km) | Aug-12 (m/km) |
|-------------------|--------------------------|--------------------------|--------------------------|
| 1 | 9.2 | 9.7 | 8.0 |
| 2 | 5.1 | 6.9 | 5.5 |
| 3 | 6.0 | 6.7 | 6.3 |
| 4 | 4.8 | 5.3 | 5.4 |
| 5 | 6.9 | 7.3 | 7.7 |
| 6 | 4.4 | 5.2 | 5.0 |
| 7 | 5.6 | 6.0 | 6.4 |
| 8 | 5.1 | 6.1 | 5.5 |
| 9 | 4.9 | 5.7 | 5.0 |
| 10 | 6.2 | 7.9 | 7.1 |

Table 3-7 Roughness values on second Otta Seal sections on Cumbana – Chacane road

| Sections 2 | Jul-11 (m/km) | Mar-12 (m/km) | Aug-12 (m/km) |
|--|--------------------------|--------------------------|--------------------------|
| 1 | 4.8 | 5.6 | 4.7 |
| 2 | 4.4 | 7.1 | 5.4 |
| 3 | 5.5 | 7.1 | 7.0 |
| 4 | 5.3 | 6.8 | 6.7 |
| 5 | 4.9 | 6.4 | 5.3 |
| 6 | 4.3 | 5.7 | 4.6 |
| 7 | 4.2 | 7.6 | 5.2 |
| 8 | 5.0 | 7.4 | 5.0 |
| GRAVEL road carriageway | 10.3 | 18.0 | 21.2 |
| Side of GRAVEL road currently used by traffic | | | 9.4 |

The roughness values are rather high for a recently surfaced road. This can be attributed to trafficking of the base layer for a significant period before surfacing. The values measured in March 2012 are highest of all, perhaps due to the fact that the sections had developed some potholes before the survey. The potholes were patched before the August/September 2012 survey, leading to lower roughness values.

The carriageway roughness on the gravel sections were up to 2 times higher than the surfaced sections and up to 4 times higher (21m/km) in August 2012. This has forced most vehicles to abandon the carriageway and drive on the sides where the measured roughness is about 9.5m/km. This reinforces the importance of routine maintenance on gravel roads and the benefits of sealing roads.

3.6 Visual condition survey

The focus here has been on the level of potholing as shown in Table 3-8 and Table 3-9. The potholed areas in themselves are low and, importantly, there does not seem to be any relationship between the bitumen spray rate and potholing.

Table 3-8 Potholing areas on first Otta Seal Sections on Cumbana – Chacane road

| Sections 1 | Bitumen Spray Rate (l/m²) | Mar-11 (m²) | Mar-12 (m²) | Aug-12 (m²) |
|-------------------|---|-------------------------------|-------------------------------|-------------------------------|
| 1 | 2.82 | 0.0 | 0.0 | 0.0 |
| 2 | 1.54 | 0.0 | 0.1 | 0.0 |
| 3 | 2.10 | 0.0 | 0.5 | 0.0 |
| 4 | 1.24 | 0.0 | 8.7 | 0.0 |
| 5 | 1.71 | 0.0 | 0.0 | 0.0 |
| 6 | 1.88 | 0.0 | 0.0 | 0.0 |
| 7 | 1.29 | 0.0 | 2.5 | 0.0 |
| 8 | 0.60 | 0.0 | 0.2 | 0.0 |
| 9 | 3.12 | 0.0 | 1.4 | 0.0 |
| 10 | 1.58 | 0.0 | 0.0 | 0.0 |

Table 3-9 Potholing areas on second Otta Seal sections on Cumbana – Chacane road

| Sections 2 | Bitumen Spray Rate (l/m²) | Mar-11 (m²) | Mar-12 (m²) | Aug-12 (m²) |
|-------------------|---|-------------------------------|-------------------------------|-------------------------------|
| 1 | 2.90 | 0.0 | 13.2 | 0.0 |
| 2 | 2.16 | 0.0 | 0.1 | 0.0 |
| 3 | 1.87 | 0.0 | 0.4 | 0.0 |
| 4 | 1.80 | 0.0 | 0.6 | 0.0 |
| 5 | 1.51 | 0.0 | 0.0 | 0.0 |
| 6 | 1.51 | 0.0 | 0.7 | 0.0 |
| 7 | 1.42 | 0.0 | 23.0 | 0.0 |
| 8 | 1.76 | 0.0 | 1.4 | 0.0 |

3.7 DCP Strength Test

The in-situ CBRs shown in Table 3-10 are quite high for a low volume road although they have been measured in the dry season. Another measurement will be carried out in the next monitoring period during the rainy season.

Table 3-10 In-situ DCP CBRs on Cumbana – Chacane road

| Date: | 02/09/2012 | |
|-----------------|----------------------------|----------------------|
| Chainage | Base CBR Values (%) | Location |
| 18+328 | 55 | RHS Outer Wheeltrack |
| 18+726 | 150 | RHS Outer Wheeltrack |
| 19+126 | 125 | Centreline |
| 19+126 | 145 | RHS Outer Wheeltrack |
| 23+830 | 50 | RHS Outer Wheeltrack |
| 24+206 | 105 | LHS Outer Wheeltrack |
| 24+618 | 55 | LHS Outer Wheeltrack |

3.8 Base Moisture

All the moisture levels of the materials taken from the base layer as shown in Table 3-11 are well below Optimum Moisture Content (OMC) although they have only been measured in the dry season. This would mean that the strength mobilised in-situ is well above that obtained in the 4-day soaked laboratory test. Another test shall be carried out in the next monitoring period during the rainy season.

Table 3-11 Base course moisture values on Cumbana – Chacane road

| Date: | 02/09/2012 | | |
|-----------------|--------------------------|---------------------|----------------------|
| OMC: | 8.7% | | |
| Chainage | Base Moisture (%) | Ratio of OMC | Location |
| 18+328 | 7 | 0.80 | Centreline |
| 18+750 | 4 | 0.46 | LHS Outer Wheeltrack |
| 19+126 | 6 | 0.69 | RHS Outer Wheeltrack |
| 23+830 | 4 | 0.46 | LHS Outer Wheeltrack |
| 24+250 | 3 | 0.34 | RHS Outer Wheeltrack |
| 24+618 | 6 | 0.69 | Centreline |

3.9 Gravel Loss

One of the most important parameters in the performance of gravel roads is the extent of gravel loss. This was measured using an automatic level, reducing the levels to determine the losses presented in Table 3-12 and Table 3-13.

Table 3-12 Gravel loss values on first gravel sections on Cumbana - Chacane road

| Cross Sections (Group 1) | Feb 11 to Nov 11 (9 months) (mm) | Dec 11 to Aug 12 (9 months) (mm) |
|-------------------------------------|---|---|
| X1 | 21 | 22 |
| X2 | 26 | 14 |
| X3 | xx | xx |
| X4 | 12 | 20 |
| X5 | 12 | 13 |
| Average | 17.75 | 17.25 |

Table 3-13 Gravel loss values on second gravel sections on Cumbana – Chacane road

| Cross Sections (Group 2) | Feb 11 to Nov 11 (9 months) (mm) | Dec 11 to Aug 12 (9 months) (mm) |
|-------------------------------------|---|---|
| X1 | 7 | 11 |
| X2 | 10 | 13 |
| X3 | xx | xx |
| X4 | 5 | 18 |
| X5 | 3 | 11 |
| Average | 6.25 | 13.25 |

Despite high values of roughness exhibited by the gravel sections, the loss of material is low. This means the mix of calcrete and sand offers a good resistance to loss and only gradation and routine maintenance should be improved to keep roughness values to a minimum.

4 Manica Province: Inhacufera – Machaze road

4.1 Description

The project site is located about 340km from the city of Chimoio – the provincial capital of Manica province. The site consists of 5km of Otta Seal sections constructed in Phase 1, 6km of Otta Seal sections constructed in Phase 2, 500m of a Sand Seal section and 5km of Otta Seal sections constructed in Phase 3.

Construction was completed towards the end of 2010. The pavement structure consists of Otta Seal surfacing on a base of 150mm of quartzitic natural gravel. For the Otta Seal sections, spray rates were varied on the experimental sections to determine the performance limiting values for use with quartzitic gravels. The maximum aggregate size used in this case is 19mm.

Baseline monitoring was undertaken at this section in July-August 2011. Since then monitoring has been carried out in March 2012 and in September 2012.

4.2 Traffic Counts

The traffic flow on this road is really low as can be seen from Table 4-1. This could be because large stretches of the road are very rough. In the last year or so, a few articulated logging trucks started using the road.

Table 4-1 Traffic count on Inhacufera - Machaze road

| Vehicle Type | 5hr Count | 12hr Projection |
|---------------------|------------------|------------------------|
| Light vehicles | 9 | 12 |
| Trucks (2-axle) | 2 | 3 |
| Articulated Truck | 4 | 5 |
| | | |
| Estimated vpd | | 20 |

4.3 Rutting

As seen in Table 4-2, no significant rutting of the base has occurred and none is expected considering the level of traffic and the fact that a quartzitic gravel base was used.

4.4 Texture Depth

The texture depths shown in Table 4-3 are higher than in Cumbana-Chacane due to the fact that 19mm maximum aggregate size was used as opposed to a maximum of 13mm used in Cumbana.

The high values show that the level of migration of the bitumen into the aggregate is low. In fact, in appearance this Otta Seal surfacing looks like a surface dressing.

Table 4-2 Rutting values on Inhacufera - Machaze road

| Chainage | Rutting Value (mm) | | Differential Rutting Value (mm) |
|----------|--------------------|-------------|---------------------------------|
| | July 2011 | August 2012 | |
| 5+500 | 0 | 5 | 5 |
| 6+500 | 3 | 3 | 0 |
| 7+000 | 12 | 4 | 0 |
| 7+500 | 3 | 3 | 0 |
| 8+000 | 6 | 6 | 0 |
| 8+500 | 5 | 5 | 0 |
| 8+900 | 6 | 4 | 0 |
| 9+500 | 6 | 6 | 0 |
| 10+000 | 6 | 6 | 0 |
| 11+000 | 7 | 10 | 3 |
| 11+050 | 4 | 7 | 3 |
| 11+186 | 3 | 3 | 0 |

Table 4-3 Texture depth values on Inhacufera - Machaze road

| Phase 2 Sections | Bitumen Spray Rate (l/m ²) | Jul-11 (mm) | Mar-12 (mm) | Aug-12 (mm) |
|------------------|--|-------------|-------------|-------------|
| 1 | 1.80 | 4.5 | 4.4 | 3.6 |
| 2 | 1.80 | 3.0 | 4.4 | 2.9 |
| 3 | 1.74 | 2.8 | 3.6 | 3.1 |
| 4 | 1.76 | 2.5 | 3.3 | 2.9 |
| 5 | 1.80 | 4.2 | 3.1 | 3.2 |
| 6 | 2.00 | 3.2 | 3.1 | 2.9 |
| 7 | 2.00 | 4.2 | 3.2 | 2.9 |
| 8 | 2.00 | 4.6 | 4.1 | 5.5 |
| 9 | 1.80 | 3.4 | 3.9 | 3.3 |
| 10 | 1.60 | 6.1 | 5.2 | 4.8 |
| 11 | 1.60 | 5.0 | 4.4 | 4.2 |
| 12 | 1.80 | 5.8 | 5.5 | 4.6 |
| 13 | 1.00 | 1.4 | 1.6 | 1.1 |
| 14 | 1.00 | 1.5 | 1.4 | 1.1 |
| Average | | 3.7 | 3.7 | 3.3 |

4.5 Roughness

The roughness of the sections studied is shown as time-series data in Table 4-4 below. The values are satisfactory for rural roads. These values are well below that registered on gravel roads, stressing the importance of sealing roads at the very least with low cost thin surfacings. No explanation can be found for the high values exhibited in March 2012.

Table 4-4 Roughness values on Inhacufera - Machaze road

| Phase 2 Sections | Jul-11 (m/km) | Mar-12 (m/km) | Aug-12 (m/km) |
|-------------------------|----------------------|----------------------|----------------------|
| 1 | 3.7 | 4.0 | 3.6 |
| 2 | 4.2 | 4.2 | 4.1 |
| 3 | 4.1 | 4.7 | 4.3 |
| 4 | 4.7 | 4.2 | 3.6 |
| 5 | 4.0 | 4.5 | 4.0 |
| 6 | 4.3 | 4.6 | 4.1 |
| 7 | 4.5 | 4.8 | 4.3 |
| 8 | 4.5 | 4.7 | 4.3 |
| 9 | 4.7 | 5.0 | 4.4 |
| 10 | 4.6 | 5.1 | 4.3 |
| 11 | 4.3 | 4.8 | 4.2 |
| 12 | 5.9 | 5.9 | 5.9 |
| 13 | 4.2 | 4.5 | 4.2 |

4.6 Visual condition survey

The major problem affecting this section is the aggregate loss at the curves, slopes and breaking zones as shown in Table 4-5. This has been aggravated by the fact that migration of the bitumen through the aggregate was poor. Mitigation measures for this defect to be considered in lifecycle cost terms are application of a fog spray or application of a sand seal on the Otta Seal. The mitigation measures have to be carefully designed whatever the case.

Table 4-5 Potholing and aggregate loss areas on Inhacufera – Machaze road

| Phase 2 Sections | Bitumen Spray Rate (l/m ²) | Defect Area (m ²) | | | Remarks |
|------------------|--|-------------------------------|--------|--------|---|
| | | Jul-11 | Mar-12 | Aug-12 | |
| 5+000-5+500 | 1.80 | | 0.4 | | Centre minor aggregate loss |
| 5+500-6+000 | 1.80 | | | | |
| 6+000-6+500 | 1.74 | | 480.0 | 500.0 | All over minor aggregate loss |
| 6+500-7+000 | 1.76 | | | | |
| 7+000-7+500 | 1.80 | | | | |
| 7+500-8+000 | 2.00 | | 9.0 | 15.0 | All over minor aggregate loss |
| 8+000-8+500 | 2.00 | | | | |
| 8+500-8+900 | 2.00 | 95.0 | 95.0 | 95.0 | Minor aggregate loss on curves and slopes |
| 8+900-9+500 | 1.80 | 15.0 | 15.0 | 15.0 | Aggregate loss at centre joints |
| 9+500-10+000 | 1.60 | 35.0 | 660.0 | 660.0 | Minor aggregate loss on breaking zones & curves |
| 10+000-10+500 | 1.40 | | | | |
| 10+500-11+000 | 1.80 | | | | |
| 11+000-11+500 | 1.00 | 0.3 | 89.0 | 100.0 | Potholing all over on Sand Seal Section |

4.7 DCP Strength Test

The in-situ strengths measured by DCP and shown in Table 4-6 are high for low volume roads but are expected since a quartzitic natural gravel was used in the base course.

Table 4-6 In-Situ DCP CBRs on Inhacufera - Machaze road

| Date: | 02/09/2012 | |
|----------|---------------------|----------------------|
| Chainage | Base CBR Values (%) | Location |
| 5+000 | 115 | LHS Outer Wheeltrack |
| 6+000 | 65 | LHS Outer Wheeltrack |
| 7+000 | 150 | Centreline |
| 8+500 | 150 | RHS Outer Wheeltrack |
| 9+500 | 110 | Centreline |
| 11+186 | 70 | RHS Outer Wheeltrack |

4.8 Base Moisture

The moisture values measured in the base layer shown in Table 4-7 are well below OMC meaning higher strengths are being mobilised than the 4-days soaked laboratory CBRs. Additional tests will be undertaken in the middle of the rainy season.

Table 4-7 Base moisture values on Inhacufera - Machaze road

| Date: | 05/09/2012 | | |
|-----------------|--------------------------|---------------------|----------------------|
| OMC: | 6.4% | | |
| Chainage | Base Moisture (%) | Ratio of OMC | Location |
| 6+000 | 4.7 | 0.73 | LHS Outer Wheeltrack |
| 7+000 | 4.5 | 0.70 | LHS Outer Wheeltrack |
| 8+500 | 3.3 | 0.52 | RHS Outer Wheeltrack |
| 9+500 | 2.1 | 0.33 | Centreline |
| 11+186 | 1.5 | 0.23 | RHS Outer Wheeltrack |

5 Zambezia Province: Zero – Mopeia road

5.1 Description

The project site is located about 140km South of Quelimane city – the provincial capital of Zambezia province. The site consists of 6km of Otta Seal sections constructed in Phase 2, 7km of Otta Seal sections constructed in Phase 3. The road links the town of Zero located on the N1 to the town of Mopeia located about 30km Eastwards of Zero.

Construction was completed towards the end of 2010. The pavement structure consists of Otta Seal surfacing on a base of 150mm of quartzitic natural gravel. For the Otta Seal sections, spray rates were varied on the experimental sections to determine the performance limiting values for use with quartzitic gravels. The maximum aggregate size used in this case is 13mm with more than 13% of fines in the surfacing aggregate.

A baseline monitoring was done for this section in July-August 2011. Since then monitoring has been carried out in November 2011, March 2012 and in September 2012.

5.2 Traffic Counts

The traffic shown in Table 5-1 is the highest of all the traffic on the Otta Seal roads. This is reflected in the appearance of the sections since, in this section, the road looks well cured.

Table 5-1 Traffic count on Zero - Mopeia road

| Date: | 08/09/2012 | |
|-----------------|------------|-----------------|
| Type | 7hr Count | 12hr Projection |
| Light vehicles | 20 | 34 |
| Trucks (2-axle) | 10 | 17 |
| Trucks (3-axle) | 3 | 5 |
| | | 0 |
| Estimated vpd | | 57 |

5.3 Rutting

The rutting values and differential rutting shown in Table 5-2 are well below the critical level of 20mm. Also there are no visible channelized wheel paths on the carriageway and therefore the rutting levels can be regarded as insignificant.

Table 5-2 Rutting values on Zero – Mopeia road

| Chainage | Rutting Value (mm) | | Differential Rutting Value (mm) |
|-----------------|---------------------------|-----------------------|--|
| | August 2011 | September 2012 | |
| 0+500 | 8 | 5 | 0 |
| 1+000 | 5 | 5 | 0 |
| 1+500 | 3 | 5 | 2 |
| 2+000 | 6 | 5 | 0 |
| 2+500 | 8 | 8 | 0 |
| 3+000 | 9 | 7 | 0 |
| 3+500 | 8 | 10 | 2 |
| 4+000 | 3 | 4 | 1 |
| 4+500 | 3 | 2 | 0 |
| 5+000 | 3 | 3 | 0 |
| 5+500 | 4 | 5 | 1 |
| 6+000 | 7 | 7 | 0 |
| 6+360 | 13 | 7 | 0 |
| 6+420 | 4 | 4 | 0 |

5.4 Texture Depth

The texture depths for Zero – Mopeia sections measured by use of the sand patch are as shown in Table 5-3. The values are good on safety grounds and also show that there is not much change after March 2012.

Table 5-3 Texture depths on Zero – Mopeia road

| Sections | Bitumen Spray Rate (l/m²) | Aug-11 (mm) | Mar-12 (mm) | Sep-12 (mm) |
|-----------------|---|--------------------|--------------------|--------------------|
| 1 | 1.5 | 2.5 | 2.2 | 1.7 |
| 2 | 1.5 | 1.2 | 1.0 | 1.1 |
| 3 | 1.5 | 1.3 | 1.3 | 1.5 |
| 4 | 1.5 | 2.3 | 1.5 | 2.0 |
| 5 | 1.5 | 1.9 | 1.8 | 1.5 |
| 6 | 1.5 | 2.5 | 2.4 | 2.0 |
| 7 | 1.7 | 2.5 | 2.4 | 2.4 |
| 8 | 1.7 | 2.9 | 1.1 | 1.1 |
| 9 | 1.5 | 2.1 | 1.8 | 1.5 |
| 10 | 1.5 | 1.3 | 1.0 | 1.0 |
| 11 | 1.5 | 1.5 | 1.2 | 1.3 |
| 12 | 1.5 | 2.0 | 1.2 | 1.3 |
| 13 | 1.5 | 1.6 | 1.7 | 1.6 |
| 14 | 1.2 | 2.2 | 1.3 | 2.0 |
| Average | 1.5 | 2.0 | 1.6 | 1.6 |

The texture depths are less than those observed on Inhacufera – Machaze road partly because of the maximum aggregate size of 13mm. Other possible reasons for the lesser texture depth can be attributed to the difference in gradation of the two aggregate types used at the two sites or the difference in traffic levels on the two roads with the gradation on Zero – Mopeia being preferred.

5.5 Roughness

The roughness values obtained by means of a bump integrator are shown in Table 5-4. The roughness values are low and impressive for a rural road and remain fairly constant over the period monitored so far. The high values in March 2012 can be attributed to the potholes that were present around that time.

Table 5-4 Roughness values on Zero – Mopeia road

| Sections | Aug-11 (m/km) | Mar-12 (m/km) | Sep-12 (m/km) |
|-----------------|--------------------------|--------------------------|--------------------------|
| 1 | 2.9 | 3.7 | 2.9 |
| 2 | 2.5 | 3.1 | 2.5 |
| 3 | 2.7 | 3.6 | 2.9 |
| 4 | 3.1 | 3.8 | 3.2 |
| 5 | 2.7 | 3.4 | 2.8 |
| 6 | 3.6 | 4.7 | 3.5 |
| 7 | 2.8 | 3.6 | 2.8 |
| 8 | 2.5 | 3.0 | 2.4 |
| 9 | 2.5 | 3.1 | 2.6 |
| 10 | 2.9 | 3.9 | 3.0 |
| 11 | 2.3 | 3.0 | 2.6 |
| 12 | 2.3 | 3.0 | 2.4 |
| 13 | 2.6 | 4.3 | 3.0 |

5.6 Visual condition survey

As shown in Table 5-5, minor potholing was observed in March 2012. This has since been patched and the road is now smooth again. The potholing in section 13 was mainly due to the turning movement of construction vehicles.

Table 5-5 Potholing areas on Zero – Mopeia road

| Sections | Bitumen Spray Rate (l/m²) | Nov-11 (m²) | Mar-12 (m²) | Sep-12 (m²) |
|-----------------|---|-----------------------------------|-----------------------------------|-----------------------------------|
| 1 | 1.5 | 0.0 | 0.0 | 0.0 |
| 2 | 1.5 | 0.0 | 0.2 | 0.0 |
| 3 | 1.5 | 0.0 | 2.8 | 0.0 |
| 4 | 1.5 | 0.0 | 0.0 | 0.0 |
| 5 | 1.5 | 0.1 | 0.6 | 0.0 |
| 6 | 1.5 | 0.0 | 0.4 | 0.0 |
| 7 | 1.7 | 0.0 | 0.0 | 0.0 |
| 8 | 1.7 | 0.0 | 0.0 | 0.0 |
| 9 | 1.5 | 0.0 | 0.0 | 0.0 |
| 10 | 1.5 | 0.0 | 0.0 | 0.0 |
| 11 | 1.5 | 0.1 | 0.3 | 0.0 |
| 12 | 1.5 | 0.0 | 0.6 | 0.0 |
| 13 | 1.5 | 0.0 | 7.1 | 0.0 |

Minor transverse and longitudinal cracks were observed between chainage 5+000 and 6+400. A DCP test done near the cracked section reveals a weak subgrade. The area being low lying and a bit swampy would suggest the presence of a slightly expansive clay underneath.

5.7 DCP Strength Test

The in-situ CBRs shown in Table 5-6 below are again good for low volume roads. A value of about 120% recorded at the chainage 6+000 was close to a longitudinal crack which suggests a different source of cracking rather than inadequate base strength.

Table 5-6 In-Situ DCP CBRs for base material on Zero – Mopeia road

| | | |
|-----------------|----------------------------|----------------------|
| Date: | 10/09/2012 | |
| OMC: | 8.50% | |
| Chainage | Base CBR Values (%) | Location |
| 0+500 | 70 | LHS Outer Wheeltrack |
| 1+500 | 60 | Centreline |
| 2+500 | 145 | RHS Outer Wheeltrack |
| 3+500 | 55 | LHS Outer Wheeltrack |
| 4+500 | 60 | Centreline |
| 6+000 | 120 | RHS Outer Wheeltrack |
| 6+900 | 125 | LHS Outer Wheeltrack |
| 7+900 | 85 | Centreline |

5.8 Base Moisture

Though measured in the dry season, the base moistures shown in Table 5-7 are well below the OMC. This is good to note since it implies that for long periods of time, the strength mobilised by the base is well above laboratory 4-day soaked values. Another set of tests will be carried out in the rainy season.

Table 5-7 Base moisture values on Zero – Mopeia road

| | | | |
|-----------------|--------------------------|---------------------|----------------------|
| Date: | 10/09/2012 | | |
| OMC: | 8.5% | | |
| Chainage | Base Moisture (%) | Ratio of OMC | Location |
| 0+500 | 4.2 | 0.49 | LHS Outer Wheeltrack |
| 1+500 | 4.3 | 0.51 | Centreline |
| 3+500 | 2.1 | 0.25 | LHS Outer Wheeltrack |
| 4+500 | 3.7 | 0.44 | Centreline |
| 6+000 | 2.5 | 0.29 | RHS Outer Wheeltrack |
| 7+900 | 3.7 | 0.44 | Centreline |

6 Cabo Delgado Province: Xitaxi – Mueda road

6.1 Description

The project site is located about 240km North of Pemba city – the provincial capital of Cabo Delgado province. The site consists of a total of 1.3km of Single Surface dressed sections constructed in phase 2, and a mix of Surface Dressed sections and Concrete Ramp sections constructed in Phase 1. The road serves as a shorter but steeper link to the town of Mueda located close to the border with Tanzania.

Construction was completed towards mid-2010. The pavement structure consists of Single Surface Dressed surfacing on a base of 150mm of cement stabilised sand (4%) and a neat sand sub-base of 150mm.

Baseline monitoring was undertaken for this section in July-August 2011. Since then monitoring was carried out in September 2012.

6.2 Traffic Counts

Traffic on this road is low and mainly composed of light vehicles as can be seen in Table 6-1 below. This is because of the very steep incline that makes it difficult for heavily loaded trucks and buses to climb.

Table 6-1 Traffic count on Xitaxi – Mueda road

| Date: | 14/09/2012 | |
|-----------------|------------|-----------------|
| Type | 8hr Count | 12hr Projection |
| Light vehicles | 12 | 18 |
| Trucks (2-axle) | 6 | 9 |
| Trucks (3-axle) | 2 | 3 |
| | | |
| Estimated vpd | | 30 |

6.3 Rutting

Cement stabilised bases are not expected to rut therefore the differential rutting shown in

Table 6-2 is low, as expected. The values seen at chainage 1+255 occur in a depression rather than a rut. A DCP test was carried out at this point and revealed a very low base strength of in-situ CBR 25%. It is probable that at this spot and also where potholing occurred, there were pockets of base sand that did not contain any cement.

Table 6-2 Rutting values on Xitaxi – Mueda road

| Chainage | Rutting Value (mm) | | Differential Rutting Value (mm) |
|----------|--------------------|----------------|---------------------------------|
| | August 2011 | September 2012 | |
| 0+000 | 4 | 5 | 1 |
| 0+100 | 4 | 4 | 0 |
| 0+205 | 8 | 8 | 0 |
| 0+295 | 3 | 5 | 2 |
| 0+305 | 9 | 9 | 0 |
| 0+445 | 8 | 8 | 0 |
| 0+455 | 3 | 6 | 3 |
| 1+245 | 6 | 8 | 8 |
| 1+255 | 23 | 21 | 0 |
| 1+655 | 9 | 11 | 2 |
| 1+665 | 5 | 5 | 0 |

6.4 Texture Depth

The texture depths shown in Table 6-3 are typical of those that are observed on Single Surface Dressings with 14mm chippings.

Table 6-3 Texture depth values on Xitaxi – Mueda road

| Sections | Bitumen Spray Rate (l/m ²) | Aug-11 (mm) | Sep-12 (mm) |
|----------|--|-------------|-------------|
| 1 | 1.4 | 2.2 | 2.2 |
| 2 | 1.4 | 3.3 | 3.0 |
| 3 | 1.4 | 3.6 | 2.6 |
| 4 | 1.4 | 2.8 | 2.9 |
| 5 | 1.4 | 2.5 | 3.6 |
| 6 | 1.4 | 3.9 | 3.8 |

6.5 Roughness

The roughness values shown in Table 6-4 are rather high for surfaced roads and, considering the fact that there are not many potholes on the road, the high values can be attributed to a base course that was constructed unevenly.

On the concrete ramps, the high roughness values occur as a result of the differences between the slab joints that cause the integrator to bounce and give high readings. A correction factor will be

developed through practical runs of the integrator during the next monitoring so as to be able to reasonably compare the roughness on the concrete ramps with that of the surface dressed sections.

Table 6-4 Roughness values on Xitaxi – Mueda road

| Sections | Aug-11 (m/km) | Sep-12 (m/km) | Remarks |
|------------------|------------------|------------------|----------------|
| 1 | 7.8 | 5.8 | SSD |
| 2 | 5.9 | 7.0 | SSD |
| 3 | 8.2 | 8.2 | SSD |
| 4 | 5.4 | 5.6 | SSD |
| Phase 1 Sections | | | |
| 5 | 6.7 | 7.8 | SSD |
| 6 | 14.0 | 13.9 | Concrete Slabs |
| 7 | 15.0 | 15.8 | SSD |
| 8 | 7.1 | 7.6 | Concrete Slabs |
| 9 | 7.8 | 8.7 | SSD |

6.6 Visual condition survey

The workmanship of the surface dressings constructed under phase 2 gives a non-aesthetic appearance, however, functionally the dressings appear to be performing adequately. The usual block cracks associated with stabilised bases can be seen but the widths are all only about 1mm.

6.7 DCP Strength Test

The in-situ CBRs shown in Table 6-5 are quite low for cement stabilised sand bases and also low compared to any of the other natural gravel bases. However if the traffic does not grow sharply, it may suffice.

Table 6-5 In-situ DCP CBRs of the base material on Xitaxi – Mueda road

| Date: | 14/09/2012 | |
|----------|---------------------|----------------------|
| Chainage | Base CBR Values (%) | Location |
| 0+005 | 85 | LHS Outer Wheeltrack |
| 0+295 | 45 | RHS Outer Wheeltrack |
| 0+445 | 75 | Centreline |
| 0+800 | 35 | RHS Outer Wheeltrack |
| 1+245 | 50 | RHS Outer Wheeltrack |
| 1+255 | 40 | LHS Outer Wheeltrack |
| 1+255 | 25 | LHS Outer Wheeltrack |

6.8 Base Moisture

Like all the other bases on the other project sites, the moistures shown in Table 6-6 are well below the OMC. Another set of moistures will be determined in the rainy season to establish the two extreme values.

Table 6-6 Base moisture values on Xitaxi – Mueda road

| | | | |
|-----------------|--------------------------|---------------------|----------------------|
| Date: | 15/09/2012 | | |
| OMC: | 8.4% | | |
| Chainage | Base Moisture (%) | Ratio of OMC | Location |
| Section 1 | 6.5 | 0.77 | LHS Outer Wheeltrack |
| Section 2 | 5.7 | 0.68 | RHS Outer Wheeltrack |
| Section 3 | 3.8 | 0.45 | Centreline |
| Section 4 | 7.2 | 0.86 | RHS Outer Wheeltrack |
| Section 4 | 3.0 | 0.36 | LHS Outer Wheeltrack |
| Section 5 | 8.1 | 0.96 | LHS Outer Wheeltrack |
| Section 5 | 4.7 | 0.56 | LHS Outer Wheeltrack |

7 Conclusions

7.1 Challenges faced

Several challenges have been faced during the monitoring so far carried out. The major ones are:

1. The faulty ROMDAS bump integrator that took a lot of time trying to fix but eventually still failed to work. Eventually TRL provided its own bump integrator for the measurement of Roughness
2. The straight edge and wedge supplied under the project were too long and inflexible to be transported to site easily. The wedges were also too small and without handles. TRL provided its own equipment.
3. The DCPs that were supplied under the project were of poor build, weak and often bent or broken. Again TRL provided its own DCP.

7.2 Preliminary conclusions

Based on data collected so far and observations made on site, the following preliminary conclusions can be drawn:

- Otta Seals generally offer good protection to bases of marginal materials as can be seen by high in-situ CBRs and low moisture contents.
- The initial rolling of Otta Seals plays an important role in the migration of bitumen through the aggregate. This can be seen by texture depths that do not decrease significantly just a few months after the construction.
- Generally the use of larger maximum aggregate sizes in Otta Seal aggregates will require extra rolling or trafficking for the bitumen to work its way up. In the event that this does not happen, aggregate loss is bound to occur during later trafficking of the road especially on slopes, curves and breaking zones as was the case on the Inhacufera - Machaze road
- Base moistures, at least in the dry season, remain well below the OMC of the material; the same remains to be seen during the tests programmed for the rainy season.
- All the different base materials used (calcrete/sand mixtures, quartzitic natural gravels, cement stabilised sand bases, and emulsion stabilised sand bases) for the projects have not shown any significant rutting and they may be used whenever they are widely available.
- When bases are trafficked before they are surfaced, the resultant final roughness after surfacing remains high as is the case of the values seen in Cumbana-Chacane and therefore trafficking should be minimised before surfacing. Conversely the roughness of Zero-Mopeia road remains low.
- For the case of gravel roads of the calcrete/sand mix, the gravel loss is quite low but the roughness increases dramatically and to minimise this sharp rise in roughness, light grading and compaction is advised at least once a year.

7.3 Upcoming tasks

To enable a more effective outcome from this phase of the AFCAP Project, the results have to be collated with the results obtained from the sister project "Analysis of the Performance of Previous Low Volume Roads" (AFCAP/MOZ/001/G). These results will be examined together when the two projects are drawing to close in March 2013.

The most vital data set that currently remains to be collected is the base course moistures and in-situ strengths for all the sites in the middle of the rainy season in February 2013. This will enable the determination of the level of relaxation of standards for base material CBR testing from say 4-days soaked values to OMC or 2-days soaked CBRs.

For the case of Marracuene – Macaneta, it would be very beneficial to take advantage of the Light Weight Deflectometer that is currently in Mozambique and measure the pavement stiffness. It is believed that the pavement stiffness of the ETB in Marracuene may not be very different from that of the N1 trunk road despite the low-cost of constructing the former. It is also believed that the ETB technique may be an inexpensive method to construct and rehabilitate city streets in Mozambique as an added benefit to its current application in rural roads.