TAN008

Design, Construction and Monitoring of Demonstration Sites for District Road Improvement in Tanzania to the Prime Minister's Office – Regional Administration and Local Government (PMO-RALG) under the African Community Access Programme (AFCAP)

Siha Final Monitoring Report

June *2013*

This project was funded by the Africa Community Access Programme (AFCAP) which promotes safe and sustainable access to markets, healthcare, education, employment and social and political networks for rural communities in Africa.

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.

This material has been funded by UKaid from the Department for International Development, however the views expressed do not necessarily reflect the department's or the managing agent's official policies.

For further information visit
https://www.afcap.org

DESIGN, CONSTRUCTION AND MONITORING OF DEMONSTRATION SITES FOR DISTRICT ROAD IMPROVEMENT IN TANZANIA TO THE PRIME MINISTER'S OFFICE – REGIONAL ADMINISTRATION AND LOCAL GOVERNMENT (PMO-RALG) UNDER THE AFRICAN COMMUNITY ACCESS PROGRAMME (AFCAP)
CONTRACT REFERENCE: TAN008
REPORT TITLE: SIHA FINAL MONITORING REPORT
DATE: 7TH JUNE 2013

Notice

This report was produced by Roughton International Limited for AFCAP for the specific purpose of providing a record of the monitoring reports

This report may not be used by any other person without express permission. In any event Roughton International Limited accepts no liability for any costs, liabilities or losses arising as a result of the use of or reliance up the contents of this report by any person other than AFCAP

Document History

JOB NUMBER:			DOCUMENT REF:			
-	For Information	Victor Rogers	Ramsey Neseyif	Ramsey Neseyif	Simon Gillett	13/06/07
Revision	Purpose Description	Originated	Checked	Reviewed	Authorised	Date

Research Consultant to Support the Design, Construction and Monitoring of Demonstration Sites for District Road Improvement in Tanzania

Contract Reference: AFCAP/TAN/008

Monitoring Report Siha

List of Tables

List of Figures

Appendices

ACKNOWLEDGEMENTS

This report was prepared by Roughton International. This work would not be a success without the commitment of the Prime Ministers Office-Regional and Local Government in particular Ms. Elina Kayanda.

Eng. Meleck Silaa, the District Engineer of Siha region, and his team has been helpful throughout the construction phase of the Lawate – Kibongoto road construction and on site assistance and supervision provided by Robert Ayieko of Roughton International has been crucial to the progress of this project.

The assistance provided by John Malissa and Salahe Juma and staff of the Central Materials Lab in Dar Es Salaam throughout the initial monitoring process in Bagamoyo is greatly appreciated.

A great many people and organisations have made significant contributions to the research of this project. Most notably DIFID and AFCAP. Their co-operation is much appreciated and gratefully acknowledged.

EXECUTIVE SUMMARY

The Prime Minister's Office of Regional Administration and Local Government (PMO-RALG) has set up the Local Government Transport Programme (LGTP), with the aim of supporting rural development and poverty alleviation. The Africa Community Access Programme (AFCAP) has subsequently been asked by PMO-RALG to assist with the implementation of demonstration sites in selected districts in Tanzania. The goal of AFCAP is to promote low cost, sustainable solutions for rural access. Improving the sustainability and affordability of rural access will lead to improved access to economic opportunities and health and education services; thereby creating opportunities for pro-poor growth and poverty alleviation.

Following completion of construction works in Siha in September 2012, baseline monitoring data was collected for comparison with data collected in subsequent monitoring periods in order to assess the performance and suitability of the various surfacing options. The final monitoring stage has now been completed. It was observed during the monitoring stage that most of the sections have performed well, particularly the double surface dressing, concrete paving blocks and concrete geocell. The concrete slab sections have successfully achieved the overall goal of providing all weather access along the road, although there is large amount of cracking particularly in the unreinforced slab. This is likely to be due to issues with the concrete mix and quality control issues during construction.

This report details the findings from the data collection during monitoring, interpretation of the data, conclusions drawn and subsequent recommendations. Now that monitoring with the assistance of the Consultant is complete, the monitoring will be carried out annually by the District Engineers for a period of eight years.

1.0 INTRODUCTION

1.1 Project Background

The Africa Community Access Programme (AFCAP) has been asked by PMO-RALG to assist with the implementation of demonstration sites in selected districts in Tanzania. The aim of this AFCAP project is to improve sustainable access to economic and social opportunities for poor rural communities in Tanzania. A further aim of the project is to provide all weather access on district roads using Environmentally Optimised Design (EOD).

A number of demonstration sections were constructed at Siha including gravel sections, concrete paving blocks, concrete strips, unreinforced concrete slabs, lightly reinforced concrete slabs, double surface dressing and bituminous penetration macadam. These pavements will improve problematic sections of the road so that all weather access is provided, dramatically reduce the demand for gravel, provide a smoother running surface to reduce vehicle operating costs, reduce travel times and reduce dust pollution.

The construction of the demonstration sections at Siha was completed in September 2012 and monitoring data has been collected in January 2013 and again in April 2013, in order to make an assessment on the performance of the sections.

1.2 Objectives of the Monitoring

The objectives of the monitoring phases are as follows:

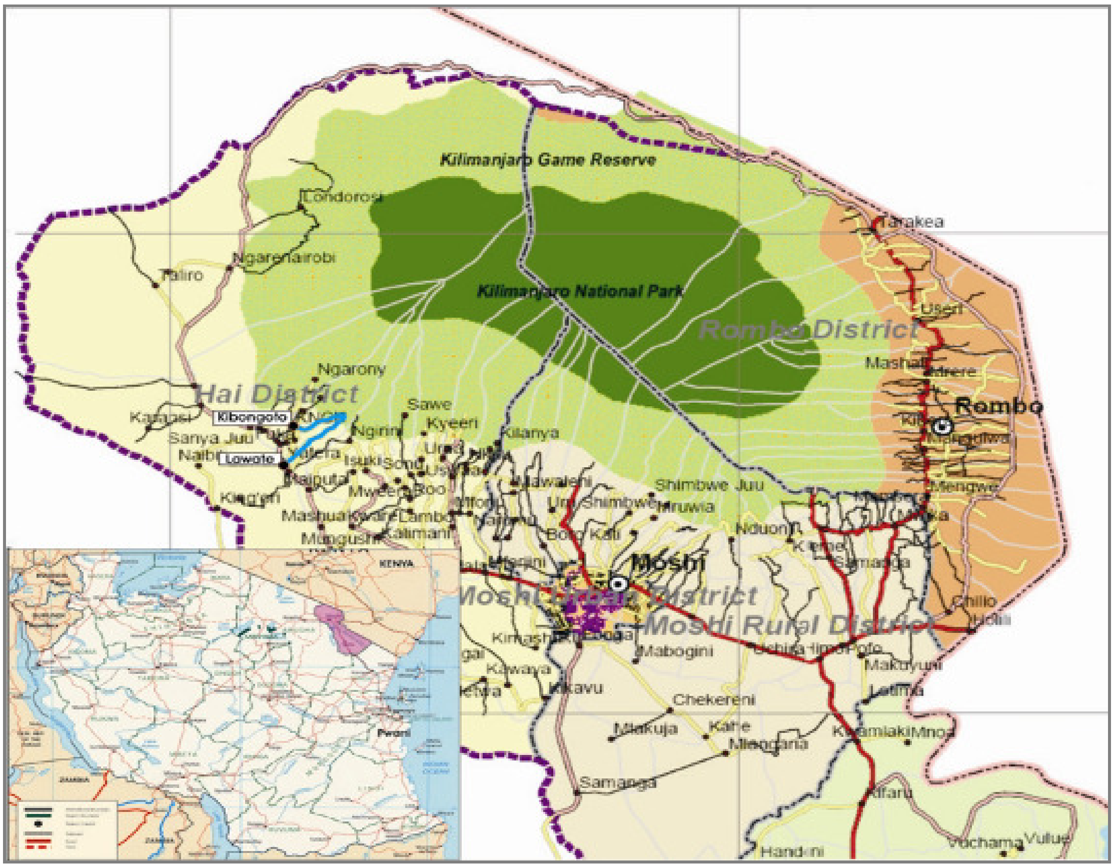
- Visually assess which of the demonstration sections have performed well and which have deteriorated rapidly, and assess the suitability of the sections.
- Assess the performance of the sections using a variety of methods including roughness measurements using the MERLIN device, DCP testing, rut depth measurements and surface profile measurements.

The monitoring phase of this project is crucial for identifying the performance of the various demonstration sections, their cost effectiveness and suitability for use on other projects. It is therefore apparent that sufficient data collection and interpretation is fundamental in achieving the long term goals of the AFCAP project, which is to increase safe, reliable and sustainable access to vital services for communities in rural Africa.

1.3 Project Site

The road is located in the foothills of Kilimanjaro in Siha District and is steep and winding in nature, passing through agricultural landscape. The road is 13.48 km long, beginning at the small town of Lawate and meandering towards Kibongot'o, passing through a number of small farms. Construction was largely completed by October 2012. The baseline monitoring in Siha was carried out in January 2013, with a subsequent monitoring visit in April 2013. The location of the road is shown in Figure 1.

Figure 1: Location of the Lawate – Kibongot'o Road



1.4 Purpose of this Report

The purpose of this report is as follows:

- To describe the monitoring methods used in order to collect the data.
- The present the findings of the monitoring and interpretation of the data collected.
- To draw conclusions on the performance of the sections and make recommendations.

2.0 DESIGN OF THE SECTIONS

2.1 Pavement Design

The pavement designs used in Siha are shown in Table 1 and the chainages at which these pavements were constructed are shown in Table 2. A range of different surfacing options were trialed at these two sites. The pavement design for Siha was carried out using the DCP design method, in order to achieve pavement designs that are economical and appropriate for the low volume rural roads.

The subgrade at the Siha site was found to be stronger than in Bagamoyo and therefore only one base layer was required. Various concrete sections were selected at Siha due to the steep slopes found on this site. The concrete surfaces give strength to the pavement whereas the bituminous surfaces do not; for this reason a thicker base layer constructed from stronger material was required for the bituminous sections. Further details of the pavement design are given in the Design Report as well as the Siha Final Rescope Report.

2.2 Geometric Design

A camber of 6% was used for gravel sections 4% for the paved sections. Carriageway widths at Siha are 6 m at the concrete paving block section, 5 m at bituminous sections, 4 m at concrete geocell and concrete slab sections with 0.5 m shoulders, 4.4 m at the concrete strip sections and 5 m at the gravel sections.

2.3 Drainage

Many existing drainage structures including culverts and drifts were present at Siha. Substantial improvement to the side drains was carried out including establishment of unlined drains as well as construction of masonry lined drains where necessary, as adequate drainage is critical to the performance of the pavements.

Table 1: Pavement Designs for the Siha Site

Surfacing Type	Pavement Layers (mm)					
	G30		G60		GWC	
Concrete Paving Blocks	100	CQ	-	-	-	-
Flexible Geocells (75mm)	100	CQ	-	-	-	-
Unreinforced Concrete Slab (75mm)	100	CQ	-	-	-	-
Unreinforced Concrete Slab (100mm)	100	CQ	-	-	-	-
Concrete Strips	100	CQ	-	-	-	-
Lightly Reinforced Concrete Slab (100mm)	100	CQ	-	-	-	-
Lightly Reinforced Concrete Slab (75mm)	100	CQ	-	-	-	-
Double Surface Dressing	-	-	150	CQ	-	-
Bituminous Penetration Macadam	-	-	150	CQ	-	-
Gravel Wearing Course	-	-	-	-	150	GP
Scarification of Existing Gravel	-	-	-	-	-	-

Note: CQ = Contractor's Quarry

GP = Gravel Pit

Table 2: Demonstration Sections in Siha

Section	Chainage (km)		Length (km)	Surfacing Type
	Start	End		
1	0.000	0.200	0.200	Concrete Paving Blocks
2	1.360	1.500	0.140	Unreinforced Concrete Slab (100mm)
3	1.960	2.180	0.220	Flexible Geocells (75mm)
4	2.180	2.580	0.400	Unreinforced Concrete Slab (75mm)
5	2.580	2.780	0.200	Gravel Wearing Course
6	2.780	3.640	0.860	Concrete Strips
7	4.340	4.540	0.200	Double Surface Dressing
8	4.540	4.780	0.240	Concrete Strips
9	4.780	5.000	0.220	Unreinforced Concrete Slab (100mm)
10	5.000	6.100	1.100	Concrete Strips
11	6.340	6.620	0.280	Unreinforced Concrete (100mm)
12	7.720	8.260	0.540	Concrete Strips

Section	Chainage (km)		Length (km)	Surfacing Type
	Start	End		
13	9.670	9.900	0.230	Unreinforced Concrete (75mm)
14	10.100	10.300	0.200	Concrete Strips
15	10.680	11.200	0.520	Concrete Strips
16	11.620	11.820	0.200	Bituminous Penetration Macadam
17	11.820	12.120	0.300	Lightly Reinforced Concrete Slab (100mm)
18	12.280	12.560	0.280	Lightly Reinforced Concrete Slab (75mm)
19	12.640	13.070	0.430	Lightly Reinforced Concrete Slab (100mm)
20	13.070	13.480	0.410	Gravel Wearing Course
	Total Length		7.170	

3.0 MONITORING METHODS

3.1 Overview

Base line data was collected following construction completion on the Bagomoyo and Siha project sites. Further sets of data were then collected at six month intervals in order to facilitate comparison and analysis, enabling conclusions on the pavement performance over time and suitability of the sections to be drawn. The pavement performance is assessed by comparing the six monthly monitoring results with the base line data.

In order to monitor the demonstration sections, monitoring beacons are required at regular intervals along the implemented pavement options. The spacing of the monitoring beacons is dependent on the length of the demonstration section; on sections less than 200 m in length the monitoring beacons are installed at 10 m intervals and on sections over 200 m in length the beacons are installed at 20 m intervals. The monitoring beacons serve the following purposes:

- To divide up the demonstration section into manageable segments to allow easy identification of the various areas, and;
- To provide a consistent and easy identification of the monitoring test points during the long term monitoring framework.

The following monitoring methods are used:

- Visual inspection;
- Photographic logging;
- Surface profile measurement between beacons;
- Surface rut measurement using a standard straight edge;
- Surface roughness using a MERLIN apparatus;
- Surface texture measurement using sand patch testing;
- Dynamic Cone Penetrometer (DCP) testing;
- Classified traffic counts, and;
- GPS Survey.

3.2 Visual Inspection

A visual inspection foot survey is carried out along all sections. The inspection allows for the location of various modes of surface distress and deformation to be recorded, thus creating a historical reference of the deterioration of the demonstration section surfaces in each survey. Modes of surface distress recorded include cracking, pot holing, corrugations, edge wear, erosion and drainage defects.

3.3 Photographic Logging

Photographic logging is carried out on all demonstration sections and provides a visual record of the deterioration identified in the visual inspection. Photographs are taken at each monitoring beacon along all of the demonstration sections in order to provide a visual record of any changes in the appearance of the road over the monitoring period. Each trial section is photographed from the centreline of the road at each beacon location, ensuring the photograph is taken at head height with the road surface in the centre of the photograph. This ensures that each section is photographed from approximately the same position throughout all monitoring periods.

3.4 Surface Profile Measurement

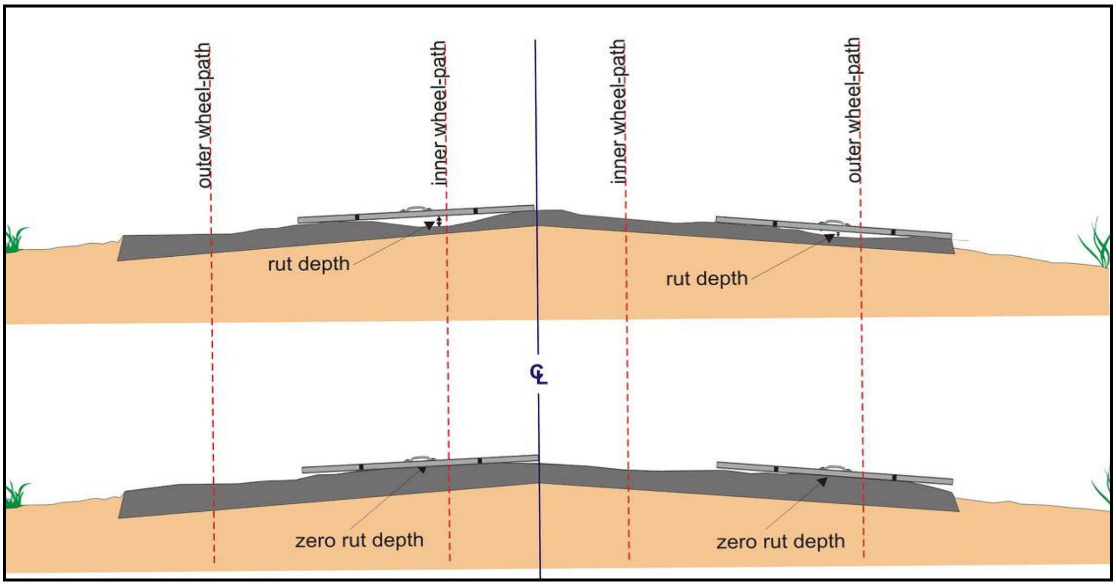
A staff and dumpy level are used to take surface profile measurements at each beacon location, so that any changes in the surface profile between each monitoring phase can be measured. Levels are taken at regular intervals across the cross-section, so that the surface profile levels can be determined. This method of measuring the surface profile is shown in Figure 2.

Figure 2: Surface Profile Measurement

3.5 Surface Rut Measurement

Rut depth measurement is carried out using a 2 m straight edge and a wedge. The wedge is marked at 1 mm increments of its depth so that when pushed under the straight edge, the depth of the rut will be indicated. Measurements are carried out across each wheel path of the carriageway as shown in Figure 3. For a single lane carriageway rut depth measurement should be taken either side of the centreline and not from the carriageway edge.

Figure 3: Rut Depth Measurement



3.6 Surface Roughness Measurement

Surface roughness measurement should be carried out using MERLIN apparatus, which records the longitudinal unevenness of a road surface by taking numerous readings along the wheel path. Taking two hundred readings along the wheel path of a road section will produce a histogram, from which a value of the International Roughness Index (IRI) can be calculated. A full, detailed user guide on the MERLIN roughness machine is given in TRL Report 229[1]. It is to be noted that there is an inherent standard error in the IRI value calculated using the MERLIN apparatus. This error is given to be up to 10%. The MERLIN apparatus is shown in Figure 4.

[1] ***The MERLIN road roughness machine: User Guide TRL Report 229,*** *M A Cundill, Transport Research Laboratory, Berkshire, 1996.*

Figure 4 MERLIN Apparatus

3.7 Surface Texture Measurement

The sand patch method is used on bituminous sections to measure surface texture, and takes place at each set of monitoring beacons in order to provide consistency in future monitoring phases. During the test procedure a measuring cylinder is filled with a measured quantity of sand, which is then poured onto the surface and spread into a circular patch. The diameter of the sand patch is measured at four diameters and the mean diameter is calculated; the mean diameter is then used to calculate surface texture. This method is illustrated in Figure 5.

Figure 5: Sand Patch Testing

3.8 Dynamic Cone Penetrometer Testing

The Dynamic Cone Penetrometer (DCP) is an instrument designed for the rapid in-situ measurement of the structural properties of existing road pavements or existing subgrade. Where pavement layers have different strengths the boundaries can be identified and the thickness of the layers determined. With a team of three operators, the instrument provides a quick and efficient method of obtaining information and tests are carried out at each set of monitoring beacons on all bituminous and gravel demonstration sections. The DCP device consists of an 8 kg weight dropping through a height of 575 mm, delivering a blow onto a penetration cone. The depth of penetration below the road surface is recorded every five blows; continuous measurements are taken until the penetration reaches a depth of 800 mm. The DCP method is shown in Figure 6.

Figure 6 DCP Testing

3.9 Classified Traffic Counts

Manual traffic counts are carried out at an observation point on the side of the road. Each passing vehicle is recorded on a survey form according to the vehicle type and the hour in which the vehicle was observed, traffic is counted in both directions for the duration of the counts. Due to the six month intervals of the monitoring periods, an assessment on seasonal variation of the traffic flows can be made.

3.10 GPS Survey

A GPS survey consists of a drive through along the project road at a target constant speed using a handheld GPS device, which will then record a GPS track and the speed along the road during the drive through. If this is carried out at each monitoring phase, the variation in actual travel speed over time can be assessed. Areas where the actual speed is significantly lower in the target speed can indicate the location of difficult spots along the road.

4.0 PERFORMANCE OF THE DEMONSTRATION SECTIONS

4.1 Monitoring programme

The baseline monitoring data for the Siha site was collected in January 2013, with one subsequent monitoring trip taking place in April 2013. During the gathering of baseline data at Siha it was noted that monitoring beacons had not been constructed, meaning that the use of makeshift spray painted markers as a substitute was necessary. This raises issues about the reliability of the measurements being taken on exactly the same points during future monitoring surveys. A method of marking monitoring beacons using a GPS device could be more accurate, although physically constructed markers are felt to be more reliable in case GPS data is lost over long monitoring periods.

During the monitoring at the Siha site some of the concrete sections are showing defects such as cracking, particularly in the unreinforced slabs. Some sections, such as the double surface dressing and the concrete paving blocks, are performing well.

The overall performance of the sections has been visually recorded in the photographic logging. A representative photograph of each section is given in the Monitoring CD. The photographic logging from each monitoring stage is included in the CD in Appendix A. The monitoring data is also included on the CD. Further details of the monitoring phases are given in the Quarterly Reports during the Monitoring Phase.

4.2 Concrete Strips

The concrete strip sections in Siha have performed fairly well and have been successful in providing all weather access at these locations. However there are some defects that have occurred in places, including longitudinal cracks, failed crack repair and pieces of aggregate protruding through the surface. Gravel erosion is apparent along the central gravel part of the sections. There are footprints in the concrete as well as motorcycle tracks.

4.3 Unreinforced Concrete Slab

Whilst the unreinforced concrete slab sections at Siha are currently achieving the ultimate goal of providing all weather access, many defects in the concrete have been observed, including longitudinal and transverse cracks, failed crack repairs, aggregate protruding through the surface, slight depressions and footprints in the concrete. The cracks are likely to be mostly shrinkage cracks rather than cracks caused by structural stress, as the traffic on the road is far too low to cause structural cracking. However some cracking may have been caused by the contractor driving heavy trucks over completed concrete sections before allowing them to gain full strength. The absence of reinforcement in the slab may have lead to increased cracking, as reinforcement helps to reduce shrinkage cracking whilst the concrete cures. The cracks in the concrete will leave the road vulnerable to water damage and may cause a durability issue. The constructed side drains are in good condition. Repair of defects by placing cement over the surface of the concrete slab is visible in places. The IRI values calculated for these sections are high, as the surface is rough.

4.4 Lightly Reinforced Concrete Slab

The Lightly Reinforced Slab sections at Siha have been constructed on the steepest slope sections along the road, and are performing visibly better than the unreinforced sections. Although there is some longitudinal cracking in a few places, this is to a much lesser degree than the cracking seen in the unreinforced slabs. Attempted crack repairs have reopened. The concrete slabs have been constructed with a suitable cross section shape to allow water to run off the surface. The finish to the concrete has given a rough surface, in order to maximize skid resistance on the steep slopes during wet weather.

4.5 Geocells

The geocell section at Siha is generally performing well, with the exception of some crumbling of the concrete on the right hand edge of the pavement at the start of the section. The surface of the geocell section on both sites is quite rough, especially at Siha, though the cross section shape allows adequate drainage.

4.6 Concrete Paving Blocks

The concrete paving blocks at the Siha site are performing very well with no major defects visible. The side drains are also in good condition, although regular cleaning of the drains must be carried out in order to prevent them from becoming blocked with litter from the adjacent Lawate market. The performance of this section is particularly important due to its location at the busy market, which imposes heavier axle loads than the other sections due to the medium size delivery trucks using this part of the road on market days. The two ramps providing vehicle access to the market are performing adequately well.

4.7 Bituminous Sections

4.7.1 Surface Dressing

The double surface dressing section at Siha is performing well, and is one of the best performing sections along the entire road, with the exception of a small pot hole at start of the section. The wheel paths appear slightly fatty. The side drains are in good condition. This section gives one of the smoothest surfaces among all of the sections at this site. However the Transitions into and out of this section needs addressing. The DCP holes need to be filled in preferably with some cement.

4.7.2 Bituminous Penetration Macadam

The bituminous penetration macadam section was constructed at the Siha site. This type of surfacing usually has the advantages of being long lasting with a low maintenance requirement. The section is not performing as well as the other bituminous sections and there is large aggregate protruding from the surface. The surface is rougher than the other bituminous surfaces. There is much loose aggregate and gravel scattered across the surface, largely obscuring it. The side drains are in good condition. However the monitoring beacons need to be picked out of the drains and refitted. The length of this section of road was measured to be 145m instead of the contractual 200m. Measurement was done using a walking measuring wheel. This consisted of Penetration Macadam. Therefore there was 55m missing from this section. It was apparent that towards the end of this section bitumen had simply been poured over concrete paving block. This had already started chipping away and the slab was visible underneath. (This can be seen on the monitoring CD, under 4 month photos Bituminous Penetration section photo 00695)

4.7.3 Rut Depths

The baseline rut depth measurements as well as the rut depth measurements that were taken at Siha in April 2013 are shown in Table 3. It can be seen from comparing the two sets of figures that there is not a significant increase in the average rut depth between the baseline and the April 2013 values, there is therefore no problem with rutting on the bituminous sections. The high figures recorded on the Bituminous Penetration Macadam section are largely due to unevenness of the surface, rather than any sub-base material deficiencies.

Table 3 Average Rut Depth on Siha Sections

Surface Type	Average Rut Depth (mm)	
	Base Line, January 2013	April 2013
Double Surface Dressing	4.29	6.18
Bituminous Penetration Macadam	9.10	11.34

4.7.4 Texture Depth

Surface texture measurement using the sand patch method was carried out as part of the base line data monitoring on all bituminous surfaces at Siha. Table 4 shows the average texture depth for each section from the baseline monitoring and the monitoring in April 2013. There has been a minimal decrease in the texture depth in the four months since the baseline Monitoring. The decrease may have occurred due to the test being carried out in a different location at the same chainage. The difference between the two results is 0.4mm.

Table 4: Texture Depth Results at Siha

Section	Surface Type	Surface Texture Depth (mm)	
		Base Line, January 2013	April 2013
7	Double Surface Dressing	1.24	0.87
16	Bituminous Penetration Macadam	2.86	2.44

4.8 Gravel Sections

The gravel wearing course sections have generally performed well, retaining good road shape. There has been some gravel loss in places as expected, leading to exposure of rocks underneath the surface and many loose stones. The results for the surface profile can be found in the monitoring CD. The gravel wearing course sections remained reasonably smooth throughout the monitoring periods, and the IRI values did not dramatically increase. However when it came to taking DCP measurements it was very difficult. This is because there were large pieces of rock protruding through the surface along the whole section and just below it. Getting through this was difficult as the DCP could not penetrate. Other locations along the same chainage also had rocks under the ground.

4.9 Surface Profile Measurement

Surface profile measurements were taken on all demonstration sections at Siha during the baseline monitoring and the monitoring in April 2013. The surface profile is largely unchanged and there were no large differences. The only difficulty was accurately relocating the points on which the baseline levels were taken.

4.10 Surface Roughness

A MERLIN was used at the Siha site to measure surface roughness and thus produce an IRI value for all demonstration sections. A summary of the IRI values calculated in the baseline data and in the April 2013 data is shown in Table 5.

Table 5: IRI Values on the Siha Site

Section	Surface Type	IRI (m/km)	
		January 2013	April 2013
1	Concrete Paving Blocks	5.33	6.29
2	Unreinforced Concrete Slab (100mm)	10.84	12.37
3	Flexible Geocells (75mm)	10.07	11.24
4	Unreinforced Concrete Slab (75mm)	9.95	11.94
5	Gravel Wearing Course	6.39	6.57
6	Concrete Strips	8.13	8.27
7	Double Surface Dressing	4.19	5.30
8	Concrete Strips	7.68	9.97
9	Unreinforced Concrete Slab (100mm)	9.79	10.39
10	Concrete Strips	7.24	9.26
11	Unreinforced Concrete (100mm)	9.18	10.48
12	Concrete Strips	7.60	8.98
13	Unreinforced Concrete (75mm)	9.08	10.39
14	Concrete Strips	7.80	9.45
15	Concrete Strips	8.49	9.78
16	Bituminous Penetration Macadam	6.34	8.51
17	Lightly Reinforced Concrete Slab (100mm)	10.03	12.13
18	Lightly Reinforced Concrete Slab (75mm)	10.68	12.74
19	Lightly Reinforced Concrete Slab (100mm)	10.03	11.66
20	Gravel Wearing Course	6.55	8.98

It was expected that there would be no significant change in the IRI values between the baseline and the April 2013 data, unless a significant pavement failure was encountered. Slight increases over time are expected under general wearing of the running surfaces. It can be seen that there are very high IRI values on the concrete slab sections, likely to have been caused by some unevenness in the surfaces. The unevenness in the surfaces is mainly due to the very steep slopes on the site; which made it difficult to construct the surfaces perfectly level and even. The quality of the finish to the concrete slabs is low in places, which will also have affected the IRI values.

In all sections the surface roughness has increased from the baseline monitoring that was done in January. The section with the least increase was the concrete strips at section 6. The concrete slabs generally increased the most in just 4 months having IRI values measured in April as high as 12. During the baseline monitoring period we found the surface to be a lot rougher than what we would have expected. The contractor had purposefully made the concrete more rough to increase the friction between the road and tyres. This helps on steep slopes to give better

4.11 Dynamic Cone Penetrometer Testing

DCP testing was carried out on the bituminous and gravel sections at the Siha site during the baseline survey in order to assess the strength of the pavement layers, the testing was carried out again in April 2013 to determine if there are any changes in the pavement strength during the monitoring period. Results of DCP testing can be seen in Table 6.

Table 6 DCP Testing Results at Siha

Material	4 Day Soaked CBR (BS 100% Heavy)	MDD (Kg/m^3)	OMC	Base Line, Jan 2013		April 2013	
				DN, mm/ blow	CBR, %	DN, mm/ blow	CBR, %
Brown Clay CL4	19	2043	6.8	3.33	89	7.35	33
Dark Reddish Clay CL3	20	1961	7.8	4.47	61	5.48	47
Light Brown Clay	8	1647	23.4	3.93	72	3.93	72

The road from Lawate to Kibongoto was split into 3 different material types in order to simplify testing and design. These were dark brown silty soil, dark reddish brown clay and light brown Clay. Both the double surface dressing and the Bituminous Penetration Macadam lie within the Dark Reddish Brown Clay. The Brown clay lies within the first 3km of the site from Lawate the Red Clay is from

From table 6 it can be seen that the Brown Clay CL4 had the highest CBR in January of 89%. The DN value was 3.33 mm/blow. When tested in April the same year the DN value had increased to 7.35 and the CBR had dropped to 33%.

The dark reddish clay had a DN value of 4.47 mm/blow in January when the baseline was taken as well as a CBR of 61%. When tested in April the DN value had risen to 5.48 mm/blow and the CBR had dropped to 47%.

The light Brown Clay had a DN value of 3.93 mm/blow in January when the baseline monitoring was done with a CBR value of 72%. When tested in April the same year the DN value was the same at 3.93mm/blow which also meant that the CBR was also 72%.

A weaker CBR was expected throughout the demonstration sections this was due to the seasonal variation of the testing. January was dry and hot when testing was carried out Therefore the soil was stronger. This can be seen in the DN values in the brown clay and the dark reddish clay with DN values that are lower in January when the baseline was taken. The lower values indicate lower penetration through the soil therefore higher in- situ strength. There was no change in the light brown clay.

4.12 Classified Traffic Counts

At the Siha site traffic counts were carried out by the monitoring team throughout the baseline phase and during the monitoring in April 2013. Two count stations were established; the first just past Lawate (chainage 2+580) and the second near Kibongot'o (chainage 12+640). The traffic counts were carried out in both directions for 12 hours, 6am to 6pm, over 5 days consecutively between Tuesday 8 January and Monday 13 January 2013. The counts at the second station started two days later than the counts at the first station. These two count stations should be used in future Monitoring stages. The average daily traffic results of all counts to date are summarised in Table 7 and Table 8.

Table 7: Average Daily Traffic Count Data Lawate Village

Traffic Counting Data (Lawate village; Ch. 2+580)								
Date	Classification							Total
	Pedestrian	Bicycle	Motorcycle	Saloon Car	Pick up/ 4WD	2-axle truck/ bus	3-axle truck	
Baseline	308	5	201	11	21	1	4	551
April 2013	395	7	160	3	18	1	0	584

Table 8: Average Daily Traffic Count Data Kibongoto Village

Traffic Counting Data (Kibongoto village; Ch. 12+640)								
Date	Classification							Total
	Pedestrian	Bicycle	Motorcycle	Saloon Car	Pick up/ 4WD	2-axle truck/ bus	3-axle truck	
Baseline	259	13	111	22	1	0	4	410
April 2013	320	15	132	7	17	0	0	491

From Table 7 the average daily count at Lawate shows that there were more pedestrians out than at the baseline stage than in April later that year. This is surprising as it was raining during the monitoring period in April. The motorcycle count however was lower. There were more saloon cars and 4WD in January than in April. Overall the Traffic count in Lawate was higher in April by 33 the majority of them were pedestrians.

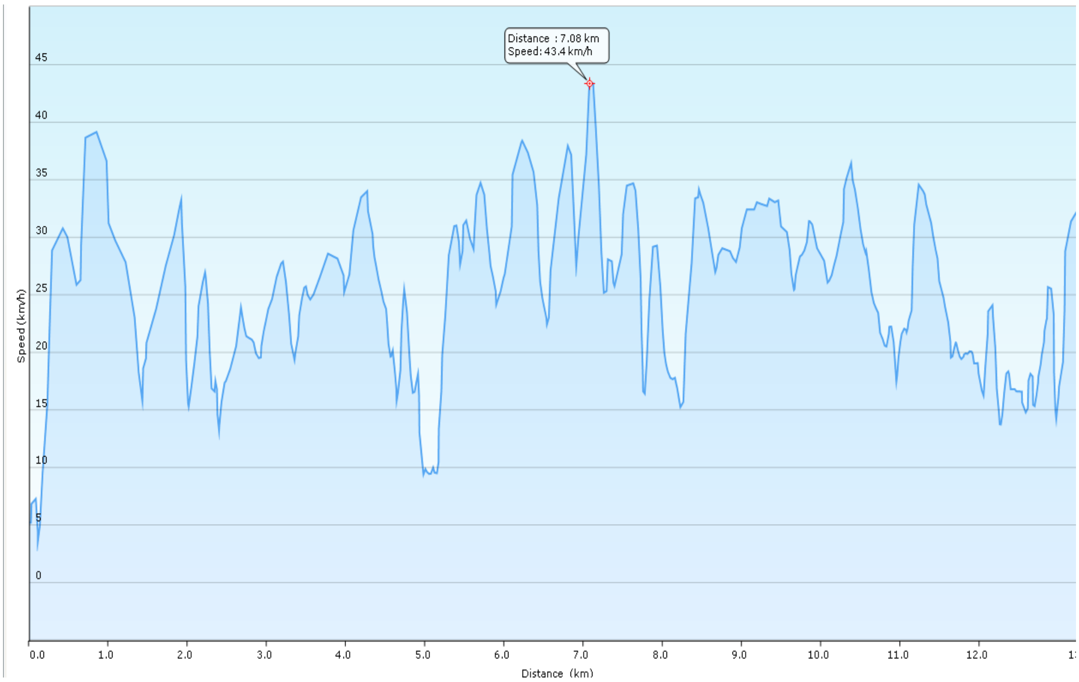
The traffic in Kibongoto is similar to that of Lawate in the fact that there was also an increase in pedestrian levels in April. There were 2 more bicycles on the road in April compared to January. There were more saloon cars during the baseline monitoring stage. There were more 4WD in April and no 3 axle trucks whereas there were 4 in January. Like Lawate there was an overall increase of 81. This was mainly pedestrians and motorcycles. The numbers are still relatively low and it will take time for large traffic volumes to noticeably increase.

4.13 GPS Monitoring

A drive through survey using the GPS device was undertaken along the road during the baseline monitoring and during the April 2013 monitoring at the Siha site, maintaining a target speed of approximately 30 km per hour. As only a small amount of time had elapsed, however it can be seen that often it was not possible to achieve the target speed of 30 km per hour. This is generally caused by the steep slopes and sharp bends, at these points it is only safe to drive at low speeds. Conversely, there are locations where it is necessary for the vehicle to travel at speeds greater than the target speed so that the vehicle is able to climb a slope.

Given the low sensitivity of this survey only significant drops in vehicle speed can be clearly identified, and the occurrence of two rainy seasons per year in Tanzania may cause seasonal differences. Figure 7 shows the results from this GPS survey for the monitoring in January 2013.

Figure 7: Vehicle Speed along the Lawate Kibongoto Road



5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Substantial improvements to the condition of the road and the provision of access have been achieved, as can be seen in the comparison of post and pre-construction photographs in the Siha Construction Report. The improvements are most notable during the rainy season, as the entire road is now passable during the rains. More detailed conclusions are as follows:

The concrete paving block section at Lawate has performed particularly well, and is deemed to be suitable for use in areas used by medium size trucks, in slow moving and turning actions. Although the side drains are functioning well there is a drainage issue in an isolated area between the start of the paving blocks and the adjacent highway; TANROADS are aware of this and would need to authorise further drainage works.

Amongst the bituminous surfacing options used at Siha the double surface dressing is deemed to be the most suitable, as well as the most cost effective. The double surface dressing has provided a smoother surface than the bituminous penetration macadam and is also simpler to construct. Double surface dressings should continue to be used on slopes of medium steepness.

The gravel sections are providing an adequate pavement option for the flatter sections, although they are more vulnerable to excessive deterioration during heavy rains. This is minimised when gravel is used on flat sections, as there is no fast flowing rain water downhill. Erosion of the gravel can be further minimised if a good road shape is maintained, as the water run-off is quicker.

The concrete sections are deemed to be suitable for providing all year round access on steep slopes, as well as improving road safety. On such steep slopes the safety of the road is of paramount importance and the roughness of the concrete surfaces provides more effective skid resistance, particularly during wet weather.

Concrete strips can provide viable, highly cost effective option in comparison to concrete slabs, though are not suitable for use on steep or winding sections due to the safety issues when two vehicles pass each other. There is significant lengths of longitudinal cracking and attempts have been made to seal the cracks. This appears to be a quality control issue, but would need further tests to confirm. A possibility is the early trafficking prior to sufficient concrete strength being achieved.

Provided that contractors are adequately trained, the geocells can be a successful pavement option in Tanzania. The flexibility provided by the geocell matrix has helped prevent cracking in the concrete.

The level of cracking seen in the concrete slabs raises some concerns, which could be due to the concrete mix. This would need core tests to quantify, but future mix designs may require a higher cement content and lower water-cement ratio, as well as strict quality control measures. The use of early strength concrete and plasticisers can also mitigate the risk of cracking. As with the concrete strips it is possible that the contractor allowed traffic on the sections prior to the concrete gaining sufficient strength.

The cracking in the reinforced slabs is less than the unreinforced slabs. Reinforced slabs may therefore be a preferable option, but this would need confirming as the comparison does not account for the early trafficking by the contractor/road users.

5.1.1 Applicability of the Pavement Options

Based on the performance of the demonstration sections throughout the monitoring stage, the following recommendations are made:

- Gravel option can be used on sections where geometry and in situ materials are favorable, and risk of excessive deterioration is at a minimum. Gravel is not recommended for use on steep slopes or in areas prone to flooding
- The bituminous surface options have proven to be effective and should continue to be used on rural access roads, on sections where a gravel road would be particularly vulnerable to erosion and excessive deterioration. The whole life costs of these options can be found in the Final report.
- The use of lightly reinforced concrete slabs is recommended on steep sections, or unreinforced concrete slabs where reinforced slabs are not affordable – subject to further confirmation. On less steep slopes, concrete strips can be used to provide a more efficient paving option.
- During discussion with the local engineers in the monitoring team it was learnt that contractors operating in the road sector often do not have experience in concrete pavements, as bituminous roads are by far the more common form of construction in Tanzania. It could therefore be beneficial for contractors to undertake some training in the construction of concrete pavements.
- The use of concrete geocells is recommended as this option has considerable benefits, as previously discussed in this report. As this is a relatively specialized area that is new in Tanzania, some practitioner training will be beneficial. The construction costs data can be found on the Monitoring CD for Siha.

5.1.2 Ongoing Maintenance

It is recommended that appropriate maintenance is continually carried out on the project roads in order to maximise the service life of the sections and prevent undue deterioration.

Little maintenance should be required on the concrete sections, although due to the issues with cracking at Siha there are some crack repair works being carried out, some of which have failed.

Sealing of cracks is important for protecting the concrete against water ingress, which will lead to deterioration. The concrete paving blocks at Lawate should not require significant maintenance work, however any dislodged blocks or other damage that may arise should be repaired.

The bituminous sections will require some maintenance during their service life, such as pothole and crack repair. An assessment of the required maintenance should be made each year during the annual monitoring that will take place under the district engineers, so that any required works can be carried out.

Suitable maintenance should be carried out on the gravel sections in order to ensure that the road shape retains an adequate camber for draining water from the surface. This is especially important during the rainy season.

Other general maintenance items that should be carried out includes the clearing of side drains and culverts, as well as the maintenance of the monitoring beacons. This will include ensuring that the beacons do not become obscured by bush, and replacing any damaged or missing beacons.

5.1.3 Monitoring Beacons

Monitoring beacons at Siha were not constructed. It is highly recommended that the monitoring beacons are constructed at Siha and are maintained, as this is vitally important for the success of continued monitoring by District Engineer.

Appendix A Monitoring Results CD

Appendix B Monitoring CD Cover