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The African Community Access Programme (AFCAP)

Prime Ministers Office - Regional Administration
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Project Reference: AFCAP/TAN/008

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

Bago - Talawanda- Bagamoyo District - Pwani Region

Construction Report

April 2012

Africa Community Access Programme (AFCAP8)

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Africa Community Access Programme (AFCAP8)

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EXECUTIVE SUMMARY

The United Republic of Tanzania located in Eastern Africa has a road network of over 55,000 km. It is estimated that some 45% of the road network in Tanzania is in goof or fair condition. These roads largely consist of gravel or earth surfaces which deteriorate rapidly and cause access problems during the wet seasons. Poor accessibility is highly problematic in rural areas where the majority of the population rely on agriculture and transport services for a means on income.

AFCAP's goal 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. AFCAP 8 aims at identifying low-cost, locally resource based methods of improving problematic lengths of road to provide sustainable rural access.

An Environmentally Optimised Design ethos has been implemented to carry out research on a rural access road in Bagamoyo. The approach adopted is to utilise a number of different demonstration sections at specific locations along access roads according to the requirements of the surrounding road environment. The pavement types selected for demonstration cover 8 different forms of construction including concrete geocells, concrete strips, surface dressing, Otta seals, sand seals, slurry seals, hand packed stone and engineered natural materials.

The Environmentally Optimised Design approach required experienced engineers to spent significant time in the field in order to identify and understand the particular problems that will be encountered, in order to explore that various possible solutions. This approach suggests the use of more expensive and substantial pavement structures for problematic sections of road, and less expensive options for flat, well draining sections that are unlikely to present access problems. This will provide a sustainable solution for year round accessibility at minimum cost.

The construction of the demonstration sections is now complete and this report includes a description of the pavement construction methods. In order to monitor the demonstration sections, various base line data have been collected. Further monitoring will take place to facilitate comparison and conclusions to be drawn regarding pavement design for rural access roads. Data records have been collected in a similar method to that of other AFCAP projects so that comparisons with other demonstration sections in other countries can be made.

It is concluded that all weather access can be provided using techniques which are suitable for local procurement and local supervision but during the design phase it is important that detailed investigations of all successful construction techniques within the project area be investigated. These should then be applied or adapted as appropriate to prevent the use of pavement construction methodologies which are not suited to local resources and skills.

The contract documents should encourage, or require, Contractors to use local labour. This has economic benefits for the local community, provides some feeling of ownership and helps create a pool of experienced labour in the area which will be of value in future construction and in maintenance of the existing roads.

Maintenance considerations should be taken into account when selecting pavement types, for example, gravel surfaces and bituminous seals require significantly more routine and periodic maintenance than concrete roads. Despite the higher initial cost of some surfacing options, lower long term maintenance considerations may render these more economically and environmentally sustainable over standard gravel wearing course. The designer must consider not only the

maintenance requirements of each surface type but also whether maintenance will actually be carried out and the effects of non performance, if this seems likely. Within this project area it must be recognised that maintenance is likely to depend largely on the willingness of the communities to contribute labour.

Implementation of the construction phase has highlighted problems which occur when research work is carried out under a more or less conventional construction contract. There is a lack of flexibility which makes changes and adjustments either too expensive or impossible whilst the nature of the contract makes it very difficult to force the contractor to rectify small areas of poor work. These problems are likely to be magnified when, as in this case, the research element is simply a part of a larger, conventional contract which must reflect the realities of the commercial world and an over-riding desire to complete the Contract.

It is necessary that a long term monitoring regime follows through on the base line data capture conducted during this work. This will involve monitoring the performance and deterioration of the trial pavements and the gravel wearing course control sections, taking into consideration the environments to which they are subjected, the standard of construction, the traffic and the maintenance required and actually carried out.

Project Aims

This project has a number of different aims and they are as follows:

- Improve sustainable access to economic and social opportunities for poor rural communities;
- Provide all weather access to district roads using Environmentally Optimised Design.
- To demonstrate alternative pavement surfaces suitable for low volume roads in Tanzania which will dramatically reduce the demand for gravel;
- To identify cost effective community based construction methods;
- To create a design philosophy/design concept for low volume rural roads;
- Change current design ideology for low volume rural roads, which presently involves extensive re-gravelling works;
- To promote the use of locally sourced construction materials and investigate the use of alternative ‘marginal’ materials – materials presently considered substandard, but which can actually perform satisfactorily on low volume roads;
- To promote the use of labour based construction methods to provide employment for people in local communities and help maintain the rural road network after construction is completed;
- Aim towards incorporation of these design concepts as part of the Tanzanian Pavement and Materials Design Manual in the future once the long term performance of these pavements has been ascertained.

1 INTRODUCTION

1.1 The Africa Community Access Programme (AFCAP)

The Africa Community Access Programme is designed to address the challenges of providing reliable access for poor communities. Reliable access is essential for rural communities in Africa. Access is required to reach basic services and all kinds of economic and social opportunities[1].

AFCAP supports innovative field research and puts this knowledge into practical use. The programme is based around a portfolio of research, demonstration, advisory and training projects. These identify and support the uptake of low-cost, proven solution for rural access that maximise the use of local resources. Project outputs then feed directly into the regional and national rural transport policies ad strategies for poverty reduction[1].

AFCAP will benefit rural communities in Africa. The programme will mean that they have improved access to investments in other sectors; better access to health and education services, improved road safety and greater gender equality in how the transport sector operates[1].

1.2 The Road Network

In the United Republic of Tanzania there are over 33 million citizens spread over 945,000 square kilometres of land area who depend on 114 Local Government Authorities (LGAs) to provide them with road network services[2]. The Government of Tanzania is committed to providing high quality and responsive services to all Tanzanians wherever they are in the country.

There are currently no paved district roads in Tanzania. The district road network consists of earth and gravel roads. The road network in Tanzania for 2008/2009 is shown in Table 1. The local government authorities (LGAs), with support from PMO-RALG, are responsible for managing the classified, local road network, consisting of 56,625 km of district, feeder and urban roads. The network of which is in good of fair condition is around 55%. The remaining roads, mainly with earth surface, are in poor condition causing them to rapidly deteriorate during heavy rains.

These largely earth and gravel based rural networks are imposing huge maintenance burdens on poorly resourced authorities and governments. The resultant maintenance demand is high, threatening the future sustainability of the entire network. Despite the high maintenance costs, these low volume rural roads are not sufficiently covered in the Tanzanian pavement design manual.

Table 1 Tanzania Mainland Road Network Length[3]

Road Class	Paved (km)	Unpaved (km)	Total (km)
Trunk	5,150	7,636	12,786
Regional	722	19,504	20,226
District	0	29,337	29,337
Feeder	0	22,703	22,703
Urban	790	5,207	5,997
Total	6662	84387	91049

1 ***Africa Community Access Programme***, *http://www.crownagents.com/afcap/about-afcap. aspx, August 2011.*

2 ***Introduction to LGA's***, *Prime Minister's Office Regional Administration and Local Government, http://www.pmoralg.go.tz/lga/index_intro. php, 2004.*

3 ***Annual Report 2008/2009***, *Roads Fund Board, The United Republic of Tanzania, June 2009.*

1.2.1 Road Maintenance Fund

Low volume rural roads should be maintained to a standard which allows year round access to vital community facilities. Current design philosophies and ideologies promote rehabilitation of continuous road sections – on rural roads; this generally involves re-gravelling the entire length. This is inefficient, costly and environmentally un-sustainable in the long term.

The Roads Fund Board does not have enough funds to carry out all the maintenance required on the road network in Tanzania. The problematic costs associated with gravel road are highlighted below in Table 2 - Coverage of Total Maintenance Needs[3]. The maintenance costs are increasing every year and the maintenance budget is not adequate to fund this maintenance. In other words, the funding for road maintenance is unsustainable. It is clear to see the benefits of a more sustainable road network at district level.

Table 2 - Coverage of Total Maintenance Needs[3]

Year	2004/2005	2005/2006	2006/2007	2007/2008	2008/2009
Maintenance Needs (Tsh Billions)	186.6	208.0	210.0	226.4	291.5
Maintenance Budget (Tsh Billions)	65.4	71.5	76.2	195.0	195.0
Percentage Coverage	35	34	36	86	67

1.3 Background to AFCAP Tanzania

The aim of the AFCAP project is to improve sustainable access to economic and social opportunities for poor rural communities. A further aim of the project is to provide all weather access on district roads using environmentally optimised design. Environmentally optimised design involves applying robust pavements at specific problematic locations along the road and applying less expensive and less wasteful designs in areas which are perfectly satisfactory all year round. The problematic sections along the roads will provide the locations of different trial sections using different sustainable solutions.

These pavements will dramatically reduce the demand for gravel, provide a smoother running surface to reduce vehicle operating costs, reduce travel times and dust pollution. The project focuses on demonstrating different low cost solutions that once demonstrated, can be repeated across Africa.

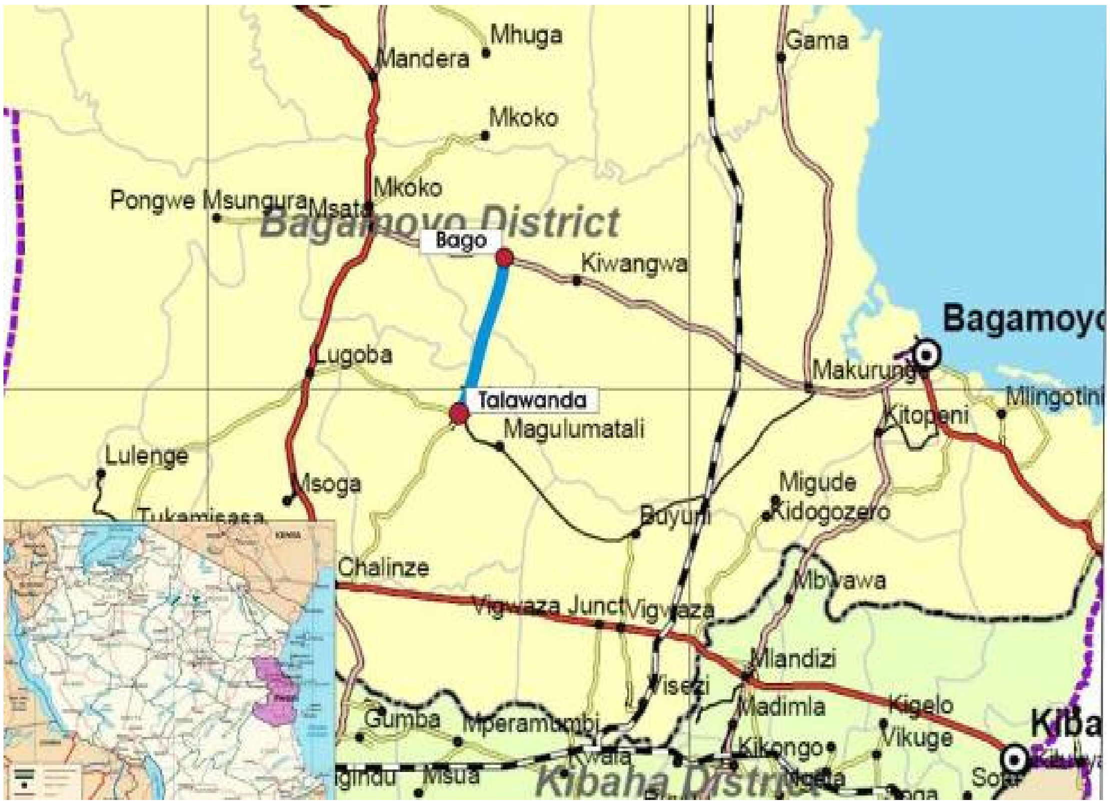
The project is also focused on using locally available materials. Substantial effort was made to use the local knowledge of the District Engineer's and the stakeholders in order to locate suitable gravel material. A number of borrow pits were located in the vicinity of the road.

At present, Tanzania has a modern and comprehensive pavement design manual, which details the design process for major arterial and trunk routes. However, there are a high percentage of low volume rural roads which are not catered for in current design manuals. These small rural roads link villages with local amenities such as shops, schools and community health facilities. Being low volume rural roads, they are generally not given the same priority in maintenance and rehabilitation schedules, with the costs involved in repairing and maintaining them to the standards outlined in current design manuals rarely justifiable.

Thus, the purpose of this project is to formulate new design methods and strategies, and accommodate these in current design standards and practices in Tanzania.

Two roads have been selected for these demonstrations in Tanzania. One road is located in the coastal region in the Bagamoyo District, which shares the typical problems of the coastal regions such as sandy subgrades and flat marshy areas containing black cotton soil. The second road is located on the slope of Kilimanjaro in the Siha District; the road is steep and winding in nature passing through agricultural landscape. At the time of this report, the construction for the project in Siha had not started and as a result, this report only covers the construction in Bagamoyo. The road in Bagamoyo passes from Bago to Talawanda as shown in Figure 1.

Figure 1 Location of the Bagamoyo Road (Bago to Talawanda)



2 THE AFCAP PROJECT RATIONALE

2.1 Tanzanian Pavement and Materials Guideline Design

Current pavement design in Tanzania does not address the need for an improved design methodology, or standard, for low volume rural roads. The Tanzanian Pavement Design Manual (or TPMDM as it will be referred to from this point forward), details the design of major trunk and arterial roads.

The TPMDM uses a combination of axle loading and subgrade strength to allocate pavement designs to specific road sections. These pavement designs determine the entire pavement structure, material type and specification for each layer.

However, arterial and trunk roads have a much higher traffic volume than is experienced on many rural roads, thus material quality and specifications must be of a much higher standard. In the case of low volume roads, these specifications for material can be relaxed to allow the use of readily available, locally sourced materials. These materials may not meet the specification for arterial or trunk roads, but, where lower traffic volumes are involved; stresses and deteriorating factors are generally lower. This allows the consideration of materials such as natural gravels, volcanic cinders, calcrete and coral rocks, which may be readily available, but due to specifications in current design manuals and local engineering principles, are not given consideration in pavement construction. Current design beliefs held by many engineers regard these materials as being substandard. While this may be the case for high volume roads, many of these materials are ideal for rehabilitating lower volume roads, but are not given consideration as no information is available on their suitability.

Trials have been carried out in various countries investigating cost effective, efficient and environmentally sustainable methods of rehabilitating and maintaining low volume rural roads in order to provide year round access for local communities. These methods utilised locally sourced materials and involved the improvement of only areas, which in their un-rehabilitated state, prevented year round access. This challenges the current unsustainable method of gravelling these roads from start to finish.

This process has become known as Environmentally Optimized Design (EOD) or Spot Improvement Design (SID). It is an aim of this project to introduce such design ideas to engineers in Tanzania.

2.2 EOD Design Philosophy

An inherent problem encountered with developing and maintaining low-volume rural roads is determining whether full rehabilitation is required or whether remediating trouble spots is more beneficial. In developing countries where the majority of people live in the countryside, vast networks of low volume roads develop. In such cases it can be more beneficial to improve roads on a ‘spot improvement’ basis rather than undertaking full remediation (unless areas requiring spot improvement are >75% of total road). For an entire section of road to be fully rehabilitated involves high expense, may only serve relatively few people and is not a priority on district roads. By utilizing funding to remediate sites over a number of routes, a cost effective method of benefiting numerous communities is developed, allowing basic access to vital amenities such as health care, schools and markets. Spot improvement differs to maintenance as it is done after basic access has been lost.

Environmentally Optimized Design ensures that specifications and designs support the functions of different road sections - assessing local environment and limited available resources. This requires analysing a broad spectrum of solutions to rectify different road sections depending on their individual requirements, ranging from engineered natural surfaces to bituminous pavements. A key cornerstone of this method is that the chosen solution must be achievable with materials, plant and contractors available locally[4].

2.2.1 Environmentally Optimised Design Process

Environmentally Optimised Design (EOD) has been defined as a system of road design that considers the variation of different road environments along the length of the road such as steep gradients, wet and marshy areas as well as passage over easy terrain[5].

The Spot Improvement Design (SID) methodology is applied to the EOD and concentrates on ensuring that each section of a road is provided with the most suitable pavement type for the specific circumstances[5] to provide basic access along the road.

A typical rural road situation is shown in Figure 2, where an earth track leads to an isolated community some way from a main road. During the dry season the road is passable. During the wet season much of the road may perform quite well but there will be some difficult problematic sections which will render the road impassable. As an example, the track, shown in Figure 2, is taken to be in the following condition:

- Good Quality Lengths – Make up a large percentage of the road
- Standard Lengths – Make up a large percentage of the road
- Problematic Sections – Make up a small percentage of the road

So the EOD philosophy challenges the standard rural access road design of applying a gravel wearing course from start to finish. The EOD method asks if the standard design is sufficient for problematic areas and is the standard design necessary for the good areas. The correct design needs to be undertaken for the different sections of the road as they are assessed. An under-design of poor sections can lead to premature failure of problematic areas and an over-design will often be a waste of funds which would be better spent on the problematic sections.

The EOD design philosophy proposes using minimal resources on the good sections, some resources on the standard sections and the majority of resources on the problematic sections.

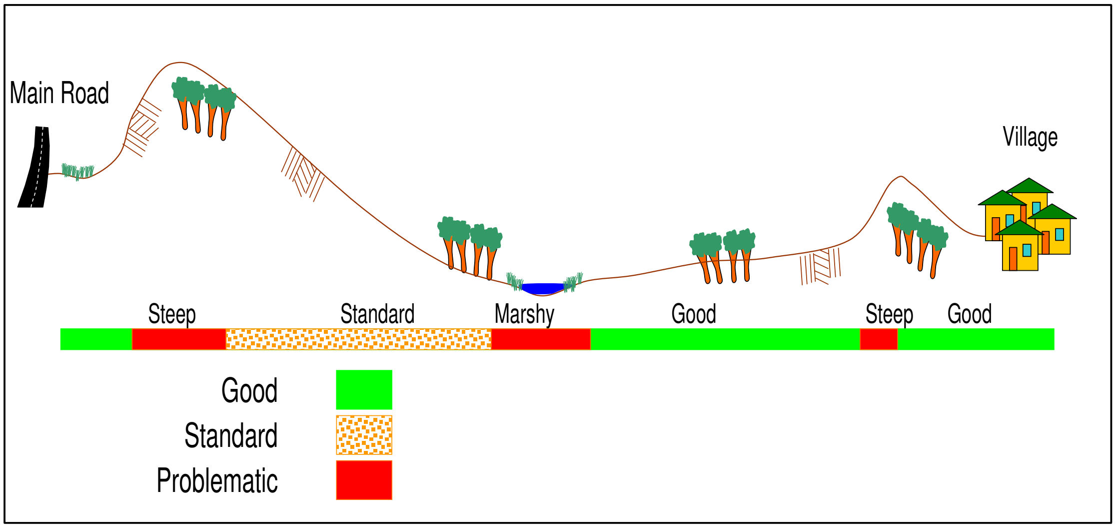
For example, the EOD design philosophy may lead to the following design:

- Good Quality Lengths – Engineered Natural Surface (Estimated cost 30% of Standard Gravel Surface)
- Standard Lengths – Standard Gravel Surface
- Problematic Sections – Suitable Economically Viable Robust Pavement Structure (Estimated Cost 500% of Standard Gravel).

4 ***Key Management Issues for Low Volume Rural Roads in Developing Countries***, *R Petts, Road Asset Management Seminar, Chandigarh, India, March 2008.*

5 ***Local Resource Solutions to Problematic Rural Road Access in Lao PDR,*** *SEACAP Acess roads on Route 3, Roughton International Scientific Paper, April 2009.*

Figure 2 Environmentally Optimised Design Process



The EOD/SID philosophy aims to replace a standard gravel pavement design with more robust pavements at specific problematic locations along rural access roads and to replace less expensive wasteful pavements in areas which are perfectly satisfactory all year round, resulting in a more economical road design.

It is clear to see the potential savings and benefits from adopting this approach to rural road design. Gravel roads are becoming uneconomical and practically unsustainable, where gravel is becoming increasingly scarce and only available at long haulage distances. This design philosophy offers a more sustainable and economical solution to standard gravel road design.

This design philosophy has been applied for the design of these roads by spending significant time in the field, understanding which sections perform well in the wet season and which sections prohibit basic access. Once the problem sections were established, suitable solutions were applied to these areas in order to provide basic access during the rain season. By demonstrating this design philosophy, engineer's in Tanzania will be able to follow the procedures taken in this report to implement a suitable EOD/SID that suits their particular problems along district roads in the future.

2.3 AFCAP Pavements

The AFCAP Tanzania project follows on from a previous project in Laos People's Democratic Republic (PDR) in South East Asia, entitled SEACAP 17 – Local Resource Solutions to Problematic Rural Road Access in Laos PDR. The SEACAP project aimed to identify cost-effective community orientated approaches for improving all year access to remote rural areas through low-cost and local resource based improvement of roads in Laos PDR. Alternative pavements and surfacing to the standard gravel pavement were tested by way of trials on short problematic sections of selected roads. Several of these pavements were previously trialled in Vietnam and Cambodia through DFID research. The pavements being demonstrated in Bagamoyo have been shown to work well in other countries under similar projects in the past. The lengths of the various demonstration sections vary from 180 – 1670 m.

The pavements types selected for the demonstrations in Bagamoyo were as follows:

- **Gravel Wearing Course**, this construction comprises 150 mm of gravel wearing course with a bearing capacity of CBR≥25% constructed on an in-situ subgrade.

- **Double Sand Seal**, this seal consisting of a machine applied film of bitumen followed by the application of excess sand which is lightly rolled into the bitumen. Constructed in two layers a sand seal is used as a permanent bituminous surfacing on low volume roads.
- **Single Otta Seal with a Sand Seal**, the Otta seal surface comprises a layer of binder followed by a layer of aggregate that is rolled into the binder using a roller or loaded trucks. It is different to surface dressing in that an 'all in' graded gravel or crushed aggregate is used instead of single sized chippings. The layer is thicker and more bitumen is used. The surface is blinded with a bitumen/sand mix. The added sand seal layer gives extra protection against moisture ingress and environmental effects on the underlying layers.
- **Hand Packed Stone**, this surface consists of a layer of large stones into which smaller chips are packed. Remaining voids are filled with sand or gravel to form a strong and semi-impervious matrix.
- **Concrete Geocells**, manufactured plastic formwork is used to construct in-situ concrete paving. The plastic formwork is sacrificial and remains embedded in the concrete creating a form of block paving.
- **Concrete Strips (Unreinforced)**, this surface uses concrete under the wheel tracks of a vehicle. The strips also contain transverse concrete strips between the wheel tracks to help stop excessive erosion down the centre of the strips
- **Concrete Strips (Reinforced)**, this surface is similar to the latter but a layer of 4 mm steel reinforcement was used in the concrete where the pavement has an expansive soil subgrade
- **Double Surface Dressing**, This method involves 2 spray applications. A primary coat is sprayed onto the road followed by a large single sized aggregate. Following this, the secondary bituminous application and dressing with smaller sized aggregate. Typical aggregate sizes are 19 – 10 mm for larger aggregate and 13 – 6 mm for smaller aggregate.
- **Slurry Seal**, a relatively thin surfacing, consisting of fine aggregates - typically <10 mm, bitumen emulsion, water, cement/lime and occasionally an additive also. The constituent materials can be mixed in a normal concrete mixer before being spread on the road surface. Spreading can be carried out by hand or machine application.
- **Engineered Natural Surface**, this construction is used where the existing subgrade material comprises natural gravel with the same engineering characteristics as the pavement layer.

2.3.1 Pre-Construction Data

Before the selection of the different pavements the following data was gathered:

- Horizontal gradient;
- Subgrade bearing capacity;
- Visual assessment;
- Cross drainage;
- Cost data;
- Distance from Bagamoyo;
- Proximity to construction materials;
- Availability of construction materials;

- Traffic;

For the design of the pavements trial pits were taken along the alignment of the road to determine the subgrade bearing capacity. Test results of the gravel from local borrow pits were also ascertained.

2.3.2 Estimated Construction Costs (Engineer's Estimate)

Local construction costs were made available by PMO-RALG and used to prepare the engineers estimate for the pavements. The rates received during tender were considerably more expensive than estimated. It was concluded that these expensive rates were submitted by the contractors because they were unfamiliar with the technologies involved in the project and tendered with high rates to hedge against adverse risk involved in their construction. However, it is suggested that once these technologies are used more commonly across Tanzania, and local contractors become familiar with the methodology then the cost will consequently be reduced.

2.4 The Design of the Rural Access Roads

2.4.1 Road Alignment

The road alignment generally followed the existing alignment of the access road before construction. Any sharp bends in the road were smoothed out during the clearing and grubbing phase of the project by the Contractor. No detailed alignment design was carried out by the Consultant, the District Engineer's Office, or the Contractor. Data from a handheld GPS was taken before and after the Construction of the road. The method of using a handheld GPS is very simple, inexpensive and available to District Engineer's in Tanzania. Photographs of the road alignment prior to construction are available in Appendix A - Photographs at 500m intervals before construction.

2.4.2 Extent of Earthworks

For this project one simple item was used for heavy grading and compaction of the road of the roadbed. This item included all earthworks, formation of the roadbed and side drains. The use of a simplified item allowed for easier pricing by the contractor and easier supervision and quantity calculations for payment by the District Engineer.

2.4.3 Subgrade Design Bearing Capacity

The road in Bagamoyo is located in a moderate climatic zone. As a result, the subgrade class is based on the 4 day soaked CBR value. Table 3, below, shows how to the subgrade is classified based on the CBR value. Soil with a CBR of < 3% is classified as low strength.

Table 3 Subgrade CBR Classification[6]

Subgrade class	CBR_{design} [%]			Density for determination of CBR_{design} [% of MDD]
	Wet or moderate climatic zones 4 day soaked value	Dry climatic zones (both requirements shall be met)		
		Tested at OMC	4 days soaked value	
S15	Min 15	Min 15	Min 7	95 BS-Heavy
S7	7 -14	7 -14	3 - 14	93 BS-Heavy
S3	3 - 6	3 - 6	2 - 6	100 BS-Light

The design subgrade bearing capacity was investigated during the design phase of the project. Alignment trial pits of the various soils were taken and a summary of the design subgrade bearing capacity is shown in Table 4.

Table 4 Summary of the Design Subgrade Bearing Capacity

Section	Chainage (km)		Length (km)	Surfacing Type	Subgrade CBR
	Start	End			
1	0.030	0.230	0.200	Single Otta seal with a sand seal (26 mm)	S3
2	5.340	5.520	0.180	Hand Packed Stone (150 mm)	Low Strength
3	5.560	6.080	0.520	Concrete Strips (100 mm - Reinforced)	Low Strength
4	6.080	7.750	1.670	Geocells (75 mm)	Low Strength
5	8.000	8.240	0.240	Double Surface Dressing (20 mm)	Low Strength
6	8.320	8.820	0.500	Geocells (75 mm)	Low Strength
7	9.980	10.670	0.690	Concrete Strips (100 mm - Unreinforced)	S7
8	11.200	11.400	0.200	Double Sand Seal (20 mm)	S7
9	12.200	12.580	0.380	Gravel Wearing Course	Low Strength
10	16.240	17.100	0.860	Concrete Strips (100 mm - Reinforced)	Low Strength
11	18.480	18.740	0.260	Concrete Strips (100 mm - Reinforced)	Low Strength
12	19.000	19.200	0.200	Gravel Wearing Course	Low Strength
13	19.480	20.040	0.560	Gravel Wearing Course	Low Strength
14	20.040	20.260	0.220	Slurry Seal (8 mm)	S3

2.4.4 Pavement Design

The different pavements being demonstrated in Bagamoyo are shown in Table 6. The pavements being constructed in Bagamoyo initially followed the pavement design in the TPMDM. Changes were made to allow for variations in the material, based on what was available in the respective

6 ***Pavement and Materials Design Manual,*** *Ministry of Works, The United Republic of Tanzania, 1999.*

region. Additionally, surface materials such as concrete and segmental block surfaces were accommodated in the designs and these are not covered in the TPMDM at present.

Therefore, the TPMDM was used to get the traditional pavement design, with suitable alterations made as required to obtain the modified environmentally optimised design.

The pavement design set out in the TPMDM and the revised pavement design for a bitumen pavement for the road in Bagamoyo is shown below in Table 5. The modifications of the pavement design are justified from a research paper entitled Collaborative Research Programme on Highway Engineering Materials in the SADC Region published by the TRL. This research paper dictates that the pavement can be reduced to the thickness shown below if the shoulders of the road are sealed. The use of sealed shoulders gives a structural benefit by maintaining a drier environment under the running surface. The provision of a sealed shoulder decreases the risk of using weaker materials in the upper pavement layers. [7]

Table 5 Modifications to the Standard Pavement Design

Pavement Types		Standard Bitumen Pavement Design	Revised Bagamoyo Bitumen Pavement Design
Surface Layer	Type	Bitumen Surface	Bitumen Surface
	Thickness	Varies	Varies
Base	Type	Natural Gravel CBR ≥ 60%	Natural Gravel CBR ≥ 60%
	Thickness	150	150
Subbase	Type	Natural Gravel CBR ≥ 25%	-
	Thickness	150 mm	-
Improved Subgrade	Type	Natural Gravel CBR ≥ 15%	Natural Gravel CBR ≥ 15%
	Thickness	150 mm	150 mm
Improved Subgrade	Type	Natural Gravel CBR ≥ 7%	-
	Thickness	150 mm	-
Subgrade	Type	CBR < 7%	CBR < 7%

[7] ***Collaborative Research Programme on Highway Engineering Materials in the SADC Region,*** *C. Gourley, Volume 1 Performance of Low Volume Sealed Roads: Results and Recommendations from Studies in Southern Africa, Transport Research Laboratory, Crowthorne, United Kingdom, November 1999.*

Table 6 Pavement Structures for the AFCAP Bagamoyo Demonstration Sections

Pavement Types		Single Otta Seal with a Sand Seal	Double Sand Seal	Double Surface Dressing	Slurry Seal	Concrete Strips (Unreinforced)	Concrete Strips (Reinforced)	Geocells	Hand Packed Stone
Surface Layer	Type	Bitumen Surface	Bitumen Surface	Bitumen Surface	Bitumen Surface	Concrete	Concrete	Concrete	Stone
	Thickness	26 mm	20 mm	20 mm	8 mm	100 mm	100 mm	75 mm	150 mm
Bedding Sand	Thickness	0	0	0	0	0	0	0	50 mm
Base	Type	Natural Gravel CBR ≥ 60%	Natural Gravel CBR ≥ 60%	Natural Gravel CBR ≥ 60%	Natural Gravel CBR ≥ 60%				
	Thickness	150 mm	150 mm	150 mm	150 mm				
Subbase	Type			Natural Gravel CBR ≥ 45%		Natural Gravel CBR ≥ 45%	Natural Gravel CBR ≥ 45%	Natural Gravel CBR ≥ 45%	Natural Gravel CBR ≥ 45%
	Thickness			150 mm		150 mm	150 mm	150 mm	150 mm
Improved Subgrade	Type	Natural Gravel CBR ≥ 15%	Natural Gravel CBR ≥ 15%	Natural Gravel CBR ≥ 15%	Natural Gravel CBR ≥ 15%	Natural Gravel CBR ≥ 15%	Natural Gravel CBR ≥ 15%	Natural Gravel CBR ≥ 15%	Natural Gravel CBR ≥ 15%
	Thickness	150 mm	150 mm	150 mm	150 mm	100 mm	100 mm	100 mm	100 mm
Improved Subgrade	Type			Natural Gravel CBR ≥ 7%			Natural Gravel CBR ≥ 7%	Natural Gravel CBR ≥ 7%	Natural Gravel CBR ≥ 7%
	Thickness			150 mm			150 mm	150 mm	150 mm
Subgrade	Type	CBR = 3%	CBR = 9%	CBR ≤ 2%*	CBR = 3%	CBR = 9%	CBR ≤ 2%*	CBR ≤ 2%*	CBR ≤ 2%*

*Indicates expansive clay subgrade

2.4.5 Specifications

Overview

The Specification for this project was formed predominantly using the Tanzanian Standard Specification for Road Works[8]. Other sources used included SATCC Standard Specifications for Road and Bridge Works and specifications from the SEACAP Project in South East Asia[9].

Methodology

General Specifications are sourced from the Tanzanian Standard Specification for Road Works 2000 wherever possible. However, other sources which were reviewed and utilised include the SEACAP Project, which supplied the information for concrete pavements and segmental block paving, such as hand packed stone blocks and concrete paving bricks. These are contained in the Special Specifications[9].

These documents supplied a standard specification using the standard materials, construction methods and method of measurement for each of the required processes. In reality, this project is based on very low volume roads and the use of marginal materials is required and permitted.

Tanzanian Standard Specification for Road Works

The Tanzanian Standard Specification for Road Works was compiled in 2000 under the Institutional Cooperation between the Ministry of Works for Tanzania, the Central Materials Laboratory (CML) and the Norwegian Public Roads Administration (NPRA). Its aim is to establish technical standards, guidelines and specifications for road and highway engineering.

Outlined below in are the main sections from the Specification, where series 8000 was introduced by the Consultant to introduce alternative pavements not covered in the Tanzanian Standard Specification[9].

Table 7 Section Reference for Tanzanian Standard Specification for Road Works

Series	Description
1000	General
2000	Drainage
3000	Earthworks and Pavement Layers of Gravel or Crushed Stone
4000	Bituminous Layers and Seals
5000	Ancillary Roadwork's
8000	Concrete and Alternative Pavements

Marginal Materials

This project promotes the use of locally sourced construction materials the use of alternative 'marginal' materials – materials presently considered substandard, but which can actually perform satisfactorily on low volume roads. The specification for construction materials may not always meet current accepted standards, but, on these roads, traffic levels and pavement stresses are low, therefore material specifications can be relaxed. This is imperative to the success of this

8 ***Standard Specification for Road Works,*** *Ministry of Works, The United Republic of Tanzania, 2000.*

9 ***Research Consultant to Support the Design, Construction and Monitoring of Demonstration Sites for District Road Improvements in Tanzania: Design Report,*** *Roughton International, November 2010.*

methodology, as locally sourced materials invariably cannot always meet the high standards required by current specifications.

A thorough investigation was carried out to locate suitable materials for construction of the road pavements. These investigations included locating suitable materials for construction of the selected subgrade, subbase, base and surfacing layers. Materials were tested to determine their suitability and the pavement design was based on the suitable materials which have been located in the area.

The key materials that were used in this project that do not meet the specifications set out in the TPMDM but may be considered suitable for low volume rural roads in Tanzania include the following;

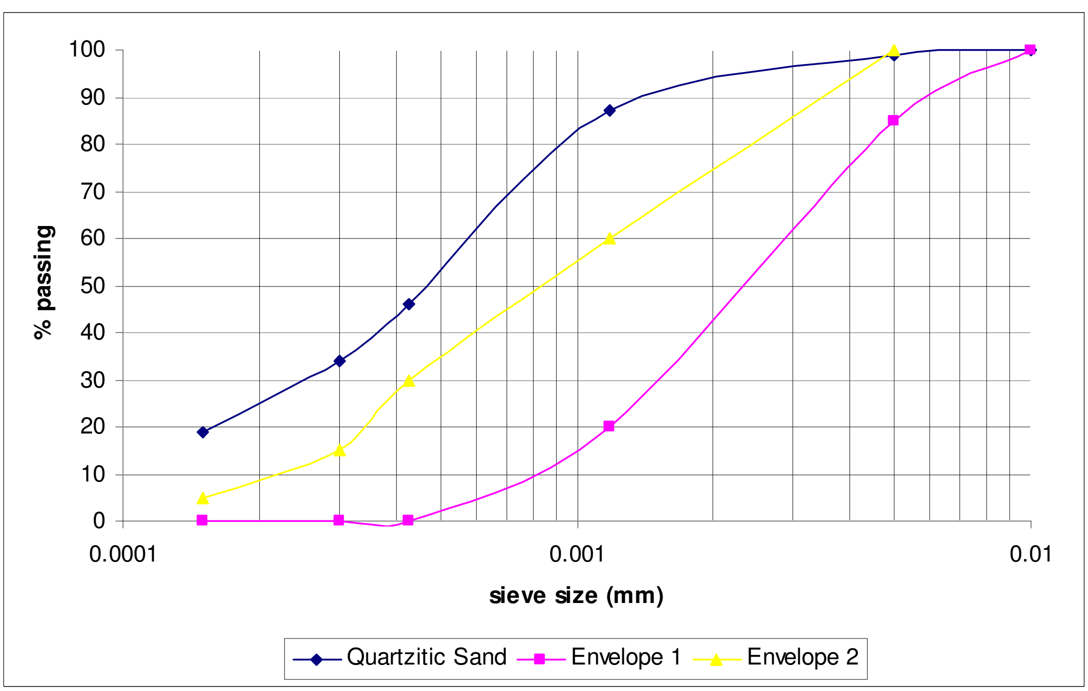
- Grading requirements for the sand seal
- Grading, plasticity index, and the ten percent fines value Otta seal aggregate
- Grading requirements of the crusher dust for the slurry seal
- CBR requirements for the pavement layers
- Grading requirements for the surface dressing aggregate

Details test for results for all materials are available in Appendix C - Test Results.

Sand

Figure 3, below, shows the grading requirements for a sand seal as set out in the TPMDM. The blue curve indicates the grading of the local sand available in Bagamoyo. The results indicate that the material is too coarse and too fine for a sand seal according to the Tanzanian specification. However, experience has shown that for low volume rural roads this material should perform satisfactorily.

Figure 3 Grading Envelope for Quartzitic Sand



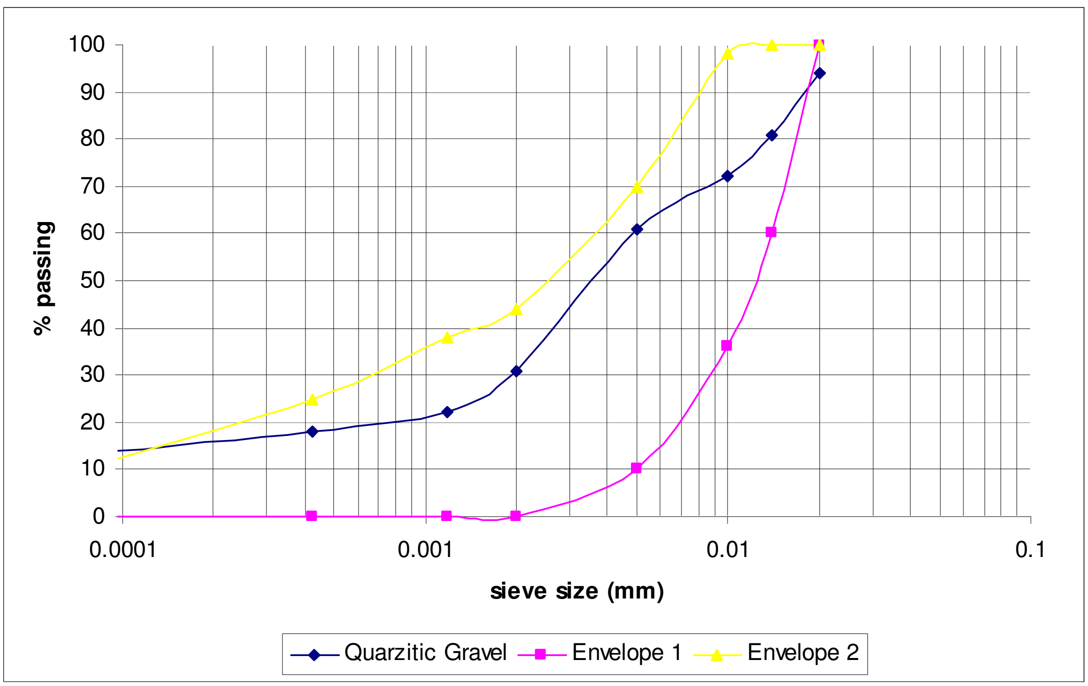
Otta Seal Aggregate

Figure 4, below, shows the grading envelope for an Otta seal aggregate as stated in the TPMDM. The curve indicates that the gravel is too coarse and too fine and that it is not suitable for an Otta seal. However, for this project a mosquito net was used to screen some of the fines and the oversize material was removed by hand to adapt the material to meet the grading specification. Furthermore, the material does not meet the PI and TFV requirements, as shown in Table 8. By screening the fine material from the gravel it also reduced the PI. The ten percent fines values also do not meet specification requirements but are considered suitable for low volume rural roads.

Table 8 Otta Seal Aggregate Requirements

	Quartzitic Gravel	TPMDM Specification
PI	26	12
TFV (Dry)	50	90
TFV (Wet)	45	54

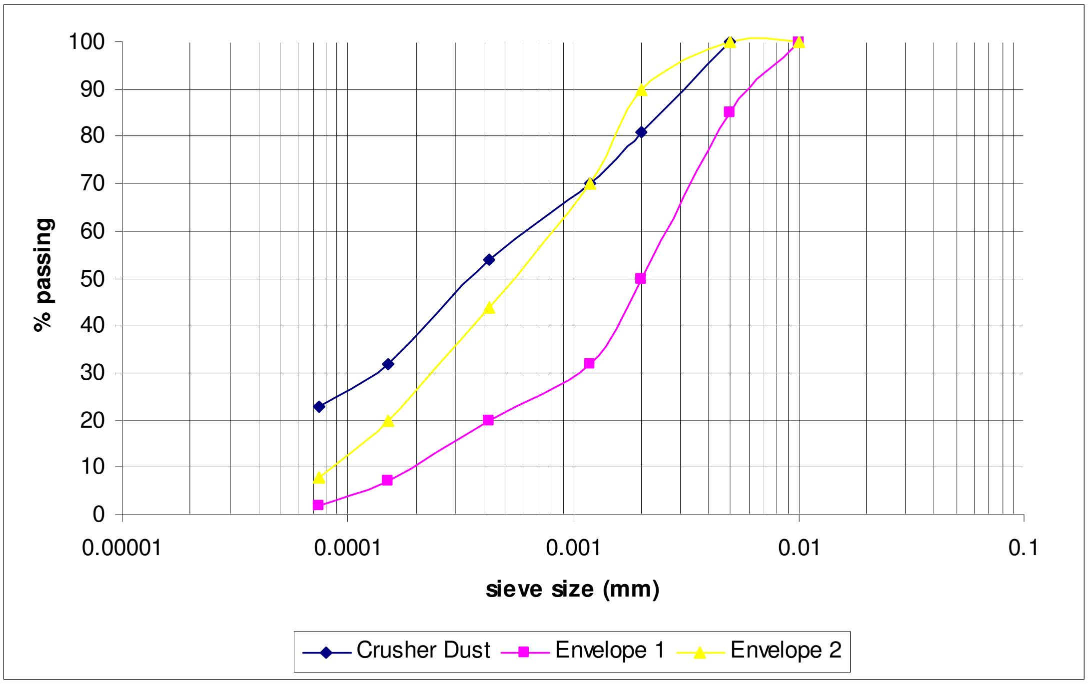
Figure 4 Grading Envelope for the Quartzitic Gravel



Crusher Dust

Figure 5, below, shows the grading envelope for crusher dust in a slurry seal, as stated in the TPMDM. The curve indicates that crusher dust is too fine to be used in a slurry seal. The result meant that additional water needed to be added to the slurry to make it flow easily.

Figure 5 Grading Envelope for the Crusher Dust



Surface Dressing Aggregate

The surface dressing aggregate did not meet the grading specification set out in the TPMDM. Table 9 shows that the aggregate is too coarse and too fine to meet the specification. The aggregate came from a quarry in the Lugoba/Chalinze area. The aggregate in this area is granite and is generally considered high quality. The quarries in the Lugoba/Chalinze area supply most crushed stone for construction in Dar es Salaam. Despite the fact that this material failed the grading requirements, the material meets the other requirements and the aggregate was considered suitable for low volume roads.

Table 9 14 mm Aggregate Grading

Sieve Size	14 mm Aggregate (% Passing)	Specification (% Passing)
20 mm	100	100
14 mm	99	85 - 100
10 mm	54	0 - 30
5 mm	2	-
2 mm	2	-
425 µm	1	< 1. 0
75 µm	1	< 0. 5

Marly Limestone

As it is the AFCAP project rationale to use locally available material, two very interesting borrow pits were utilised along the road in Bagamoyo. Our research has indicated that this material is a marly Limestone. The material has a self cementing property and our testing has indicated that the material CBR increases over time. A simple test was used to study the self cementing properties of the material. A sample of the marly Limestone was brought to the lab, the sample was split in two, the CBR of the material was then tested for one half of the sample, the other half was compacted into a CBR mould and left untouched for one month. Then after the one month period had elapsed the CBR mould was soaked for 4 days and the test was carried out on the sample. The results of the tests are shown below in Table 10. The TPMDM does not cover this type of material and it is believed that this material is abundant along the east coast of Tanzania. It is clear that this material could have large implications for use in roads in Tanzania.

Table 10 Marly Limestone CBR Results

	Normal CBR Procedure		CBR After 1 Month	
Borrow pit no.	Borrow pit 3	Borrow pit 4	Borrow pit 3	Borrow pit 4
CBR (%) (100% BS-Heavy)	30	58	35	77

Both borrow pits were trialled as pavement layers for different pavement types, including the bitumen pavements, geocells and the concrete strips. The performance of each of the materials will be monitored and their performance will be compared. Conclusions on their performance for low volume road construction will be made, possible specifications for the material in low volume rural road construction and recommendations for further study of this material will be drawn.

Conclusions

The Consultant would not have used these ‘marginal’ materials if we did not think that they would perform reasonably well. These materials are considered fit for their purpose. However, the performance of these ‘marginal’ materials will be assessed during the monitoring period and recommendations will be made on their suitability for low volume rural roads in Tanzania. The technical advisor to the project oversaw all the decisions made with regards using these materials.

3 THE CONSTRUCTED DEMONSTRATION PAVEMENTS

3.1 Constructed Demonstration Sections

In total fourteen demonstration sections were to be constructed in Bagamoyo. Two of the three gravel wearing course sections were constructed as control sections (sections 8 and 11). These control sections have varying topographic conditions. Due to problems encountered during the construction of geocell sections these were reduced accordingly and 13 sections were completed. A full list of the demonstration sections constructed is shown in Table 11. Detailed photographs of the construction of each section are available in Appendix B - Photographs Detailing the Construction Methodology.

Table 11 Schedule of Demonstration Sections in Bagamoyo

Section	Chainage (km)		Length (km)	Surfacing Type
	Start	End		
1	0.030	0.230	0.200	Single Otta Seal with a Sand Seal (26 mm)
2	5.340	5.520	0.180	Hand Packed Stone (150 mm)
3	5.560	6.080	0.520	Concrete Strips (100 mm - Reinforced)
4	6.080	6.740	0.660	Geocells (75 mm)
5	8.000	8.240	0.240	Double Surface Dressing (20 mm)
6	9.980	10.670	0.690	Concrete Strips (100 mm - Unreinforced)
7	11.200	11.400	0.200	Double Sand Seal (20 mm)
8	12.200	12.580	0.380	Gravel Wearing Course (150 mm)
9	16.240	17.100	0.860	Concrete Strips (100 mm - Reinforced)
10	18.480	18.740	0.260	Concrete Strips (100 mm - Reinforced)
11	19.000	19.200	0.200	Gravel Wearing Course (150 mm)
12	19.480	20.040	0.560	Gravel Wearing Course (150 mm)
13	20.040	20.260	0.220	Slurry Seal (8 mm)
	Total Length		5.170	

3.1.1 Experimental Pavements on Expansive Clays/Black Cotton Soils

Expansive soils, such as Black Cotton Soil, are fairly widespread across Tanzania. The mechanism of expansion is that of seasonal wetting and drying, with consequent movement of the water table. Soils at the edge of the road wet up and dry out at a different rate than those under a surfacing, thus bringing about differential movement. It is this movement, rather than low soil strength, most expansive soils being strong in the equilibrium moisture condition, which brings about failure. Differential movement will result in longitudinal cracks in the surfacing, thus facilitating the ingress and egress of water and accelerating the moisture change cycle. Failure of embankments and severe deterioration of the ride quality are also likely. [10]

It was decided to experiment with some new design methods for the project in Bagamoyo. The ideal solution for treatment of areas of black cotton soil is removing it entirely. However, this is costly and uneconomical for a rural road. An alternative option was excavating 600 mm to 1000

[10] ***Pavement and Materials Design Manual,*** *Ministry of Works, The United Republic of Tanzania, 1999.*

mm of the material, replacing it with non-plastic fill, use the excavated soil to increase the slope of the shoulders and reshape and re-compact the base and surface every few years.

The cost of this method was considered to be unjustifiable for a low volume rural road. The modified experimental design method used for this project provides surfacing such as hand packed stone, concrete strips (reinforced) or geocells on top of an improved subgrade layer that can accommodate some movement in the subgrade and can be easily maintained. Their performance will be monitored and recommendation for their suitability on low volume rural roads will be made.

In addition we are experimenting with a synthetic geo-grid system with a double surface dressing to prevent movement in the black cotton soil subgrade. This method is discussed below in 3.1.2.

3.1.2 Section 5 - Geosynthetics

Two geosynthetic materials were used in the construction of section 5 (double surface dressing); as a result, section 5 was divided into 5 sub-sections numbered from 5. 1 to 5. 5. The subgrade on this section is expansive clay (black cotton soil) and as a result we used a Fornit 30 base reinforcement geosynthetic. This involves installing a base reinforcement grid and applying the natural gravel base course over the gravel. For this project the Fornit 30 was laid flat on the G15 improved subgrade and 300 mm of Marley limestone gravel was compacted in two layers on top of the Fornit 30.

The use of the Fornit 30 geo-grid reinforcement has proven to provide substantial improvement to the structural capacity of road construction over problematic soils. For example, in Ireland, where road construction has occurred over the peat bogs, Fornit 30 geo-grid has successfully been used at the subgrade/sub base interface, to help stiffen the sub base/ base course layers and therefore reduce the risk of rutting at the surface course. We therefore considered that such solutions could be used to control the mechanisms associated with the wetting and drying of expansive clays which underlie certain parts of section 5. This method of constructing bitumen pavements on expansive clays is unique to this project and could have massive affects on the approach to constructing on expansive clays in Tanzania and across Africa if it proves to be successful.

The second geosynthetic that was used on section 5 was the Fortrac 3D-30 surface erosion control geosynthetic. This material is used to reduce the wearing of the bitumen surface, and reduce the period between reseals and prolong the life of the pavement. The geo-grid was laid flat on the base course and a standard double surface dressing was laid directly on top of the geo-grid.

The performance of these geosynthetic materials will be assessed during the monitoring period. The various sub-sections of section 5 are shown below in Table 12.

Table 12 Section 5 Sub-Sections

Section	Chainage (km)		Length (km)	Surfacing Type
	Start	End		
5	8.000	8.240	0.240	Double Surface Dressing (20 mm)
5.1	8.000	8.080	0.080	No geosynthetic
5.2	8.080	8.150	0.070	Fornit 30 base reinforcement geosynthetic
5.3	8.150	8.180	0.030	Fornit 30 base reinforcement & Fortrac 3D-30 surface erosion control
5.4	8.180	8.220	0.040	Fortrac 3D-30 surface erosion control geosynthetic
5.5	8.220	8.240	0.020	No geosythetic

3.1.3 Section 4– Geocells

Significant problems were encountered during the construction of the two proposed geocell sections. The completion of these sections was greatly hampered by the clearing of materials, which were sourced from South Africa, through Dar es Salaam Port. Due to a miscommunication between the supplier and the contractor the required South African Development Community (SADC) certificate of origin was not supplied. This resulted in the contractor incurring a tax on importing the geocells.

Along with this the contractor issued a statement indicating that as geocells are a relatively new technology in the Tanzanian construction industry and the local contractor's unfamiliarity with the pavement material it was not understood that concrete was required to cover the geocell mat and was thus not taken into account during tender. This was despite detailed tender documents highlighting the need for concrete in the construction of these pavement sections.

A revised length of geocell pavement was agree upon which lead to the removal of Section 6 and Section4 being reduced by approximately 1000m, leaving the total length of geocell pavement to be constructed at 600m.

3.1.4 Section 14 - Slurry Seal

Section 13 was divided into two sub-sections. The first sub-section 13.1 contains lime as the additive in the slurry and the second sub-section 13.2, contains cement as the additive. Comparisons will be made of the performance of the two different mixes over the monitoring period.

Table 13 Section 13 Sub-Sections

Section	Chainage (km)		Length (km)	Surfacing Type
	Start	End		
13	20.040	20.260	0.220	Slurry Seal (8 mm)
13.1	20.040	20.150	0.110	Slurry Seal with lime additive
13.2	20.150	20.260	0.110	Slurry Seal with cement additive

3.1.5 Construction Materials

Four borrow pits were located in the vicinity of the road. Borrow pit number 1 was located during the design phase, however this borrow pit was not utilised during the construction phase as the other borrow pits were considered sufficient. A summary of the properties and location of the materials is shown in Table 14. It has been concluded that BP 4 is the superior borrow pit with a high CBR. It has also been shown that BP 3 contains some smectite (clay). However, both marly limestone gravels were used as pavement layers for each of the different pavement types and their performances will be compared over the monitoring period.

The marly limestone from borrow pit number 4 was used in the construction of the hand packed stone. There was an abundance of marly limestone in the area. The stone is very strong and cubic in shape which made the stone very suitable for the construction of the hand packed stone. The stone was also used in the construction of the headwalls of the culverts, the cut-off walls of the drifts and to line the ditches on sections 2 and 4.

The gravel from BP 2 was used as the Otta seal aggregate. Some of the fines and the oversize material were removed from the gravel before it was used in the Otta seal.

Table 14 Borrow Pit Summary

Chainage (km)	Offset (km)	Description	Borrow Pit No.	PI	CBR (95%)	CBR (98%)
2.700	1.25	Red Quartzitic Gravel	BP 2	26	20	-
8.030	0.00	Marly Limestone Gravel	BP 4	14	46	52
13.860	0.00	Marly Limestone Gravel	BP 3	14	25	30

Table 15, indicates which borrow pit each pavement layer came from during construction. This is important to note because some of the pavement layers have higher specifications than required and some have lower specifications than indicated in the design.

Table 15 Schedule of Pavement Layers

Section	Chainage (km)		Length (km)	Surfacing Type	Pavement Layers (mm)									
	Start	End			G7		G15		G45		G60		GWC	
1	0.030	0.230	0.200	Single Otta Seal with a Sand Seal	150	BP 2	-	-	-		150	BP 4	-	-
2	5.340	5.520	0.180	Hand Packed Stone	150	BP 2	100	BP 3	150	BP 4	-	-	-	-
3	5.560	6.080	0.520	Concrete Strips	150	BP 2	100	BP 3	150	BP 4	-	-	-	-
4	6.080	6.740	0.660	Geocells	150	BP 2	100	BP 3	150	BP 4	-	-	-	-
5	8.000	8.240	0.240	Double Surface Dressing	150	BP 2	150	BP 3	150	BP 4	150	BP 4	-	-
6	9.980	10.670	0.690	Concrete Strips	-	-	100	BP 3	150	BP 3	-	-	-	-
7	11.200	11.400	0.200	Double Sand Seal	-	-	150	BP 3	-	-	150	BP 4	-	-
8	12.200	12.580	0.380	Gravel Wearing Course	-	-	-	-	-	-	-	-	150	BP 3
9	16.240	17.100	0.860	Concrete Strips	150	BP 3	100	BP 3	150	BP 3	-	-	-	-
10	18.480	18.740	0.260	Concrete Strips	150	BP 3	100	BP 3	150	BP 3	-	-	-	-
11	19.000	19.200	0.200	Gravel Wearing Course	-	-	-	-	-	-	-	-	150	BP 3
12	19.480	20.040	0.560	Gravel Wearing Course	-	-	-	-	-	-	-	-	150	BP 3
13	20.040	20.260	0.220	Slurry Seal	150	BP 3	-	-	-	-	150	BP 3	-	-
	Total Length (km)		5.170											

3.1.6 Passing Bays

Passing bays were installed at regular intervals along the various different demonstration sections to allow vehicles to pass sufficiently. The road has a 3 m carriageway, in general, and a 1 m shoulder on either side of the carriageway. The passing bays are particularly important on the concrete strips sections. Although the passing bays are important to allow the vehicles to pass adequately and safely, the shoulder is generally sufficient in an emergency scenario for most vehicles to pass each other. The passing bays were originally going to be constructed using a concrete surface, however, this is extremely expensive and it was agreed between the District Engineer, the Consultant and a representative from PMO-RALG that the passing bays would remain as gravel. A schedule of passing bays is shown in Table 16.

Table 16 Schedule of Passing Bays

Passing Bays	
Section	**Chainage (km)**
2	5+420
3	5+600
3	5+830
4	6+100
4	6+400
4	6+600
4	6+880
4	7+580
5	8+110
6	8+400
6	8+640
7	10+100
7	10+440
10	16+340
10	16+480
10	16+720
10	17+100
11	18+620
11	18+680

3.2 Construction Costs

The construction costs for one kilometre of each of the pavements and a square metre cost for each of the pavements using the contractor that constructed the different pavements is shown in Table 21.

In each case the cost per square metre is the cost of the designated pavement construction above the prepared subgrade. On this basis the cost of Engineered Natural Earth is nil since this is, effectively, the prepared subgrade in an area where the in situ material is of a high enough quality to act as the road pavement/ surface.

It is the consultant's belief that some of the rates for construction received by the contractor's in Bagamoyo were unjustifiably high. An analysis of these rates highlights some of these irregularities.

Table 17 Aggregate Bid Rates

Item Description	Tanzanian Schillings			Unit
	Bid 1*	Bid 2	Bid 3	
Natural Aggregate, Otta Seal	148,500	503,900	18,000	m^3
Surface Dressing, 14 mm aggregate	148,500	432,000	85,000	m^3
Surface Dressing, 7 mm aggregate	148,500	550,000	85,000	m^3

*Indicates the contractor that won the contract in Bagamoyo

Firstly, it is worth noting that the contractor had priced the natural aggregate for the Otta seal as crushed aggregate from a quarry. When it came to constructing the pavement, the contractor wanted to use a crushed rock aggregate and was very reluctant to use a natural aggregate because the contractor was worried that the quality of the pavement would suffer from using a natural aggregate. Consequently, since a natural aggregate was used in the pavement, but the contractor had priced the aggregate as a crushed rock aggregate, the cost of the pavement is higher than it should have been if the contractor had priced this item correctly. The rates for the three bids are shown in Table 17. It can be concluded that bid 3, 18,000 Tshs is close to the 'real cost' for the natural aggregate for the Otta seal.

Table 18 Cement Mortared Stone Walls Bid Rates

Item Description	Tanzanian Schillings			Unit
	Bid 1*	Bid 2	Bid 3	
Cement Mortared Stone Walls	150,000	125,000	115,000	m^3

*Indicates the contractor that won the contract in Bagamoyo

The District Engineer has indicated that the cost of cement mortared stone walls is very expensive for all the bids, put particularly high for bid 1, which was the contractor who won the contract. This rate is considered overpriced, especially considering the fact that there was more than enough suitable stone in the area and the fact that their was no risk to the contractor that they would be unable to perform the task because the contractor had a number of skilled masons and their workmanship was of a very high standard.

Table 19 Natural Gravel Bid Rates

Item Description	Tanzanian Schillings			Unit
	Bid 1*	Bid 2	Bid 3	
Natural Gravel Class, G7	18,500	18,000	19,000	m^3
Natural Gravel Class, G15	19,200	18,000	19,000	m^3
Gravel Wearing Course	19,200	35,000	30,000	m^3
Natural Gravel Class, G45	34,500	35,000	30,000	m^3
Natural Gravel Class, G60	62,300	35,000	81,000	m^3

*Indicates the contractor that won the contract in Bagamoyo

The rates for natural gravel class, G7 and G15 from all 3 contractors were very similar, between 18,000 and 19200 Tsh. The rate for natural gravel class, G45 is between 30,000 and 35,000 Tsh and the cost of natural gravel class, G60 is 35,000, 62500 and 81,000 Tsh. However, all the gravel came from the same borrow pits and the haulage distance is similar. Even taking into account the extra passes with a roller to compact G45 and G60 to a higher field density, it does not justify the huge extra costs that the contractors have included in there rates.

Table 20 Bitumen Bid Rates

Item Description	Tanzanian Schillings			Unit
	Bid 1*	Bid 2	Bid 3	
Prime Coat, MC-30	4,100	2,800	3,500	litres
80/100 penetration grade bitumen	4,100	3,400	3,000	litres
Otta Seal, MC-3000 cutback bitumen	6,350	3,400	3,500	litres
Sand Seal, MC-3000 cutback bitumen	4,500	3,400	3,500	litres

*Indicates the contractor that won the contract in Bagamoyo

The rates for bitumen vary significantly. The rates used during construction are from bid 1. This contractor's rates are the highest out of the three bids. It is concluded that these high rates are down to the contractor's lack of experience with bitumen work, lack of quality equipment and lack of skilled staff. Another possibility for the high rates is that it may have been very difficult for the contractors to price for short lengths of various different bitumen works. If only one bitumen pavement was selected for each of the demonstration sections you would expect the price to reduce significantly. Also, there is no real reason for the contractor price the MC-3000 for the Otta seal higher than for the sand seal.

Conclusions

Based on the abovementioned analysis, it is concluded that the contractor's have over priced some of the items. However, it is expected that once the contractors in Tanzania become familiar with the techniques of these various different surfacing options there will be less risk involved and the rates will reduce.

Table 21 Construction Costs

Section	Chainage (km)		Length (km)	Surfacing Type	Costs (Tshs)		Costs (USD)	
	Start	End			Total Cost/km (Tshs)	Cost/m² (Tshs)	Total Cost/km (USD)	Cost/m² (USD)
1	0.030	0.230	0.200	Single Otta seal with a sand seal (26 mm)	128,527,500	25,706	85,685	17.137
2	5.340	5.520	0.180	Hand Packed Stone (150 mm)	97,707,000	19,541	65,138	13.86
3	5.560	6.080	0.520	Concrete Strips (100 mm - Reinforced)	99,786,780	19,957	66,525	14.15
4	6.080	6.740	0.660	Geocells (75 mm)	97,303,500	19,461	64,869	12.97
5	8.000	8.240	0.240	Double Surface Dressing (20 mm)	149,190,090	29,838	99,460	19.89
6	9.980	10.670	0.690	Concrete Strips (100 mm - Unreinforced)	78,540,930	15,708	52,361	11.14
7	11.200	11.400	0.200	Double Sand Seal (20 mm)	118,797,250	23,759	79,198	15.84
8	12.200	12.580	0.380	Gravel Wearing Course	14,832,000	2,966	9,888	1.98
9	16.240	17.100	0.860	Concrete Strips (100 mm - Reinforced)	99,786,780	19,957	66,525	14.15
10	18.480	18.740	0.260	Concrete Strips (100 mm - Reinforced)	99,786,780	19,957	66,525	14.15
11	19.000	19.200	0.200	Gravel Wearing Course	14,832,000	2,966	9,888	1.98
12	19.480	20.040	0.560	Gravel Wearing Course	14,832,000	2,966	9,888	1.98
13	20.040	20.260	0.220	Slurry Seal (8 mm)	101,525,000	20,305	67,683	13.54
	Total Length		5.170					

*For comparison purposes, costs in this table, originally tendered in Tshs, are shown in US dollars at the June 2010 exchange rate of USD 1 = Tshs 1500

3.2.2 Environmentally Optimised Design

The EOD approach states that you spend a small amount of resources on the good lengths of the road, spend some resources on the standard sections of the road and spend most resources on the problematic sections and as a result you will have a make cost saving compared to gravelling the entire road from start to finish. An analysis of this philosophy was investigated for this project. Table 22 gives a summary of what was done on each section of the road length, varying from engineered natural earth, gravel wearing course and the different surfaces.

Table 22 Summary of all Road Sections

Chainage (km)		Length (km)	Surfacing Type	Pavement Layers (mm)				
Start	End			G7	G15	G45	G60	GWC
0.000	0.030	0.030	Engineered Natural Earth (Red Soil)	-	-	-	-	-
0.030	0.230	0.200	Single Otta seal with a sand seal (26 mm)	150	-	-	150	-
0.230	3.730	3.500	Engineered Natural Earth (Red Soil)	-	-	-	-	-
3.730	5.340	1.610	Engineered Natural Earth (Quartzitic Gravel)	-	-	-	-	-
5.340	5.520	0.180	Hand Packed Stone (150 mm)	150	100	150	-	-
5.520	5.560	0.040	River Crossing (Drift)	-	-	-	-	-
5.560	6.080	0.520	Concrete Strips (100 mm - Reinforced)	150	100	150	-	-
6.080	6.740	0.660	Geocells (75 mm)	150	100	150	-	-
6.680	8.000	1.320	Gravel Wearing Course	-	-	-	-	100
8.000	8.240	0.240	Double Surface Dressing (20 mm)	150	150	150	150	-
8.240	8.320	0.080	Gravel Wearing Course	-	-	-	-	100
8.320	8.820	0.500	Geocells (75 mm)	150	100	150	-	-
8.820	9.980	1.160	Gravel Wearing Course	-	-	-	-	100
9.980	10.670	0.690	Concrete Strips (100 mm - Unreinforced)	-	100	150	-	-
10.670	11.200	0.530	Engineered Natural Earth (Light Red Soil)	-	-	-	-	-
11.200	11.400	0.200	Double Sand Seal (20 mm)	-	150	-	150	-
11.400	12.200	0.800	Gravel Wearing Course	-	-	-	-	100
12.200	12.580	0.380	Gravel Wearing Course	-	-	-	-	150
12.580	13.520	0.940	Gravel Wearing Course	-	-	-	-	100
13.520	14.180	0.660	Engineered Natural Earth (Marley Limestone)	-	-	-	-	-
14.180	16.240	2.060	Gravel Wearing Course	-	-	-	-	100
16.240	17.100	0.860	Concrete Strips (100 mm - Reinforced)	150	100	150	-	-
17.100	18.480	1.380	Gravel Wearing Course	-	-	-	-	100
18.480	18.740	0.260	Concrete Strips (100 mm - Reinforced)	150	100	150	-	-
18.740	19.000	0.260	Gravel Wearing Course	-	-	-	-	400
19.000	19.200	0.200	Gravel Wearing Course	-	-	-	-	150
19.200	19.480	0.280	Gravel Wearing Course	-	-	-	-	100
19.480	20.040	0.560	Gravel Wearing Course	-	-	-	-	150
20.040	20.260	0.220	Slurry Seal (8 mm)	-	150	-	150	-
Total Length		20.260						

Table 23 Summary of EOD

Surface	Length (%)	Length (km)	Costs per km (USD)	Cost (USD)
Engineered Natural Earth	32	6.33	8,905	56,366
Gravel Wearing Course	40	8.09	16,926	136,930
Concrete Strips (Unreinforced)	14	2.77	59,966	166,106
Geocells	14	2.77	72,257	200,152
Surfacing*	28	5.54	66,111	366,258
Cost of EOD	100	20.26	27,619	559,553
Cost of Double Surface Dressing	100	20.26	107,778	2,183,589
Cost of Standard Gravel Solution	100	20.26	16,926	342,918

*Surfacing cost is the average of the two cheapest solutions;

**For comparison purposes, costs in this table, originally tendered in Tsh, are shown in US dollars at the June 2010 exchange rate of USD 1 = Tsh 1500

Table 23 above shows a summary of the costs associated with environmentally optimised design for this project. The costs include all earthworks, clearing, grubbing, and removal of topsoil and trees, drainage and passing bays. The cost used for surfacing is the average cost of the two cheapest solutions; concrete strips and geocells. The analysis indicates that the cost of the EOD approach is more expensive than the standard gravel solution. The total cost of gravelling the entire road is 62% of the EOD approach. Also shown, is the cost of a double surface dressing for the entire length of the road. This is included in the analysis because it is assumed that under normal circumstances, if a district road was to be upgraded to bitumen standard then the double surface dressing would be most common choice. It is considerably more expensive to use a double surface dressing for the entire length of the road than either the environmentally optimised design approach or the standard gravel solution.

A number of other aspects should be taken into account for this project. Firstly, as this is a demonstration project to showcase the different surfaces available, we suspect that we received high rates because so many different pavements were being used and in many cases only for short lengths of the road. In reality, if you were to adopt the EOD approach you would probably only use one or two of the cheapest pavements, economies of scale would dictate that if you were to use just one or two pavements and increase the quantity of these pavements it would bring the costs down. One can assume that this would be the case.

Secondly, a number of the pavements were constructed through three of the villages along the road. It was not essential that these paved roads were constructed in order to provide year round access along the road, but were introduced to demonstrate how a pavement surface can be used to reduce dust pollution in highly populated areas.

In total 40% of the road was gravelled during construction. The objective of EOD is not to gravel such large lengths of road; it had originally been proposed to construct longer engineered natural earth sections. It was requested by the District Engineer to use the contingency funds to gravel some additional sections to make the road better as a whole. However, for our analysis we will not take this into account for the costs.

This analysis also does not to take into account maintenance and the whole life cost of the pavements. The whole life cost analysis is covered in section 4.1.3.

It is important to note that the contractor issued a statement towards the end of the project, prior to constructing the geocell sections, that due to their lack of familiarity they had not tendered for concrete to cover the geocell mat in the price of the pavement. This has lead to the tendered cost of the geocell pavement being much lower than what its actual cost will be.

It is also worth noting that the District Engineer had just upgraded an earth road to gravel standard from Talawanda to Lugoba, a road that continues on from the project road.

The construction of this road finished before the beginning of the long rains in Tanzania (March 2011). After a few a rains the road became impassable. The road was not impassable for the entire length but it was at specific problematic locations that prevented access. This highlights the fact that a gravel road does not guarantee basic access and the problems associated with it. It has already been seen during the most recent rain season that the project road provides all weather access.

Conclusions

For this project, the cost of the standard gravel solution was less expensive than the EOD approach. However, there are a number of viable reasons for this and it is recommended that another project should be carried out where the primary objective is to just apply the EOD approach and only one pavement should be used for each of the problematic sections, gravelling should only be carried out on necessary sections, the remainder of the road should be engineered natural earth and a detailed analysis should follow.

3.3 Quality Control

Throughout the course of the construction it was a key to take measurements and testing to control the quality of the work. Numerous samples of the construction materials were tested at Tanroads Central Materials Lab in Dar es Salaam. The contractor regularly took concrete cubes for testing the strength of the concrete. The results were of an acceptable standard. All test results are available in Appendix C - Test Results.

The field team spot checked the invert levels of the pipe culverts. All spot checks met required levels and slope.

The field team tested the field density of the roadbed, improved subgrade and pavement layers using the Troxiler method. After testing the field density of the improved subgrade layer for section 7, it was revealed that it did not meet the specification and the contractor was instructed to re-compact that section. All other sections met the required specification.

The layer thickness was spot checked and verified by a combination of core drilling and dumpy level by the field engineer and District Engineer’s office. The G7 improved subgrade layer did not meet required thickness and the contractor was requested to scarify, add more material and compact the G7 layer in order to meet specification. The repeating of the layer thickness took the contractor several weeks and resulted in large additional cost to the contractor.

The bitumen distributor was calibrated for each of the different spray rates and bitumen types before the bitumen work began.

Photographs of each of these testing methods are available in Appendix B.

3.4 Standard Gravel Pavement

Three sections were constructed as control sections using a 150 mm gravel wearing course layer. The purpose of these sections is to compare the performance and cost of the demonstration pavements that are new to Tanzania to the current solution rural low volume rural roads, a gravel wearing course. For this project the gravel wearing course was constructed using Marly limestone gravel with a CBR≥25% and also meeting the shrinkage product and grading coefficient requirements set out in the TPMDM.

Advantages

This pavement is advantageous over other pavements because it is relatively cheap and utilises local materials.

Disadvantages

A gravel pavement does not guarantee that a road will remain passable throughout the year. This method is not sustainable in the long term and has high maintenance requirements, utilising gravel which is a finite resource. Also, this pavement increases vehicle operating costs and the surface texture does not compare to the smooth running surface of a paved road.

3.5 Concrete Strips

The construction method is similar to any other concrete work. The concrete was cast in-situ using formwork and concrete mixers on a prepared natural gravel subbase of 150 mm thickness. No dowels were used in between the concrete. Once the concrete was constructed, gravel was spread down the centre of the strips and as a shoulder for the strips. The additional gravel was compacted using a pedestrian roller. An intermittent concrete strip was installed at 5 m intervals down the centre of the strips to prevent water from flowing down the centre of the strips during the rain season. The thickness of the concrete used was 100 mm and the compressive strength was 20 MPa.

An additional layer of 4 mm steel mesh was used on the sections with an expansive clay subgrade to help accommodate some movement in the subgrade.

Advantages

The cost of this pavement is relatively cheap compared with some of the other pavements, making more efficient use of concrete than other concrete pavements. The pavement is not complicated and easily constructed. The pavement is suitable for labour based construction utilising local labour, small concrete mixers and a pedestrian roller.

Disadvantages

Difficulties occur when vehicles meet each other along the strips. This problem was overcome by using passing bays at regular intervals. However, it is accepted that not all vehicles will use these and there will be edge breaks on the strips and this will increase maintenance costs. Though the pavement is very simple to construct and the steps involved are not complicated, the construction of this pavement does take a very long time compared to the other pavements.

3.6 Concrete Geocells

The concrete geocell pavement requires two trenches to be excavated along either side of the road 200 mm wide by 150 mm deep to "tuck in" the geocells. A thin layer of sand is spread to level the base. Reinforcement bars are cut to short lengths and used to peg the geocell formwork into place which is then tightened using rigging strings. The concrete used for the geocells should be mixed to a "pumpable" consistency using 6-13mm coarse aggregate and locally sourced alluvial sand. The concrete mixture is spread and levelled flush to the top of the geocells. It is important that the concrete does not form a slab over the top of the geocell formwork. The concrete is finished and cured as with other concrete work.

Advantages

This pavement has all of the advantages of the concrete slabs such as the use of locally sourced materials and the fact that little sophisticated equipment is required. Construction is well suited to labour based work. The resulting pavement is of a high strength and therefore offers long serviceability with little maintenance. The flexibility of the geocell mat allows a small amount of movement in the pavement and should therefore not crack in the presence of subsurface deficiencies but will deform slightly. It is hoped that pavement thickness can be reduced in future whilst maintaining performace and therefore reduce costs.

Disadvantages

Many contractors and labourers may be unfamiliar with the geocell pavement and a geocell expert was mandatory on site as a requirement of the manufacturer. Lack of familiarity with the geocell material caused slow production. Though the pavement is very simple to construct and the steps involved are not complicated, the construction of this pavement is time consuming compared to the other pavements. It is hoped that as contractors gain familiarity with geocell construction then these problems will be easily avoided.

3.7 Double Sand Seal

This pavement comprised a marly limestone natural gravel base of 150 mm primed with MC-30 bitumen at a rate of 1 l/m². The sand used in the surface is locally sourced quartzitic (alluvial) sand. The sand did not meet specification for a sand seal as set out in the TPMDM. However, since the aim of this project was to fully utilise locally sourced materials and this marginal material was seen as fit for its purpose it was consequently used in this demonstration. The MC-3000 bitumen was sprayed at a rate of 1.2 l/m² and the sand was spread at a rate of 0.011 m³/m² for both layers, as specified by the TPMDM, and rolled with a 12 tonne pneumatic tyre roller, these spray rates were deemed acceptable for the material used on low volume roads. Areas that showed signs of bleeding were blinded with sand for several days after construction. A one month period elapsed between successive seals, during which time the road was open to traffic.

Advantages

This surface uses local sand and was quick to construct. The gravel base course is much cheaper than a crushed rock base.

Disadvantages

The contractor had difficulties in locating MC-3000 bitumen in Tanzania and was unwilling to cut 80/100 penetration grade bitumen because they did not have the necessary skills or knowledge to do so, they also did not have suitable plant to do so. The contractor’s bitumen distributor had a total spray bar width of 2.3 m, which required the contractor to make more than once pass to spray the full width of the road. The preferred method would be to have a wider spray bar and to spray the section in a single pass with the bitumen distributor. The rate of 4500 Tshs per litre of bitumen made this pavement very expensive when compared to the hand packed stone and the concrete pavements.

3.8 Hand Packed Stone

This pavement was constructed from stone that was sourced from borrow pit number 3 at chainage 8+030 km. The stones are naturally cubic in nature and were ideally suited for the construction of the hand packed stone pavement. The stones have a nominal thickness of 150 - 200 mm and neatly placed on a 50 mm bed of sand constructed. The stones were placed tightly placed side by side and a hammer was used to compact them into the bed of sand. Smaller stones were then packed into the voids between larger stones and sand was used to fill the remaining voids between the stones.

Advantages

This pavement is suitable for labour based construction, easily constructed, cost effective, utilises local materials and can be easily maintained by local authorities, contractors and stakeholders. The pavement can be constructed on flat or steep sections and depending on our findings during the monitoring period, may be suitable to be constructed on expansive clay.

Disadvantages

The resulting surface is very rough and only desirable for short problematic lengths of road. Suitable rock sources must be available within an economic haulage distance. The construction requires a high level of expertise and a significant amount labour and may not be suitable for a general contractor.

3.9 Slurry Seal

This surface was constructed by adding crusher dust, cationic stable grade emulsion (60% bitumen), water, cement/lime into a concrete mixer and then spreading the resultant mixture onto the roadbed using rubber squeegees. Several trial mixes of the slurry were carried out before construction. The final mix included the following:

- Adding of 69 litres of crusher dust;
- Slowly adding 2.25 litres of cement/lime;
- Very slowly pouring 10.5 litres of water into the mixer;
- Slowly pouring 17 litres of bitumen emulsion into the mixer;
- Very slowly pouring 9 additional litres of water into the mixer;

The mix should flow easily and have a creamy consistency. The slurry was the placed into a wheelbarrow, placed on the roadbed with shovels and spread using rubber squeegees. Once spread evenly a drag, made from a mosquito net, and was used to give the surface a smooth finish. Approximately 4 hours later once the slurry began to break, the seal was compacted using a lightly loaded truck. The total length of the slurry seal section is 220 m. The first 110 m of the section was constructed using lime in the slurry mix and the remaining 110 m of the section was constructed using cement in the slurry mix. This pavement was primed with MC-30 bitumen at a rate of 1.0 l/m^2 before construction of the slurry seal.

Advantages

This surfacing is suitable for labour based construction, can be constructed quickly, is suitable for low traffic volumes, and does not require high tech equipment or highly skilled labour.

Disadvantages

This method is expensive, does not utilise local materials, is not suitable for steep gradients and requires significant maintenance relative to other pavement types.

3.10 Double Surface Dressing

This pavement comprised a marly limestone natural gravel base of 150 mm primed with MC-30 bitumen at a rate of 1.0 l/m^2. The bitumen used for this surfacing was 80/100 penetration grade bitumen. The first layer of bitumen was sprayed at a rate of 1.4 l/m^2 and 14 mm aggregate was spread at a rate of 0.011 m^3/m^2. The second layer of bitumen was sprayed at a rate of 1.0 l/m^2 and the aggregate was spread at a rate of 0.007 m^3/m^2. The aggregate was rolled with a 12 tonne pneumatic tyre roller.

Advantages

Most contractors are familiar with this surfacing type in Tanzania. Suitable chippings and bitumen are readily available in Tanzania. This surfacing is durable, suitable for steep gradients and high traffic volumes.

Disadvantages

The rate of 4,100 Tsh per litre of bitumen and the extra cost associated with crushed aggregate made this pavement very expensive when compared to the other pavements

3.11 Single Otta Seal and a Sand Seal

This pavement comprised a marly limestone natural gravel base of 150 mm primed with MC-30 bitumen at a rate of 1.0 l/m^2. The aggregate used in this seal was sourced from borrow pit number 2. The aggregate was quartz and the fines had to be screened from the gravel before construction. The aggregate used came from borrow pit number 2. The sand used in the surface is locally sourced quartzitic (alluvial) sand. The sand did not meet specification for a sand seal as set out in the TPMDM. However, since the aim of this project was to fully utilise locally sourced materials and these marginal material were seen as fit for their purpose and they were consequently used in this demonstration. The MC-3000 bitumen was sprayed at a rate of 1.7 l/m^2 and the aggregate was spread at a rate of 0.016 m^3/m^2 for the Otta seal layer. For the sand cover seal, the MC-3000 bitumen was sprayed at a rate of 0.8 l/m^2 and the sand was spread at a rate of 0.011 m^3/m^2 and rolled with a 12 tonne pneumatic tyre roller, these rates are as specified in the TPMDM were deemed acceptable for the materials used on low volume roads.. A one month period elapsed between successive seals, during which time the road was open to traffic.

Advantages

Both the gravel for the Otta seal and the sand for sand seal were sourced locally and the surfaces were constructed quickly. The use of a standard gravel base course resulted in a cheaper non erodible dust free running surface.

Disadvantages

The contractor had difficulties in locating MC-3000 bitumen in Tanzania and was unwilling to cut 80/100 penetration grade bitumen because they did not have the necessary skills or knowledge to do so, they also did not have suitable plant to do so. The contractor's bitumen distributor had a total spray bar width of 2.3 m, which required the contractor to make more than once pass to spray the full width of the road. The preferred method would be to have a wider spray bar and to spray the section in a single pass with the bitumen distributor. The rate of 6500 Tsh per litre of bitumen made this pavement very expensive when compared to the hand packed stone and the concrete pavements.

3.12 Engineered Natural Surface

This pavement utilises the existing in-situ soil which is graded, reshaped and compacted to form the carriageway. This pavement was constructed with a crossfall of 4% to divert water in the side ditches. Three different in-situ soils were used to form this pavement in Bagamoyo, consisting of an in-situ marly limestone, quartzitic gravel and red sandy soil.

Advantages

This pavement is very low cost and suitable for low traffic volumes. The pavement is suitable for local maintenance and can be constructed using simple grading equipment.

Disadvantages

This pavement requires a high level of maintenance. This pavement may become impassable during heavy rains if not properly maintained and the drainage must be kept working at all times. Furthermore, there can be dust pollution problems during the dry season.

Photographs detailing the method of constructing each of the pavements are available in Appendix B - Photographs Detailing the Construction Methodology.

3.13 Discussion and Conclusions

The contractor's workmanship for the concrete pavements was of a high standard. The contractor did not attempt to use excess water in the mix, always compacted the concrete and cured the concrete using sand. As a result, there was no bleeding or cracking in the concrete. The contractor regularly took concrete cubes for quality control, yielding adequate results.

The contractor had a number of skilled masons, and the stone (marly limestone) available locally was very suitable for the hand packed stone pavement. Consequently, the hand packed stone pavement was constructed to a high standard.

For this project the bitumen pavements were not as successful as the other pavement types. In order to construct a bitumen pavement specialist equipment is required. The contractor was unable to obtain a small bitumen heater for the project, significant effort was made by the consultant, the contractor and the DE's office to try and locate a suitable bitumen heater. The bitumen distributer that the contractor had was very old (1983), the spray bar was an inadequate length for the road width, the temperature gauges attached to the spray bar did not work and the motor to circulate the bitumen in the distributer was unreliable and frequently broke down. The contractor's equipment was not suitable for cutting bitumen and as a result they had to locate MC-3000 bitumen from local suppliers. The contractor expressed concern throughout the project that they had serious difficulties in locating MC-3000 bitumen in Dar es Salaam. MC-3000 bitumen is not available locally in Tanzania. Reliability of machinery was a factor in the speed of construction; concrete mixers often broke down requiring concrete to be mixed and poured by hand, greatly slowing production of concrete strip and geocell sections.

Furthermore, successful construction requires skilled technicians with experience in the construction of bituminous pavements. The contractor did not have skilled workers that were familiar with bitumen pavement construction. The contractor has benefited significantly from the experience of the consultants experienced staff. Based on the foregoing, it can only be concluded that these are the reasons that led the contractor to bid extremely high rates for bitumen.

During construction a minimum level of quality control must adhered to. The contractor was often found to be not carrying out work to the required standard; this was evident in the layer thickness of the G7 improved subgrade layer which had to be repeated. The field density results generally yielded high results, as did the concrete cube results. However it is advised that as much quality control as possible is implemented during construction.

4 MAINTENANCE REQUIREMENTS, CAPACITY AND COST

4.1.1 Execution of maintenance

Realistic predictions of future maintenance during the life of the rural road are important. All pavements will require maintenance to preserve them. Failure to maintain will lead to accelerating deterioration as ruts become gullies and surfacing faults turn into ever larger potholes

The maintenance requirements for the road pavement will vary considerably depending on the pavement design, quality of construction and the traffic to which it is subjected. There is, in general, a trade-off between pavement first cost and subsequent maintenance costs. This trade-off, however, is not constant but will vary with conditions of use. A gravel pavement used on a stretch of straight and level embankment will require substantially less maintenance than the same pavement employed on a steep gradient with severe curves.

The most cost effective choice of pavement can be assessed on the basis of the estimated whole life cost of the pavement, that is the initial construction cost plus the amortised costs of future pavement maintenance. Whilst such analysis assumes maintenance will be carried out, it should also consider the case where little or no maintenance is provided due to lack of funds.

In the case of roads carrying substantial traffic this estimation is complicated by the need to consider the cost implications for that traffic, i.e. Vehicle Operating Costs (VOC), of varying road conditions resulting from alternative maintenance scenarios together with variations in the maintenance requirements generated by different traffic levels. In the case of rural roads with extremely light traffic maintenance requirements will be the result more of environmental effects (primarily, if not wholly, rainfall) than of repetitive traffic loading, particularly in the cases of natural and gravel surfaces where wheel loading is also significant.

4.1.2 Community Participation

Providing year round access need not involve maintaining entire road lengths. The proposed methodology involves selecting areas which in their poor condition prevent year round access, then rehabilitate only these. In addition, these works should incorporate locally sourced materials, locally sourced labour and labour based construction methods wherever possible. This allows the roads to be easily maintained by the local residents during its lifetime. This is imperative to the success of this methodology[11].

4.1.3 Whole Life Costs

The bulk of routine maintenance (vegetation control, drainage maintenance, etc.) is common to all roads regardless of pavement type. For this analysis assessment has been carried out of only the maintenance requirements of the various pavement types including both regular detail surface maintenance and heavy or periodic maintenance.

Any evaluation of whole life costs is strictly a provisional estimate and it would be unwise to place too much reliance on it. However, an initial estimate of whole life costs has been prepared using the same rates during construction in Bagamoyo. The initial construction cost includes all earthworks, clearing, grubbing and removal of top soil, drainage and passing bays. This estimate has been made using assumptions shown below:

- Gravel pavement (Flat): Grade twice yearly; Re-gravel in years 10 and 18
- Gravel Pavement (Hilly): Grade thrice yearly; Re-gravel in years 10 and 18

[11] ***Research Consultant to Support the Design, Construction and Monitoring of Demonstration Sites for District Road Improvements in Tanzania: Design Report,*** *Roughton International, November 2010.*

- Geocells: Replace 5% of the pavement after each 5 years
- Concrete Strips: Replace 5% of the pavement after each 5 years
- Reinforced concrete strips: Replace 6% of the pavement after 5 years
- Hand Packed Stone: Replace 6% of the pavement each 5 years
- Single Otta Seal with Sand Seal: Single sand seal after the first 8 years and every subsequent 4 years and replace 2% of the pavement
- Double Sand Seal: Single sand seal after the first 6 years and every subsequent 4 years and replace 3% of the pavement
- Slurry Seal: Single sand seal every 3 years and repair 2% of the pavement
- Double Surface Dressing: Single surface dressing every 6 years and replace 2% of the pavement

Table 24 Comparison of the Whole Life Costs of the Bagamoyo Demonstration Pavements ($USD/km)

Working Life	Gravel Pavement - Flat	Gravel Pavement - Hilly	Geocells - 75 mm	Concrete Strips (Unreinforced)	Concrete Strips (Reinforced)	Hand Packed Stone	Single Otta Seal with Sand Seal	Double Sand Seal	Slurry Seal	Double Surface Dressing
Year 0	-19822	-19822	-75168	-62877	-77041	-77034	-95634	-89147	-77632	-109409
Year 1	-3733	-5600								
Year 2	-3733	-5600								
Year 3	-3733	-5600							-12287	
Year 4	-3733	-5600								
Year 5	-3733	-5600	-3261	-2646	-4026	-4025				
Year 6	-3733	-5600						-13309	-12287	-12664
Year 7	-3733	-5600								
Year 8	-3733	-5600					-12647			
Year 9	-3733	-5600							-12287	
Year 10	-13477	-15344	-3261	-2646	-4026	-4025		-13309		
Year 11	-3733	-5600								
Year 12	-3733	-5600					-12647		-12287	-12664
Year 13	-3733	-5600								
Year 14	-3733	-5600						-13309		
Year 15	-3733	-5600	-3261	-2646	-4026	-4025			-12287	
Year 16	-3733	-5600					-12647			
Year 17	-3733	-5600								
Year 18	-13477	-15344						-13309	-12287	-12664
Year 19	-3733	-5600								
Year 20	-3733	-5600	-3261	-2646	-4026	-4025	-12647			
Salvage	7929	7929	30067	31438	38520	30814	47817	44573	38816	54704
NPV 6%	**-65,247**	**-85,449**	**-60,377**	**-45,806**	**-58,684**	**-64,109**	**-97,854**	**-96,186**	**-105,883**	**-94,273**
NPV 10%	**-50,946**	**-65,396**	**-60,760**	**-47,041**	**-59,894**	**-64,236**	**-96,393**	**-94,235**	**-101,115**	**-94,127**

Table 25 Pavement Type in Order of NPV for Whole Life Costs

Pavement Type	Whole Life Cost - USD/km	NPV		Whole Life Cost - USD/km	Pavement Type
		6%	10%		
Concrete Strips (Unreinforced)	62877	-45,806	-47,041	62877	Concrete Strips (Unreinforced)
Concrete Strips (Reinforced)	77041	-58,684	-50,946	19822	Gravel Pavement - Flat
Geocells - 75 mm	75168	-60,377	-59,894	77041	Concrete Strips (Reinforced)
Hand Packed Stone	77034	-64,109	-60,760	75168	Geocells - 75 mm
Gravel Pavement - Flat	19822	-65,247	-64,236	77034	Hand Packed Stone
Gravel Pavement - Hilly	19822	-85,449	-65,396	19822	Gravel Pavement - Hilly
Double Surface Dressing	109409	-94,273	-94,127	109409	Double Surface Dressing
Double Sand Seal	89147	-96,186	-94,235	89147	Double Sand Seal
Single Otta Seal with Sand Seal	95634	-97,854	-96,393	95634	Single Otta Seal with Sand Seal
Slurry Seal	77632	-105,883	-101,115	77632	Slurry Seal

An economic analysis was performed for the various sections of road using the HDM4 – Road User Costs (RUC) model available from the World Bank[12]. This tool allows a cost benefit analysis to be performed for a road using a "with" and "without" project alternative for a project life of 20 years. Each section of the road was modelled as 1km stretch and the data obtained from the base line monitoring process was used to determine a prediction of the IRI and surface roughness values over the life of each pavement, with continued monitoring these values can be modified to provide a more accurate analysis. Detailed results from the economic analysis are available in Appendix D – Whole Life Economic Analysis.

Table 25, given above, shows the Net Present Value (NPV) of the whole life costs of the different pavement types. The different pavement types are ranked. The Table shows 6% rankings to the left and 10% rankings to the right.

As noted above, these results must be viewed with caution. Although the rankings change somewhat depending on whether a 6% or 10% discount rate is adopted the overall pattern is much the same with only minor differences.

Two key features emerge from this analysis, the first is that the concrete pavements and the hand packed stone outrank the gravel pavements on hilly terrain, highlighting the short sightedness of re-gravelling steep roads and the expensive whole life cost involved. The other key feature worth noting is that the gravel pavements outrank the bitumen pavements; this is result of the extremely high rate that was quoted for bitumen. However, it is important to also note that the whole life costs shown in this table only includes regular maintenance and does not reflect the cost of emergency maintenance for wash outs and a gravel pavement offers no guarantee that the road will be kept

12 ***HDM-4 Road User Costs Model**, Version 2.00, Roads and Highways – Road Software Tools, The World Bank, 2011.*

open at all times during the rain season. In addition, a gravel road cannot compete with the superior finish of a sealed road.

An analysis was also performed to calculate the total society costs of each pavement type. These can be seen, again ranked by NPV, in Table 26 Pavement Type in Order of NPV for Total Society Costs The total society costs include the financial implications to the road user in terms of vehicle operating costs, such as those associated with vehicle maintenance and fuel. These give an overall more accurate representation of the cost of each pavement type.

Table 26 Pavement Type in Order of NPV for Total Society Costs

Pavement Type	Total Society Cost - USD/km	NPV 6%	NPV 10%	Total Society Cost - USD/km	Pavement Type
Concrete Strips (Unreinforced)	1,123,688	645,193	483,539	1,123,688	Concrete Strips (Unreinforced)
Geocells	1,139,810	659,238	496,977	1,139,810	Geocells
Concrete Strips (Reinforced)	1,136,290	660,125	498,767	1,136,290	Concrete Strips (Reinforced)
Single Otta Seal with Sand Seal	1,187,414	684,370	509,732	1,187,414	Single Otta Seal with Sand Seal
Double Sand Seal	1,177,717	686,033	519,061	1,177,717	Double Sand Seal
Gravel Flat	1,414,228	701,294	530,484	1,414,228	Slurry Seal
Slurry Seal	1,206,693	702,185	544,859	1,206,693	Hand Packed Stone
Double Surface Dressing	1,218,658	719,807	550,220	1,218,658	Double Surface Dressing
Hand Packed Stone	1,263,269	725,718	559,218	1,263,269	Gravel Flat
Gravel Hilly	1,451,568	796,113	576,703	1,451,568	Gravel Hilly

There is a noticeable difference in the results in this analysis from those not including road user costs. It is noticeable that pavement types which exhibit a smoother running surface, characterised by a lower International Roughness Index (IRI) value, performed better under this analysis. Hand packed stone is highlighted as a less desirable pavement option due to its rough surface finish which results in very high road user costs. The use of a double surface dressing performs poorly in this analysis due to its high initial and maintenance costs as highlighted in Table 27 Internal Rate of Return by Pavement Type

This analysis also emphasises the cost of the use of gravel on rural roads, a combination of regular maintenance at high cost and poor surface conditions resulting in large road user costs highlight the inefficient use of gravel to surface rural roads in Tanzania and across Africa.

It is important to note that this analysis is based on the construction rates made available from the contractor of the Bago – Talawanda road. Due to complications in the use of geocell technology, the price of concrete was not included for this section, thus it appears a cheaper and more cost effective surface option than it would otherwise be.

As previously stated, the HDM4-RUC model facilitates a cost benefit analysis of “with” and “without” project alternatives through this analysis an internal rate of return (IRR) is calculated taking into account construction, maintenance and road user costs. Each pavement type was modelled individually against a “without” project alternative of natural gravel wearing course, as this would otherwise be the approach adopted by local government to surface a rural road such as this.

These results are shown in Table 27 Internal Rate of Return by Pavement Typeranked in order of IRR.

Table 27 Internal Rate of Return by Pavement Type

Pavement Type	Whole Life Costs - USD/km	Road User Costs - USD/km	Total Society Costs - USD/km	CO2 Emissions - Tons	IRR
Concrete Strips (Unreinforced)	42,023	1,081,665	1,123,688	709.9	26.83%
Geocells	58,145	1,081,665	1,139,810	709.9	21.25%
Concrete Strips (Reinforced)	54,625	1,081,665	1,136,290	709.9	20.50%
Single Otta Seal with Sand Seal	146,222	1,041,192	1,187,414	682.7	17.15%
Double Sand Seal	97,810	1,079,907	1,177,717	707.3	16.52%
Slurry Seal	112,538	1,094,155	1,206,693	707.7	14.84%
Hand Packed Stone	62,320	1,200,949	1,263,269	692.9	12.66%
Double Surface Dressing	92,697	1,125,961	1,218,658	702.4	11.15%
Gravel Flat	106,035	1,308,193	1,414,228	839.9	N/A
Gravel Hilly	151,310	1,308,193	1,451,568	839.9	N/A

It is important to note that road user costs are clearly the major contributor to the overall society costs of each pavement option over a design life of 20 years. It therefore crucial that sufficient monitoring of these demonstration sections is carried out in order to provide reliable data for the simulation of these pavements for future economic analysis. As previously stated these analyses were carried out using only the base line data to predict future conditions, with further monitoring the input data will be modified to present a more accurate analysis.

What can be identified from these results is that concrete surfacing options, most notably unreinforced concrete strips, provide a cost effective solution to surfacing low volume rural roads, illustrated by an IRR of 26.83% against a the use of gravel.

Double surface dressing is presented as the least attractive surfacing option financially due to a combination of high initial and maintenance costs and high road user costs. A hand packed stone surface presents a better IRR value due to its low construction and maintenance costs but has the highest road user costs of any of the alternative surfacing options.

Whilst these results demonstrate the financial comparison and benefits of each pavement type, it is important to consider other factors when selecting a surface option for a low volume rural road, for example vertical and horizontal alignment and dust pollution amongst others.

The first conclusion that can be made is that all of the alternative surface options trialled provide a more sustainable and cost effective solution than the application of a gravel wearing course. Secondly, it is clear that both unreinforced and reinforced concrete strips present the most cost effective pavement method in providing year round access to rural communities with a single Otta seal with sand seal being the bituminous section which provides the best return.

5 MONITORING OF THE DEMONSTRATION SECTION AND INTERPRETATION OF THE DATA

5.1 The Base-Line Data

It is crucial that the long term performance of these pavements are monitored and assessed. After the construction of the access road a set of base line data was gathered. Monitoring will continue at six month intervals, for a two year period by the Consultant and a further eight years by the District Engineer's office. The pavement conditions will be assessed by comparing the monitoring results with the base line data.

5.2 Monitoring Beacons

During the construction process, the contractor installed monitoring beacons at regular intervals along either side the demonstration sections. The spacing of these beacons is dependent on the length of the demonstration section; sections under 200 m in length have monitoring beacons installed at 10 m intervals and sections over 200 m in length have beacons installed at 20 m intervals. The monitoring beacons serve two purposes:

- To divide up the demonstration section into segments to allow easy identification of the various areas, and.
- To provide a consistent and easy identification of monitoring locations for cross section, photographic logging etc. for the long term monitoring framework.

The beacons have been surveyed and their position fixed with the intent that damaged or missing beacons can be reinstated as necessary during the monitoring period.

5.3 AFCAP – Monitoring Programme

Once the various demonstration sections were constructed, monitoring beacons were installed on both sides of the road, parallel to the carriageway. For the demonstration sections of 200 m lengths or less, base line data will be gathered at 10 m intervals. For sections greater than 200 m in length, base line data will be gathered at 20 m intervals. We will only monitor where there is a beacon. The base line measurements were carried out using the following:

- Visual inspection;
- Photographic logging;
- Surface profile measurement between beacons;
- Rut measurement using a standard straight edge;
- Surface roughness using a MERLIN apparatus;
- Surface texture by sand patch testing;
- Classified traffic counts;
- GPS Monitoring;
- Dynamic Cone Penetrometer.

Additionally, if one or more of the pavements fail during the monitoring period we will take DCP tests to assess the mode of failure. Photographs detailing the monitoring methods are available in Appendix E - Photographs Detailing Monitoring Methods.

5.4 Monitoring Methods

5.4.1 Visual Inspection

A visual inspection foot survey was carried out along the four sealed pavement surfaces of the road. It was not necessary to carry out the survey along the unsealed sections of the trial as the deterioration of these sections is highly proportional to rainfall and weather conditions as apposed to stress from vehicle loading. The inspection allowed for the location of various modes of surface distress and deformation to be recorded to enable a survey by survey historical reference of the deterioration of the demonstration section surfaces.

Markings to indicate various modes of surface distress such as potholes, linear cracking, crocodile cracks and others were recorded on pre set out data sheets. The data sheets split the road section into 10 or 20 meter segments in relation to the roadside monitoring beacons for that section. This method allows areas of considerable surface distress to be easily identified and the rate of deterioration monitored between surveys.

A short description of each demonstration section was also recorded. This detailed the condition of the road surface with regards to distress and erosion of the surface and shoulders, drainage condition and any potential future areas of concern.

5.4.2 Photographic Logging

Photographic logging of the demonstration sections was carried out to provide a visual indication of the condition of the road, facilitating comparisons during the long term monitoring programme. Each trial section is photographed from the centreline of the road at each of the roadside monitoring beacons ensuring the photograph is taken at head height with the road surface in the centre of the photograph. Carrying out the logging in such a manner ensures that each segment is photographed from approximately the same position throughout all future monitoring periods.

5.4.3 Surface Profile Measurement

Surface profile measurements are taken at every beacon location to monitor gravel loss across the carriageway and shoulders.

The procedure involves the use of a dumpy level and levelling staff. A measuring tape is laid across the road and used to locate the levelling staff at 50cm intervals across the road's cross section for measurements to be taken. Collecting this data enables the production, logging and comparison of surface profiles at regular intervals along the road throughout future monitoring surveys.

Dumpy levels and levelling staffs are common equipment and simple to use, these were obtained from the contractor and the Tanzanian roads authority Central Materials Lab in Dar Es Salaam.

5.4.4 Rut Measurement

Measurements were taken for rut measurements using a 2m standard straight edge and a marked wedge. This survey was carried out as the relationship between rutting and deflection is well documented, therefore with a comprehensive range of rut depth measurements on each trial section, realistic models of deterioration against traffic loading can be produced.

Surface rut measurements were taken between each set of monitoring beacons to ensure consistency in all future monitoring surveys. Rut depth is recorded across each wheel path of a road, the as the demonstration sections have been constructed as part of a single lane road. The road is mainly utilised by motorcycles travelling in both directions with occasional one way traffic of cars of four wheel drive, this has creating two visible wheel paths across which measurements were taken.

Rutting is caused by the deformation of the surface and sub base material due to vehicular loading. The rigid concrete strip surfacing will not exhibit uniform rutting, as any compaction of the sub grade material will more than likely lead to cracking in the strips. Rutting of the gravel wearing course will be dramatically effected by rainfall and water run off and therefore it is not possible to form a relationship between rutting and vehicle loading. Following this, it was not necessary to perform this survey on all sections of the road and measurements were only carried out on the flexible sealed surfaces.

The surface rut measurement test is simple and straightforward and makes use of readily available equipment that was made by local workers in the nearby villages. This equipment is now remaining with the District Engineer for use in future monitoring stages.

5.4.5 Surface Roughness Measurement

Testing was carried out using a MERLIN machine, acquired from the Tanzanian roads authority Central Materials lab in Dar es Salaam, to measure the surface roughness of each demonstration section. The MERLIN machine records the longitudinal unevenness of a road surface through taking numerous readings along each wheel path of a section of road. A probe attached to a pivot arm with a pointer moves over a chart when unevenness in the road causes the probe to be displaced.

Taking approximately two hundred readings along each wheel path of a road section will produce a sufficient histogram from which a value of the International Roughness Index (IRI) can be obtained. Carrying out this test over both wheel paths of a demonstration section will produce an IRI value for that section. The MERLIN machine is wheeled along each wheel path of the monitored section stopping at appropriate intervals depending on the length of the section in order to achieve two hundred readings per wheel path. On a 200m section the MERLIN is stopped and a reading marked on the field sheet after each rotation of the wheel requiring two passes of each wheel track to be completed.

Road surface roughness is an important measure of road condition and has been used in determining vehicle operating costs for the demonstration sections.

5.4.6 Surface Texture Measurement

A sand patch test was used to monitoring the surface texture of all concrete and bituminous surface options. The sand patch method is a simple test which involves the use of a measuring cylinder of volume 50ml filled with sand meeting the grading illustrated in Table 28 Sand Patch Test Particle Grading. This is poured onto the dry clean surface of the road and spread in a circular motion using a wooden paddle 65mm in diameter with a hard rubber disc secured to the face. The sand is spread to the largest diameter which results in the surface depressions being filled with sand to a level of the peaks and troughs. The diameter of the resulting circle is then measured a 45 degree intervals. From these measurements an average can be obtained and texture depth calculated.

Testing was carried out on all bituminous and concrete surface options at 100m intervals. This test method uses very basic equipment that can be made in nearby villages.

Table 28 Sand Patch Test Particle Grading

Sieve Size (mm)	% passing
0.600	100
0.300	90-100
0.150	0-15

5.4.7 Classified Traffic Counts

Traffic counts were carried out by the contractor at the beginning and the end of the construction phase of the project. The traffic counts were carried out for seven days consecutively from 03/09/2010 to 09/09/2010, before construction and from 13/08/2011 to 19/08/2011, after construction. Day 1 to day 5 was 12 hour traffic counts and day 6 to day 7 was 24 hour traffic counts. Two count stations were established, the first station at Bago village (Ch. 0+640) and the second at Ludiga village (Ch. 11+040).

The main points to note from traffic data are that the majority of the traffic consists of pedestrians, bicycles and motorcycles. Also, most of the traffic on this road is contained in the first 2-3 km of the road and the traffic vastly decreases the further down the road you travel. Furthermore, a visual inspection of the traffic over the past year of construction indicates that the trucks along the road are mostly seasonal and heavily linked to the harvesting season of crops. The results of these traffic counts are displayed in Table 29 below.

Table 29 Traffic Counts on the Project Roads

	Bago village Chainage 0+640 km		Ludiga village Chainage 11+040 km	
	Before	After	Before	After
Pedestrian	2664	1172	1410	1122
Bicycle	2186	1720	1224	1303
Motorcycle	1557	1471	292	1045
Saloon Car	14	28	5	11
Pick Up/ 4WD	55	94	34	30
2-Axle Truck/Bus	82	2	0	2
3-Axle Truck	0	0	0	0

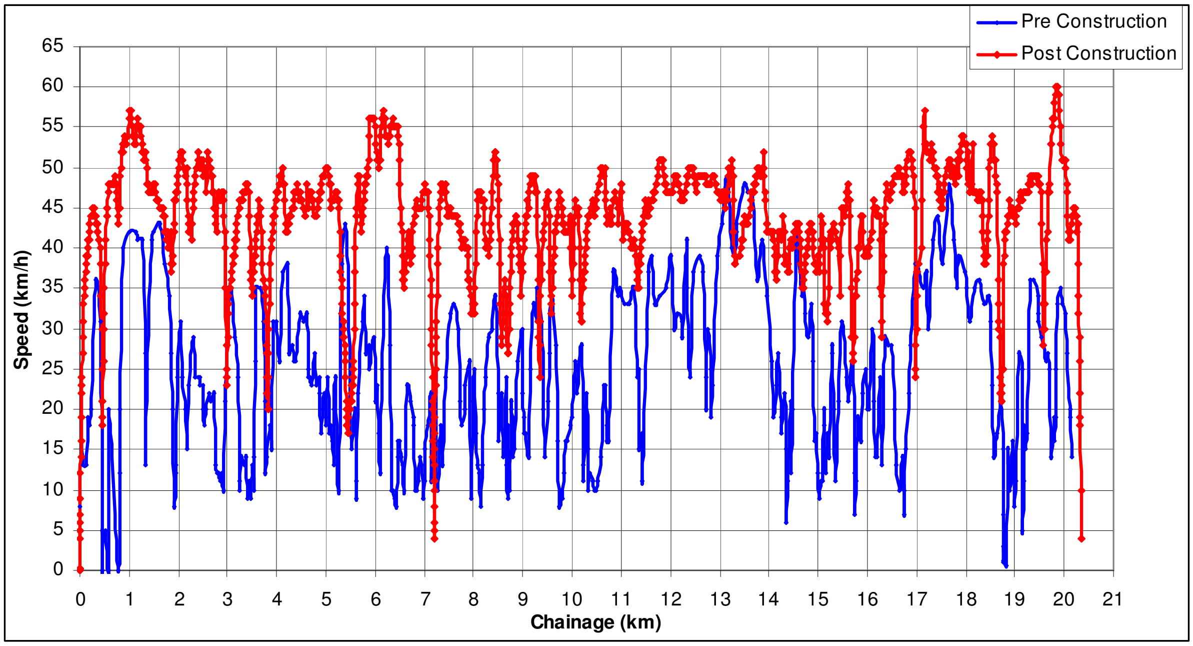
The current traffic counts provide little data to make any significant conclusions at this stage. Significant variations in results may be due to seasonal activities such as pineapple harvesting. These seasonal variations should be taken into account when scheduling and carrying out future traffic counts to ensure consistency in the data collected.

Future traffic accounts, which will occur at 6 month intervals for the 2 year monitoring period, will facilitate further analysis. It is expected that these future traffic counts will demonstrate a greater increase in vehicle numbers as the benefits of the new road are recognised by the surrounding population. Detailed traffic count data is available in Appendix F **- Traffic Count Data**.

5.4.8 GPS Monitoring

A drive through survey has been carried out to monitor the relationship between vehicle speed and surface condition. The driver was instructed to drive down the road trying to maintain a target speed of 50-55 km/h where possible and slowing for rough or dangerous sections to achieve a comfortable and safe journey. The GPS unit records the trip information and this can be used to highlight the areas at which the driver was forced to slow down due to the road condition. A drive through survey was carried out before and after construction of the demonstration sections. A graphical representation of these surveys is shown in Figure 6. From this it is clear that there is an improvement in access along the road after construction of the demonstration sections. Minimum speeds post construction are much higher than minimum speeds before the demonstration sections had been implemented. The average speeds from the GPS survey before and after construction are 22.1 km/h and 42.4 km/h respectively. The dips in vehicle speed post construction, for example those at approximately chainage 5.5 km and 7.2 km are due to drifts that have been constructed at those locations and are not areas where access is a problem.

Figure 6 - GPS Drive through Survey



5.4.9 Dynamic Cone Penetrometer Testing

Standard Dynamic Cone Penetrometer (DCP) testing was carried out at 100m intervals on all gravel and bituminous surfaces of the road following completion of construction. The DCP equipment involves an 8kg weight which is raised and dropped over a distance of 575mm and a 60° cone to penetrate the surface. The weight is lifted and dropped 5 times and the depth of penetration is recorded on a field sheet. Measurements are recorded at 5 blow intervals until the depth of penetration reaches 800mm. A penetration rate can then be calculated from the recorded measurements and can be used to calculate the CBR value of the various pavement layers identified.

This testing was carried out to monitor the performance of the pavement layer materials following construction with the road in use. DCP testing is an affordable and simple method to measure pavement strength. Equipment was obtained from a South African supplier and will remain with the District Engineer to be used in future monitoring procedures.

5.5 Data and Results

The consultant has written a database which contains information pertaining to each of demonstration sections. The results of these surveys and the required field sheets have been included on a database contained on a Compact Disk available in Appendix I - Monitoring Database Compact Discl. Field sheets have also been provided in Appendix H – Monitoring field sheets

Appendix I - Monitoring Database Compact Disc.

The analysis of results can only be conducted when a time series of data is available and will form a part of the future monitoring reports.

5.6 Surface Performance

The long term performance of these pavements will be assessed after the monitoring period. Maintenance will be an important factor in the long term performance of these surfaces. The bitumen pavements will require reseals at regular intervals and the concrete pavements will require pothole maintenance.

5.7 Future Monitoring Framework

After collection of all required base line data the consultant will implement the future monitoring framework which determines the monitoring work to be carried out for the next 10 years.

The consultant will monitor the road for two years following collection of the base lined data. This will be at 6 month intervals. The above mentioned methods of monitoring will be carried out on these occasions. Following this the district engineers with continue to monitor the road for eight years collecting data on a yearly basis. It is important that the Bagamoyo District Engineer and his staff are suitably trained over the 2 year monitoring phase in order for the work to be successfully handed over and continued after this period. A training methodology for each monitoring method will be compiled and the training and involvement of personnel will be documented in the report following each stage of monitoring.

Consistency in the methods of data collection is imperative to the credibility of the results and conclusions that can be drawn from long term monitoring. Therefore it is important that methods used in collection of the base line data are closely adhered to. Maintenance of the monitoring beacons is also crucial to the accuracy and time frame in which the monitoring can be carried out. Sufficient maintenance of monitoring beacons should be carried out in the routine maintenance by the district engineer's team.

It is also important that the timing of the monitoring surveys is consistent. As this part of Tanzania is subject to two rainy seasons, the long rains during March to May, and the short rains from October to December, sufficient scheduling of the future monitoring programme is important to ensure consistency in monitoring conditions. A draft schedule for each monitoring stage has been set out below in Figure 7.

Figure 7 - Future Monitoring Schedule

	Base Line	6 Months	12 Months	18 Months	24 Months
Date	September/ October 2011	April 2012	October 2012	April 2013	October 2012

6 INFORMATION DISSEMINATION

An important aim of this project is knowledge transfer and it is imperative that the lessons learned from this project are properly communicated to the local government authorities in Tanzania, government authorities in other Sub-Saharan African countries facing similar problems to those faced in Tanzania and the international community.

Capacity building is also critical and it was the responsibility of the consultant to assist the local government authorities and the contractor with any technical aspects involved in the construction of the different pavements. During the construction period of the project before the bitumen work began, the consultant held a one day bitumen workshop to explain to explain the construction method of the different pavements to the local district council and the contractor. The workshop helped to prepare the contractor for the bitumen and to let them know what was required of them once they began. The workshop was presented by the technical advisor to the project.

Two research students are also undertaking part-time M.SC research programmes at the University of Dar es Salaam on the AFCAP project in Bagamoyo. The two research students have been involved since the tender stage of the project. The two students both work full time for Tanroads and their research programmes are part funded by Tanroads and AFCAP.

During the construction phase of the project a journalist training programme was held for young Tanzanian journalists from Dar es Salaam. The training programme was conducted by the TRL and the project road in Bagamoyo was used as an example for the journalists to write a story on the work under AFCAP. The aim of the training programme was to build a closer relationship with the journalists from the newspapers in Dar es Salaam and the Tanzanian Road Fund and the work that they are doing throughout Tanzania.

Once the long term monitoring of the pavements is completed the consultant will prepare guidelines for selecting viable surface options for rural roads design guides for the various solutions and standard specifications and propose any amendments to the Tanzanian Manuals for Pavement and Materials Design and Field Testing[13].

The consultant will also be taking part in site visits to the demonstration sites and regional workshops in order to disseminate the findings and outputs of the research programme. Also, since this assignment is a component of a set of inter-related projects across Africa under the AFCAP programme we will be sharing and exchanging knowledge and experiences between other projects within the AFACP programme. Furthermore, we will participate in a group study visit to Mozambique where a similar project is being implemented with AFCAP[13].

All reports and findings from this project will be made available to the public online from the DFID website.

The consultant would further like to recommend that the project findings are submitted to international conferences as possible research papers and present the conclusions and recommendations in order to try and make the international community aware of the research that is being carried out in Sub-Saharan Africa under the AFCAP programme.

13 ***Terms of Reference***, *Department for International Development, Africa Community Access Programme, 2009*

7 CONCLUSIONS AND RECOMMENDATIONS

7.1 General Comment

Owing to the long term nature of this project there are only limited conclusions to be drawn at this intermediate stage.

The design process has shown the requirement for experienced engineers to spend time in the field understanding the particular problems of the route(s) and exploring the possible solutions. Solutions adopted should take account of both local materials and available local skills.

The construction process has provided data regarding the cost of constructing various types of alternative pavement and the problems which may be found in their construction. It has also highlighted the problems which can be encountered when trying to implement a research operation on the back of a regular commercial construction contract.

Unsurprisingly, data shows that the cost of improved pavements is higher than that of gravel and basic surfaces. Accordingly it is recommended that an Environmentally Optimised Design philosophy is considered as the normal approach to basic access road provision whereby the simplest pavement structures are used for undemanding, flat sections of road and the higher cost, improved structures be used on sections prone to failure, typically steep gradients.

At this stage, the advantages and disadvantages for each pavement structure, other than the construction costs, cannot be clearly defined and it would be difficult to compile a design methodology that made a definitive recommendation for a specific pavement structure in particular circumstances. This emphasises that in order to draw conclusions in respect of specific pavement types, the medium and long term monitoring of the trial sections is of critical importance. However, general comments and thoughts from the current short term performance of the various pavements types in the short time since they were constructed are summarised in Table 30 below.

Table 30 Advantages and Disadvantages of Implemented Pavement Types

Pavement Type	Local Materials	Flat terrain	Steep Terrain	Populated Areas	Marshy Areas	Low Strength Subgrades	Small Contractor Suitability	Likely Cost Advantage	Maintenance Reduction
Gravel Pavement	+	+	-	-	-	+	+	+	-
Un-reinforced Concrete	-	+	+	+	+	-	+	+	+
Concrete Strips (Reinforced)	-	+	+	+	+	+	+	+	+
Concrete Geocells	-	+	+	+	+	+	+	+	+
Concrete Strips (Unreinforced)	-	+	+	+	+	-	+	+	+
Concrete Paving Blocks	-	+	+	+	+	-	+	-	+
Hand Packed Stone	+	+	+	-	+	+	+	+	-
Single Otta Seal with a Sand Seal	-	+	-	+	+	-	+	-	+
Double Sand Seal	-	+	-	+	-	-	+	-	+
Slurry Seal	-	+	-	+	+	-	+	-	-
Double Surface Dressing	-	+	+	+	+	-	+	-	+
Engineered Natural Surface	+	+	-	-	-	-	+	+	-

Note: + indicates positive advantage; - indicates a probable disadvantage

7.2 Conclusions

Only limited conclusions can be made at this early stage of the project. The roads will be monitored for two years following construction after which more substantial conclusions can be drawn.

The following are the preliminary conclusions for the project so far:

- It can already been seen that the demonstration sections provide all weather access along the entire length of the road. Necessary maintenance will be a key factor in assuring that the road remains passable all year round.
- Incorporation of local materials and use of local labour is important in the design and selection of the different pavement structures and should be included wherever possible. This is critical for cost-effective and sustainable solutions for low volume rural roads and an important requirement for the EOD philosophy.
- Concrete block paving, concrete pavements and bituminous bound pavements can be undertaken successfully by small scale contractors using imported and local materials. These initially expensive pavements result in sustainable pavements with reduced maintenance needs.
- Concrete strips appear likely to offer the best value for money of all surfacing options demonstrated. However, thought needs to be given to the locations and design of passing bays to ensure their proper use.
- All of the pavements, but in particular the Engineered Natural Surface will perform much better during the wet season if the drainage is functional. A detailed drainage investigation should be conducted at the design stage resulting in drainage designed to function ‘with nature’ ensuring that water is not routed incorrectly. Routine drainage maintenance before the wet season will be of great help in ensuring that the road remains open throughout the wet season.
- Geocell pavements are suited to small contractors as suitable concrete can be mixed in small mixers using local materials. However, it is essential that sufficient knowledge and training is given to contractors for the use of new materials and techniques.

Modifications were made to the Tanzanian standard designs and these are deemed appropriate and suited to the locations. However, final recommendations on specifications and design guidelines will be made after the monitoring period.

The material investigations in the two regions for this project cannot simply be applied to other regions in Tanzania and a detailed materials investigation should be carried out before any similar project.

The construction cost of the all-weather surface types exceeds the construction cost of the standard gravel road significantly. However, there are potential long term savings and benefits from adopting the Environmentally Optimised Design approach to rural road design. It is concluded that these all-weather surface types should be applied at the problematic spots on a rural access road where they are needed to maintain all weather access or, possibly, for social reasons rather than along the entire length. This design philosophy offers a more sustainable and economical solution to standard gravel road design.

Maintenance considerations and costs should be taken into account when selecting pavement types, for example gravel surfaces and bituminous seals require significantly more routine and periodic maintenance that concrete roads. Stone surfaces are potentially most suited for long term community maintenance without significant outside assistance or funding.

7.3 Recommendations

As this is a research and demonstration project it is not expected that future roads implementing the EOD philosophy will make use of such a wide range of pavement types at short section lengths. Costs for this project are expected to be higher than those of future projects for these reasons. Conclusions from the future monitoring of this project will allow recommendations to be made as to the most suitable pavement types for particular conditions. It is assumed that as contractors become more familiar with these new materials and methods as well as the use of fewer pavements types over longer section lengths will result in a noticeably lower cost per km and m2 for each pavement type.

Suitable equipment, knowledge and skill are crucial for the completion of the work to an acceptable standard. The contractor's unfamiliarity with bitumen resulted in high bid rates and a lower quality of work on these sections. Thus, the costs of the bitumen pavements are expected to reduce once local contractors become more familiar with the materials and methods involved in this surfacing.

When using contractors to undertake small scale but accurate work in which they have little or no expertise, it is vital that considerable training is provided in order that the non-standard or unfamiliar construction techniques are conducted properly. It is recommended that small scale local contractors are trained and given a tender advantage over large international contractors. This will empower local communities, provide a sense of ownership within communities and ensure that expertise and economic benefit remains in communities. It is important that suitable supervision and quality control are provided on site to ensure the work of inexperienced contractors meet the specifications.

There should be further study carried out on the use of marly limestone in road construction including the possible use of lime stabilisation of the material. The use of hand packed stone, concrete strips and concrete geocells should be investigated for further use on expansive clays on low volume rural roads.

Some materials used did not meet specification according to the Tanzanian pavement design manual, however these were deemed acceptable for use on low volume rural roads. Findings from the future monitoring of this project will enable recommendations and modifications to be made to the Tanzanian pavement design manual as to the future use of such materials in low volume roads.

7.4 Future Work

Long Term Monitoring

It has been agreed that in order for this work to be of value beyond that discussed in this report it is necessary for a long term monitoring regime to follow through on the base line data capture.

The consultant will monitor the demonstration sections for two years following the collection of the base line data. The consultant will carry out all monitoring methods as previously detailed at 6 month intervals. The consultant will analyse the collected data and use the results to draw guidelines and specifications and make recommendations with regard to the various surfaces.

Following this, the district engineers will continue to monitor the demonstration site for a further eight years on a yearly basis.

As with any data collection, consistency in monitoring methods and conditions is fundamental to the accuracy of the results. It is important that previous monitoring methods are replicated and the future monitoring schedule is appropriately planned with regards to seasonal weather conditions

Maintenance Considerations

After the collection of the base line data the condition of the demonstration sections will be monitored at 6 month intervals. During these monitoring exercises, the deterioration and defects on the gravel sections will be highlighted as a comparison with the demonstration sections. The consultant must also monitor and comment on the implementation and effectiveness of maintenance on the project roads.

It is important that the road is maintained to an accessible standard however it is equally important that the true deterioration of the road surface is monitored over a sufficient time period in order to obtain realistic and reliable data or pavement deterioration. It is also crucial that all monitoring beacons are sufficiently maintained and easily located to improve the accuracy and time taken at each monitoring phase. Therefore it is important that an acceptable maintenance programme is agreed with the district engineer to facilitate the most reliable and accurate monitoring data whilst ensuring that year round access is maintained and the road does not reach a state in which costly major maintenance is required.

APPENDIX A - PHOTOGRAPHS AT 500M INTERVALS BEFORE CONSTRUCTION

Chainage 0 km

Chainage 0.5 km

Chainage 1.0 km

Chainage 1.5 km

Chainage 2.0 km

Chainage 2.5 km

 Chainage 3.0 km	 Chainage 3.5 km
 Chainage 4.0 km	 Chainage 4.5 km
 Chainage 5.0 km	 Chainage 5.5 km

	
Chainage 6.0 km	**Chainage 6.5 km**
	
Chainage 7.0 km	**Chainage 7.5 km**
	
Chainage 8.0 km	**Chainage 8.5 km**

 Chainage 9.0 km	 Chainage 9.5 km
 Chainage 10.0 km	 Chainage 10.5 km
 Chainage 11.0 km	 Chainage 11.5 km

Chainage 12.0 km

Chainage 12.5 km

Chainage 13.0 km

Chainage 13.5 km

Chainage 14.0 km

Chainage 14.5 km

 Chainage 15.0 km	 Chainage 15.5 km
 Chainage 16.0 km	 Chainage 16.5 km
 Chainage 17.0 km	 Chainage 17.5 km

Chainage 18.0 km

Chainage 18.5 km

Chainage 19.0 km

Chainage 19.5 km

Chainage 20.0 km

APPENDIX B - PHOTOGRAPHS DETAILING THE CONSTRUCTION METHODOLOGY

Section 1 - Single Otta Seal with a Sand Seal (0+030 km to 0+230 km)	
	1: Before construction Chainage: 0+050 km
	2: After heavy grading and compaction of the roadbed Chainage: 0+030 km Date: 22/12/2010
	3: After spreading and compaction of layer 150mm of G7 improved subgrade Chainage: 0+030 km Date: 20/01/2010
Photograph	**Description**

Section 1 - Single Otta Seal with a Sand Seal (0+030 km to 0+230 km)	
	4: After spreading and compaction of layer 150mm of G60 pavement layer Date: 18/05/2011
	5: Using a theodolite to set out the final width of the road, 5m road width Chainage: 0+030 km Date: 17/05/2011
	6: Construction of stone-masonry lined ditch Chainage: 0+030 km Date: 19/05/2011
Photograph	**Description**

Section 1 - Single Otta Seal with a Sand Seal (0+030 km to 0+230 km)	
	7: G60 base after construction of lined drains Chainage: 0+030 km Date: 20/06/2011
	8: Completed MC-30 prime coat sprayed at a rate of 1 l/m² Chainage: 0+030 km Date: 10/07/2011
	9: Sweep clear all loose material from the surface Chainage: 0+030 km Date: 23/07/2011
Photograph	**Description**

Section 1 - Single Otta Seal with a Sand Seal (0+030 km to 0+230 km)	
	10: Screen the fines and the oversize material from the gravel Chainage: 0+030 km Date: 15/07/2011
	11: Spray MC-3000 bitumen at a rate of 1. 7 l/m² Chainage: 0+030 km Date: 23/07/2011
	12: Spread aggregate evenly across the surface at a rate of 0. 016 m³/m² Chainage: 0+030 km Date: 23/07/2011
Photograph	**Description**

Section 1 - Single Otta Seal with a Sand Seal (0+030 km to 0+230 km)	
	13: Roll the aggregate into the bitumen using a 12 tonne pneumatic tyred roller Chainage: 0+030 km Date: 23/07/2011
	14: The Otta seal should receive as many passes as possible with the roller for the next 2 days Chainage: 0+030 km Date: 23/07/2011
	15: For the following week after construction, add additional gravel to the tyre tracks or anywhere that bleeding occurs Chainage: 0+030 km Date: 24/07/2011
Photograph	**Description**

Section 1 - Single Otta Seal with a Sand Seal (0+030 km to 0+230 km)	
	16: The road should be trafficked for as long as possible before the next seal Chainage: 0+030 km Date: 26/07/2011
	17: The Otta seal surface texture one day after construction Chainage: 0+030 km Date: 24/07/2011
	18: The Otta seal surface texture three weeks after construction Chainage: 0+030 km Date: 15/08/2011
Photograph	**Description**

Section 1 - Single Otta Seal with a Sand Seal (0+030 km to 0+230 km)	
	19: Clear the surface of any loose material Chainage: 0+030 km Date: 17/08/2011
	20: Spray MC-3000 bitumen at a rate of 0. 8 l/m² Chainage: 0+030 km Date: 17/08/2011
	21: Spread sand at a rate of 0. 011 m³/m² Chainage: 0+030 km Date: 17/08/2011
Photograph	**Description**

Section 1 - Single Otta Seal with a Sand Seal (0+030 km to 0+230 km)	
	22: Completed Otta seal with sand seal section Chainage: 0+030 km Date: 04/10/2011
Photograph	**Description**

Section 2 - Hand Packed Stone (5+340 km to 5+520 km)	
	1: Before construction
	2: After heavy grading and compaction of the roadbed Chainage: 5+340 km Date: 03/12/2010
	3: After spreading and compaction of 150mm of G7 improved subgrade layer Chainage: 5+540 km Date: 21/01/2011
Photograph	**Description**

Section 2 - Hand Packed Stone (5+340 km to 5+520 km)	
	4: After spreading and compaction of 100mm G15 improved subgrade layer Chainage: 5+340 km Date: 25/03/2011
	5: After spreading and compaction of 150mm of G45 pavement layer Chainage: 5+340 km Date: 19/05/2011
	6: After spreading of 50mm of bedding sand for hand packed stone pavement Chainage: 5+440 km Date: 26/05/2011
Photograph	**Description**

Section 2 - Hand Packed Stone (5+340 km to 5+520 km)	
	7: Use of string lines to ensure line and level of hand packed stone Chainage: 5+440 km Date: 26/05/2011
	8: Placing and packing of stone blocks Chainage: 5+440 km Date: 19/05/2011
	9: Hand packed stone section is constructed in 1. 5 m half width sections to accommodate traffic Chainage: 5+440 km Date: 26/05/2011
Photograph	**Description**

Section 2 - Hand Packed Stone (5+340 km to 5+520 km)	
	10: Compact 1m gravel shoulder using pedestrian roller Chainage: 5+400 km Date: 23/06/2011
	11: Fill the voids between the stones with sand Chainage: 5+500 km Date: 04/07/2011
	12: Completed hand packed stone section Chainage: 5+340 km Date: 04/07/2011
Photograph	**Description**

Section 2 - Hand Packed Stone (5+340 km to 5+520 km)	
	13: Nominal thickness of 150 - 200mm Chainage: 5+440 km Date: 26/05/2011
	14: Surface texture Chainage: 5+500 km Date: 15/08/2011
Photograph	**Description**

Section 3 - Concrete Strips Reinforced (5+560 km to 6+080 km)	
	1: Before construction Chainage: 5+960 km
	2: After heavy grading and compaction of the roadbed Chainage: 5+880km Date: 08/01/2011
	3: After spreading and compaction of 150mm of G7 improved subgrade layer Chainage: 5+880km Date: 27/01/2011
Photograph	**Description**

Section 3 - Concrete Strips - Reinforced (5+560 km to 6+080 km)	
	4: After spreading and compaction of 100mm of G15 improved subgrade layer Chainage: 5+880 km Date: 25/03/2011
	5: After spreading and compaction of 150mm of G45 improved subgrade layer Chainage: 5+920 km Date: 18/05/2011
	6: 4 mm steel reinforcement used in concrete over the expansive clay sections Chainage: 5+920 km Date: 08/06/2011
Photograph	**Description**

Section 3 - Concrete Strips - Reinforced (5+560 km to 6+080 km)	
	7: After construction of concrete strips and gravel shoulder Chainage: 5+920 km Date: 28/06/2011
	8: Completed concrete strips section Chainage: 5+560 km Date: 15/08/2011
Photograph	**Description**

Section 4 - Concrete Geocells (6+080 km to 6+740 km)	
	1: Before construction Chainage: 6+200 km
	2: After heavy grading and compaction of the roadbed Chainage: 6+080 km Date: 29/12/2010
	3: After spreading and compaction of 150mm of G7 improved subgrade layer Chainage: 6+080 km Date: 08/03/2011
Photograph	**Description**

Section 4 - Concrete Geocells (6+080 km to 6+740 km)	
	4: After spreading and compaction of 100mm of G15 improved subgrade layer Chainage: 6+180 km Date: 25/03/2011
	5: After spreading and compaction of 150mm of G45 improved subgrade layer Chainage: 6+180 km Date: 16/05/2011
	6: Construction of lined drains using marly limestone Date: 08/06/2011
Photograph	**Description**

Section 4 - Concrete Geocells (6+080 km to 6+740 km)	
	7: Completed lined drain Date: 08/06/2011
	8: Setting out of trenches for securing geocells Date: 07/11/2011
	9: Excavating trench for securing geocells Date: 07/11/2011
Photograph	**Description**

Section 4 - Concrete Geocells (6+080 km to 6+740 km)	
	10: Spreading thin layer of sand to level base Date: 07/11/2011
	11: Setting out pegs to secure geocells Date: 07/11/2011
	12: Laying out of geocells Date: 07/11/2011
Photograph	**Description**

Section 4 - Concrete Geocells (6+080 km to 6+740 km)	
	13: 15m of geocell section cut to size and secured Date: 07/11/2011
	14: Concrete pour and spreading Date: 08/11/2011
	15: Levelling concrete using straight edge Date: 08/11/2011
Photograph	**Description**

Section 4 - Concrete Geocells (6+080 km to 6+740 km)

Photograph	Description
	16: Smoothing concrete finish Date: 08/06/2011
	17: Brush stroke finish to concrete Date: 08/11/2011
	18: Curing of concrete with sand Date: 09/11/2011

Section 4 - Concrete Geocells (6+080 km to 6+740 km)	
	19: Completed Concrete Geocell Section Chainage: 6+080 Date: 06/02/2012
Photograph	**Description**

Section 5 – Double Surface Dressing (8+000 km to 8+240 km)	
	1: Before construction Chainage: 8+000 km
	2: After heavy grading and compaction of the roadbed Chainage: 8+000 km Date: 22/12/2010
	3: After spreading and compaction of 150mm of G7 improved subgrade layer Chainage: 8+000 km Date: 16/03/2011
Photograph	**Description**

Section 5 – Double Surface Dressing (8+000 km to 8+240 km)	
	4: After spreading and compaction of 150 mm of G15 improved subgrade layer Chainage: 8+000 km Date: 31/03/2011
	5: Place Fornit 30 base reinforcement geosythetic on the G15 surface to accommodate movement from the expansive clay subgrade Chainage: 8+080 to 8+180 km Date: 24/06/2011
	6: Dumping and spreading of G45 subbase Chainage: 8+080 to 8+180 km Date: 24/06/2011
Photograph	**Description**

Section 5 – Double Surface Dressing (8+000 km to 8+240 km)	
	7: After spreading and compaction of 150 mm of G45 subbase Chainage: 8+000 km Date: 28/06/2011
	8: After spreading and compaction of 150 mm of G60 base Chainage: 8+000 km Date: 04/07/2011
	9: Completed MC-30 prime coat sprayed at a rate of 1 l/m² Chainage: 8+080 km Date: 26/07/2011
Photograph	**Description**

Section 5 – Double Surface Dressing (8+000 km to 8+240 km)	
	10: Place Fortrac 3D-30 geosythetic on to reduce erosion of the surface dressing Chainage: 8+150 to 8+220 km Date: 26/07/2011
	8: Completed first layer of surface dressing Chainage: 8+000 km Date: 27/07/2011
	9: Surface texture of first layer of surface dressing Chainage: 8+080 km Date: 15/08/2011
Photograph	**Description**

Section 5 – Double Surface Dressing (8+000 km to 8+240 km)	
	10: Surface texture of surface dressing including Fortrac 3D-30 geosythetic Chainage: 8+150 to 8+220 km Date: 26/07/2011
	8: Completed double surface dressing Chainage: 8+000 km Date: 19/08/2011
Photograph	**Description**

Section 6 - Concrete Strips (9+980 to 10+670 km)	
	1: Before construction Chainage: 10+220 km
	2: After heavy grading and compaction of the roadbed Chainage: 9+960 km Date: 04/02/2011
	3: After spreading and compaction of 100mm of G15 improved subgrade layer Chainage: 10+040 Date: 31/03/2011
Photograph	**Description**

Section 6 - Concrete Strips (9+980 to 10+670 km)	
	4: After spreading and compaction of 150mm of G45 improved subgrade layer Chainage: 10+060 km Date: 28/04/2011
	5: Setting out centre line of concrete strips Chainage: 9+980 km Date: 04/05/2011
	6: Set out concrete strip Chainage: 9+980 km Date: 07/05/2011
Photograph	**Description**

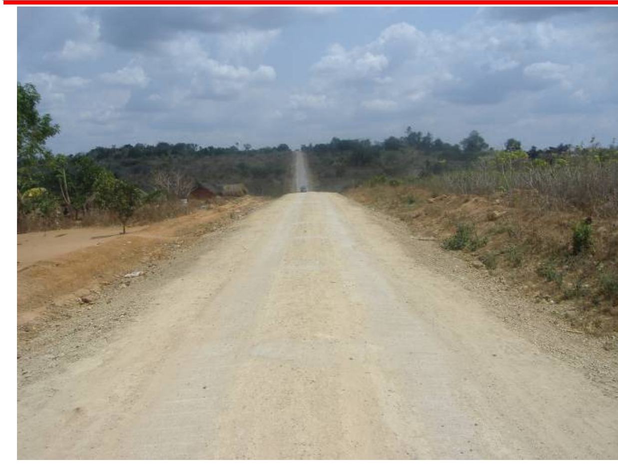
Section 6 - Concrete Strips (9+980 to 10+670 km)	
	7: Construction of formwork for concrete strips Chainage: 9+980 km Date: 07/05/2011
	8: Concrete pour Date: 09/05/2011
	9: Compact concrete Date: 09/05/2011
Photograph	**Description**

Section 6 - Concrete Strips (9+980 to 10+670 km)	
	10: Insert contraction joints Date: 09/05/2011
	11: Brush stroke finish to the concrete Date: 09/05/2011
	12: Curing the concrete with sand Date: 09/05/2011
Photograph	**Description**

Section 6 - Concrete Strips (9+980 to 10+670 km)

Photograph	Description
	13: Partially completed concrete strip section (100mm thickness) Date: 16/05/2011
	14: Dumping of gravel for the shoulders and the centre of the strips Date: 12/06/2011
	15: Compact the shoulder and intermittent gravel with a pedestrian roller Date: 23/06/2011

Section 6 - Concrete Strips (9+980 to 10+670 km)	
	16: Excavate gravel for intermittent concrete Date: 15/07/2011
	17: Pour intermittent concrete strip Date: 15/07/2011
	18: Cure the intermittent concrete with sand Date: 15/07/2011
Photograph	**Description**

Section 6 - Concrete Strips (9+980 to 10+670 km)	
	19: Completed concrete strips section Chainage: 9+980 km Date: 16/08/2011
Photograph	**Description**

Section 7 – Double Sand Seal (11+200 to 11+390 km)	
	1: Before construction Chainage: 11+300 km
	2: After heavy grading and compaction of the roadbed Chainage: 11+280 km Date: 20/01/2011
	3: After spreading and compaction of 150 mm of G15 improved subgrade layer Chainage: 11+280 km Date: 31/03/2011
Photograph	**Description**

Section 7 – Double Sand Seal (11+200 to 11+400 km)	
	4: After spreading and compaction of 150 mm of G60 improved subgrade layer Chainage: 11+260 km Date: 29/06/2011
	5: Spraying prime coat in half width sections Chainage: 11+240 km Date: 08/07/2011
	6: Completed MC-30 prime coat sprayed on 4. 6 m width carriageway Chainage: 11+200 km Date: 24/07/2011
Photograph	**Description**

Section 7 – Double Sand Seal (11+200 to 11+400 km)	
	7: Spray MC-3000 bitumen at a rate of 1. 2 l/m² Chainage: 11+260 km Date: 24/07/2011
	8: Spread sand at a rate of 0. 011 m³/m² Chainage: 11+240 km Date: 24/07/2011
	9: Roll the sand into the bitumen using a 12 tonne pneumatic tyre roller. The road should be immediately opened to traffic Chainage: 11+200 km Date: 24/07/2011
Photograph	**Description**

Section 7 – Double Sand Seal (11+200 to 11+400 km)	
	10: The sand seal should be receive as may passes with the roller as possible over the next 2 days Chainage: 11+260 km Date: 24/07/2011
	11: The road should be trafficked for as long as possible between successive seals Chainage: 11+280 km Date: 15/08/2011
	12: The road should be cleared of any loose material before beginning the second seal Chainage: 11+300 km Date: 17/08/2011
Photograph	**Description**

Section 7 – Double Sand Seal (11+200 km to 11+400 km)	
	13: Spray MC-3000 bitumen at a rate of 1. 2 l/m² Chainage: 11+300 km Date: 17/08/2011
	14: Spread sand at a rate of 0. 011 m³/m² Chainage: 11+300 km Date: 17/08/2011
	15: Compact the sand as soon as possible using a pneumatic tyre roller (12 tonnes) Chainage: 0+030 km Date: 17/08/2011
Photograph	**Description**

Section 7 – Double Sand Seal (11+200 km to 11+400 km)	
	13: Some bleeding occurred during rolling of pavemet Chainage: 11+300 km Date: 17/08/2011
	14: Any bleeding was blinded with sand Chainage: 11+300 km Date: 17/08/2011
	15: Completed double sand seal section Chainage: 11+200 km Date: 06/10/2011
Photograph	**Description**

Section 8 – Gravel Wearing Course (12+200 to 12+580 km)	
	1: Before construction Chainage: 12+400
	2: After heavy grading and compaction of the roadbed Chainage: 12+540 Date: 20/01/2011
	3: After spreading and compaction of 150mm of gravel wearing course Chainage: 12+540 Date: 31/03/2011
Photograph	**Description**

Section 8 – Gravel Wearing Course (12+200 to 12+580 km)	
	4: Completed gravel wearing course section Chainage: 12+200 Date: 18/08/2011
Photograph	**Description**

Section 9 – Concrete Strips (16+240 to 17+100 km)	
	1: Before construction Chainage: 16+400 km
	2: After heavy grading and compaction of the roadbed Chainage: 16+460 km Date: 29/12/2010
	3: After spreading and compaction of 150mm of G7 improved subgrade layer Chainage: 16+460 km Date: 08/02/2011
Photograph	**Description**

Section 9 – Concrete Strips (16+240 to 17+100 km)	
	4: After spreading and compaction of 100mm of G15 improved subgrade layer Chainage: 16+420 km Date: 12/04/2011
	5: After spreading and compaction of 150mm of G45 improved subgrade layer Chainage: 16+400 km Date: 08/06/2011
	6: Completed concrete strips section Chainage: 16+240 km Date: 18/08/2011
Photograph	**Description**

Section 10 – Concrete Strips (18+480 to 18+740 km)	
	1: Before construction Chainage: 18+480 km
	2: After heavy grading and compaction of the roadbed Chainage: 18+480 km Date: 29/12/2010
	3: After spreading and compaction of 150mm of G7 improved subgrade layer Chainage: 18+480 km Date:20/02 /2011
Photograph	**Description**

Section 10 – Concrete Strips (18+480 to 18+740 km)	
	4: After spreading and compaction of 100mm of G15 improved subgrade layer Chainage: 18+540 km Date: 11/04/2011
	5: After spreading and compaction of 150mm of G45 improved subgrade layer Chainage: 18+480 km Date: 16/06/2011
	6: Completed concrete strips section Chainage: 18+480 km Date: 18/08/2011
Photograph	**Description**

Section 11 – Gravel Wearing Course (19+000 to 19+200 km)	
	1: Before construction Chainage: 19+100 km
	2: After heavy grading and compaction of the roadbed Chainage: 19+000 km Date: 29/12/2011
	3: After spreading and compaction of 150mm of gravel wearing course Chainage: 19+480 km Date: 11/04/2011
Photograph	**Description**

Section 11 – Gravel Wearing Course (19+000 to 19+200 km)	
	4: Completed gravel wearing course section Chainage: 19+000 km Date: 18/08/2011
Photograph	**Description**

Section 12 – Gravel Wearing Course (19+480 to 20+040 km)	
	1: Before construction Chainage: 19+480 km
	2: After heavy grading and compaction of the roadbed Chainage: 19+480 km Date: 29/12/2011
	3: After spreading and compaction of 150mm of gravel wearing course Chainage: 19+480 km Date: 11/04/2011
Photograph	**Description**

Section 12 – Gravel Wearing Course (19+480 to 20+040 km)	
	4: Completed gravel wearing course section Chainage: 19+480 km Date 18/08/2011
Photograph	**Description**

Section 13 – Slurry Seal (20+040 to 20+260 km)	
	1: Before construction Chainage: 20+260 km
	2: After heavy grading and compaction of the roadbed Chainage: 20+260 km Date: 29/12/2010
	3: After spreading and compaction of 150mm of G15 improved subgrade layer Chainage: 20+260 km Date: 04/02/2011
Photograph	**Description**

Section 13 – Slurry Seal (20+040 to 20+260 km)	
	4: After spreading and compaction of 150mm of G60 improved subgrade layer Chainage: 20+260 km Date: 16/06/2011
	5: Clear the surface of any dust and loose material Chainage: 20+180 km Date: 05/07/2011
	6: Lightly wet the roadbed before prime coat Chainage: 20+240 km Date: 05/07/2011
Photograph	**Description**

Section 13 – Slurry Seal (20+040 to 20+260 km)	
	7: Spray prime coat of 700 mm width Chainage: 20+260 km Date: 05/07/2011
	8: Spray prime coat of 2150 mm width Chainage: 20+260 km Date: 05/07/2011
	9: Spray prime coat of 2150 mm width Chainage: 20+260 km Date: 05/07/2011
Photograph	**Description**

Section 13 – Slurry Seal (20+040 to 20+260 km)	
	10: Completed MC-30 prime coat sprayed on 5m width carriageway Chainage: 20+260 km Date: 05/07/2011
	11: Close the road to traffic for at least 24 hours after prime coat Chainage: 20+260 km Date: 05/07/2011
	12: Spread sand to soak up any pools of excess bitumen Chainage: 20+240 km Date: 06/07/2011
Photograph	**Description**

Section 13 – Slurry Seal (20+040 to 20+260 km)	
	13: Sweep the dust and loose material from the road surface Chainage: 20+240 km Date: 15/07/2011
	14: Place wooden strips of 8 mm thickness to ensure the correct thickness is achieved Chainage: 20+240 km Date: 15/07/2011
	15: Add 69% crusher dust to a cement mixer Chainage: 20+240 km Date: 15/07/2011
Photograph	**Description**

Section 13 – Slurry Seal (20+040 to 20+260 km)	
	16: Add to 2% cement or lime to the mixer Chainage: 20+240 km Date: 15/07/2011
	17: Add 6% water to the mixer Chainage: 20+240 km Date: 15/07/2011
	18: Add 17% cationic stable grade bitumen emulsion to the mixer Chainage: 20+240 km Date: 15/07/2011
Photograph	**Description**

Section 13 – Slurry Seal (20+040 to 20+260 km)	
	19: Add additional 5% water to the mixer until the mix has a creamy consistency Chainage: 20+240 km Date: 15/07/2011
	20: Half fill wheelbarrows with the slurry Chainage: 20+240 km Date: 15/07/2011
	21: Shovel the slurry onto the road and spread evenly with rubber squeegees Chainage: 20+240 km Date: 15/07/2011
Photograph	**Description**

Section 13 – Slurry Seal (20+040 to 20+260 km)	
	22: Use squeegees to give as smooth a finish as possible Chainage: 20+240 km Date: 15/07/2011
	23: Use a drag to smooth out the surface Chainage: 20+240 km Date: 15/07/2011
	24: Allow the slurry 3-4 hours to set Chainage: 20+240 km Date: 15/07/2011
Photograph	**Description**

Section 13 – Slurry Seal (20+040 to 20+260 km)	
	25: As soon as the slurry gets to the point where it will not stick to the tyres of a vehicle it should be compacted using a pneumatic tyre roller (or truck) and then the surface should immediately be opened to traffic Chainage: 20+240 km Date: 15/07/2011
	26: Finished slurry seal surfacing Chainage: 20+200 km Date: 18/07/2011
	24: Slurry seal surface texture Chainage: 20+240 km Date: 29/07/2011
Photograph	**Description**

Engineered Natural Earth	
	1: Engineered Natural Earth - Red Soil 0+230 to 3+370 km Chainage: 0+500 km Date: 18/08/2011
	2: Engineered Natural Earth – Quartzitic Gravel 3+730 to 5+340 km Chainage: 4+000 km Date: 18/08/2011
	3: Engineered Natural Earth – Light Red Soil 10+670 to 11+200 km Chainage: 10+680 km Date: 16/08/2011
Photograph	**Description**

Engineered Natural Earth	
	4: Engineered Natural Earth – Marley Limestone 13+520 to 14+180 km Chainage: 13+540 km Date: 18/08/2011
Photograph	**Description**

Construction of Drifts	
	1: Excavation
	2: Excavation of cut-off wall and toe of drift
	3: Pour concrete toe of drift and concrete base of cut-off wall
Photograph	**Description**

Construction of Drifts	
	4: Construction of masonry cut-off wall and guidestones
	5: Lay steel mesh
	6: Wet surface before concrete pour
Photograph	**Description**

Construction of Drifts	
	7: Pour concrete
	8: Compact concrete
	9: Brush stroke finish the concrete
Photograph	**Description**

Construction of Drifts	
	10: Curing the concrete
	11: Excavation of gabion mattress
	12: Gabion mattress
Photograph	**Description**

Construction of Culverts	
	1: Excavation
	2: Setting level of culvert
	3: Cast concrete bed
Photograph	**Description**

Construction of Culverts	
	4: Lay concrete pipe
	5: Construct formwork around concrete and bed
	6: Pour concrete for encasing of the concrete pipe
Photograph	**Description**

Construction of Culverts	
	7: Compacting concrete
	8: Construction of apron
	9: Construction of masonry headwall and wingwall
Photograph	**Description**

Construction of Culverts	
	10: Finished headwall
	11: Curing the concrete
	12: Backfilling of culvert using in-situ material
Photograph	**Description**

Construction of Culverts	
	13: Backfilling of culvert using gravel material
Photograph	**Description**

Construction of Scour Checks (9+980 to 10+670 km)	
	1: Excavation Date: 06/05/2011
	2: Construction of stone masonry Date: 06/05/2011
	3: Packing of stone rip-rap Date:06/05/2011
Photograph	**Description**

Construction of Scour Checks (9+980 to 10+670 km)	
	4: Completed scour checks Date: 12/05/2011
Photograph	**Description**

Verification of Layer Thickness	
	Checking the road levels using a dumpy level
	Core drilling to verify layer thickness
	Core drilling to verify layer thickness
Photograph	**Description**

Quality Control of Pipe Culverts	
	Verification of the invert level and slope of pipe culverts
Photograph	**Description**

Calibration of the Bitumen Distributor	
	Calibrating the bitumen spray rates
Photograph	**Description**

Verification of Field Density	
	Testing field density using the Troxiler method
	Testing field density using the Troxiler method
	Testing field density using the Troxiler method
Photograph	**Description**

Borrow Pit 2 (Red Quartzitic Gravel)– 2+700 km	
	Stockpiled gravel Chainage: BP2 – 2+700 Offset: 1. 25 km Date: 16/03/2011
	Borrow pit inspection Chainage: BP2 – 2+700 Offset: 1. 25 km Date: 04/03/2011
Photograph	**Description**

Borrow Pit 3 (Marly Limestone)– 13+860 km	
	Removal of top soil from borrow pit Chainage: BP3 – 13+860 Offset: 0 km Date: 16/03/2011
	Transition from top layer of borrow pit to bottom layer of borrow pit Chainage: BP3 – 13+860 Offset: 0 km Date: 16/03/2011
	Marly limestone Chainage: BP3 – 13+860 Offset: 0 km Date: 16/03/2011
Photograph	**Description**

Borrow Pit 3 – 13+860 km (Marly Limestone)	
	Top layer of BP 3 (Contains clay) Chainage: BP3 – 13+860 Offset: 0 km Date: 16/03/2011
	Bottom layer of BP 3 Chainage: BP3 – 13+860 Offset: 0 km Date: 16/03/2011
	Side of BP 3 Chainage: BP3 – 13+860 Offset: 0 km Date: 16/03/2011
Photograph	**Description**

Borrow Pit 4 – 8+030 km (Marly Limestone)	
	Marly limestone Chainage: BP4 – 8+030 Offset: 0 km Date: 27/08/2010
	Marly limestone Chainage: BP4 – 8+030 Offset: 0 km Date: 16/05/2011
	Marly limestone Chainage: BP4 – 8+030 Offset: 0 km Date: 16/05/2011
Photograph	**Description**

APPENDIX C - TEST RESULTS

Sand Test Results

TANZANIA NATIONAL ROADS AGENCY Good roads for national development	SUMMARY SHEET **SOIL TESTS** **SAND**	CML CENTRAL MATERIALS LABORATORY

Project: Bago - Talawanda Road	**Date:** 21/10/2010	**Date:** 21/10/2010
Client:	**Location: Borrow pit Chaniage 0+000km**	**Offset: ~ 4km**
Contract No. 2010/2011/		
Responsible Technician:		

Location/ Chainage		Results	Specification							
Sample No			BS 882: 1990							
Depth (m)		% passing								
Grading	75mm									
	63mm									
	50mm									
	37.5mm									
	20mm									
	10mm									
	5mm	100								
	2mm	99								
	1.18mm	87								
	600µm	56								
	425µm	46								
	212 µm	25								
	150µm	19								
	75µm	10								
Atterberg Limits	LL (%)									
	PL (%)									
	PI (%)									
	LS (%)									
Moisture Content	%									
Particle Density	kg/m^3									
Bulk Density	kg/m^3									
Soil classification	BSCS									
Compactoin	MDD (kg/m^3)									
BS Light / Heavy	OMC (%)									
Field	FDD (kg/m^3)									
Density	FMC (%)									
CBR (%)	90 % heavy DD									
(Unsoaked)	95 % heavy DD									
	100 % heavy DD									
CBR (%)	90 % heavy DD									
(4 days soaked)	Swell (%)									
	95 % heavy DD									
	100 % heavy DD									
	Swell (%)									

Aggregate Test Results

TANZANIA NATIONAL ROADS AGENCY	SUMMARY SHEET **AGGREGATES TESTS**	CML CENTRALS MATERIALS LABORATORY

Project: Bagamoyo - Talawanda road	**Date:** 29/10/2010	**Date:** 29/10/2010	
Client:	**Aggregate Tests from Quarry in Lugoba**	**Approved :**	
Contract No. 2010/2011/			
Responsible Technician:			

Location		Lugoba							
Lab No.									
Type of rock									
Grading	75mm								
	50mm								
	28mm								
	20mm								
	14mm								
	10mm								
	5mm								
	2mm								
	1.18mm								
	600µm								
	425µm								
	75 µm								
Dust content	< 425µm (%)								
Filler content	< 75µm (%)								
Moisture content	%								
Plasticity index	%								
Specific gravity	ρ_s	2.954							
Relative density	ρ_d - ρ_s - ρ_a								
Water absorption	%	0.2							
Flakiness index	%								
Bitumen Affinity	%	80							
Elongation index	%								
ACV	%								
TFV (10% FACT) (Soaked)	kN	90							
TFV (10% FACT) (Dry)	kN	100							
AIV	%								
LAA - Los Angeles Abrasion Value	% Grading : **B**	27							
SSS	% Loss								

Aggregate Tests - Double Surface Dressing

TANZANIA NATIONAL ROADS AGENCY

TANROADS — Good roads for national development

SUMMARY SHEET

AGGREGATES TESTS

CML — CENTRALS MATERIALS LABORATORY

Project: Bago - Talawanda road	**Date:** 22/4/2011		**Date:** 22/4/2011
Client:	**Checked :**		**Approved :**
Contract No.			
Responsible Technician:			

Location		Lugoba	Lugoba							
Lab No.		7mm	14mm							
Type of rock										
Grading	75mm									
	50mm									
	28mm									
	20mm	100	100							
	14mm	99	99							
	10mm	98	54							
	5mm	14	2							
	2mm	0	2							
	1.18mm	0	1							
	600µm	0	1							
	425µm	0	1							
	75 µm	0	1							
Dust content	< 425µm (%)									
Filler content	< 75µm (%)									
Moisture content	%									
Plasticity index	%									
Specific gravity	ρ_s									
Relative density	ρ_d - ρ_s - ρ_a									
Water absorption	%									
Flakiness index	%	27	15							
Bitumen Affinity	%									
Elongation index	%									
ACV	%									
TFV (10% FACT) (Soaked)	kN		120							
TFV (10% FACT) (Dry)	kN		160							
AIV	%									
LAA - Los Angeles Abrasion Value	% Grading : **B**									
SSS	% Loss									

Borrow Pit Test Results

Borrow Pit 1 Test Results – 15 +330 km – Grey Quartzitic Gravel

TANZANIA NATIONAL ROADS AGENCY TANROADS Good roads for national development	SUMMARY SHEET **SOIL TESTS**	CML CENTRAL MATERIALS LABORATORY

Project: Bagamoyo - Talawanda road	**Date:** 02/09/2011	**Date:** 02/09/2011
Client: M/s AFCAP	**Checked**	**Approved**
Contract No.		
Responsible Technician:		

Location					15+330	15+330				
Sample No.					GREY 1	GREY 2				
Borrow Pit					Borrow Pit 1					
Grading	75mm									
	63mm									
	50mm				100					
	37.5mm				88	100				
	20mm				75	85				
	10mm				53	56				
	5mm				40	40				
	2mm				17	19				
	1.18mm				9	12				
	600µm				5	8				
	425µm				4	7				
	212 µm				3	6				
	150µm				2	5				
	75µm				2	4				
Atterberg Limits	LL (%)				36	36				
	PL (%)				23	22				
	PI (%)				13	14				
	LS (%)				7	7				
Moisture Content	%									
Particle Density	kg/m^3									
Bulk Density	kg/m^3									
Soil classification	BSCS									
Compactoin	MDD (kg/m^3)									
BS Light / Heavy	OMC (%)									
Field	FDD (kg/m^3)									
Density	FMC (%)									
CBR (%)	95 % heavy DD									
(Unsoaked)	98 % heavy DD									
CBR (%)	100 % light DD									
(4 days soaked)	Swell (%)									
	95 % heavy DD									
	100 % heavy DD									
	Swell (%)									

Borrow Pit 2 Test Results – 2 +700 km – Red Quartzitic Gravel

TANZANIA NATIONAL ROADS AGENCY

TANROADS – Good roads for national development

SUMMARY SHEET

SOIL TESTS

CML – CENTRAL MATERIALS LABORATORY

Project: Bagamoyo - Talawanda road	**Date:** 01/03/2011	**Date:** 3/1/20111
Client:	**Checked**	**Approved**
Contract No. 2010/2011/		
Responsible Technician:		

Location (km)					2+700					
Sample No.					S - 4					
Borrow Pit					Borrow Pit 2					
Grading	75mm									
	63mm									
	50mm									
	37.5mm				100					
	20mm				91					
	10mm				77					
	5mm				60					
	2mm				21					
	1.18mm				13					
	600µm				12					
	425µm				11					
	212 µm				10					
	150µm				10					
	75µm				9					
Atterberg Limits	LL (%)				54					
	PL (%)				24					
	PI (%)				30					
	LS (%)				14					
Moisture Content	%									
Particle Density	kg/m^3									
Bulk Density	kg/m^3									
Soil classification	BSCS									
Compactoin	MDD (kg/m^3)				2140					
BS Heavy	MDD 95% (kg/m^3)				2033					
BS Heavy	OMC (%)				6.8					
CBR (%)	95 % heavy DD									
(Unsoaked)	98 % heavy DD									
CBR (%)	100 % light DD									
(4 days soaked)	Swell (%)									
	95 % heavy DD				20					
	100 % heavy DD									
	Swell (%)				1.79					

TANZANIA NATIONAL ROADS AGENCY

TANROADS — Good roads for national development

SUMMARY SHEET

SOIL TESTS

CML — CENTRAL MATERIALS LABORATORY

Project: Bagamoyo - Talawanda road	**Date:** 02/09/2011		**Date:** 02/09/2011
Client: M/s AFCAP	**Checked**		**Approved**
Contract No.			
Responsible Technician:			

Location		2+700	2+700	2+700						
Sample No.		RED 1	RED 2	RED 3						
Borrow Pit			Bowor Pit 2							
Grading	75mm									
	63mm									
	50mm		100	100						
	37.5mm	100	96	96						
	20mm	94	86	79						
	10mm	72	74	64						
	5mm	61	56	48						
	2mm	31	25	20						
	1.18mm	22	17	12						
	600µm	19	15	10						
	425µm	18	14	9						
	212 µm	16	12	8						
	150µm	15	11	7						
	75µm	13	10	6						
Atterberg Limits	LL (%)	48	52	51						
	PL (%)	22	29	25						
	PI (%)	26	23	26						
	LS (%)	14	11	14						
Moisture Content	%									
Particle Density	kg/m^3									
Bulk Density	kg/m^3									
Soil classification	BSCS									
Compactoin	MDD (kg/m^3)									
BS Light / Heavy	OMC (%)									
Field	FDD (kg/m^3)									
Density	FMC (%)									
CBR (%)	95 % heavy DD									
(Unsoaked)	98 % heavy DD									
CBR (%)	100 % light DD									
(4 days soaked)	Swell (%)									
	95 % heavy DD									
	100 % heavy DD									
	Swell (%)									

Borrow Pit 3 Test Results – 13 +860 km – Marly Limestone

TANZANIA NATIONAL ROADS AGENCY

TANROADS Good roads for national development

SUMMARY SHEET

SOIL TESTS

CML CENTRAL MATERIALS LABORATORY

Project: Bagamoyo - Talawanda road	**Date:** 01/03/2011	**Date:** 3/1/20111
Client:	**Checked**	**Approved**
Contract No. 2010/2011/		
Responsible Technician:		

Location (km)											
Sample No.		S - 1	S - 2	S - 3	S - 4						
Depth (m)											
Grading	75mm										
	63mm	100	100								
	50mm	88	94	100							
	37.5mm	76	72	87	100						
	20mm	59	54	79	91						
	10mm	50	47	58	77						
	5mm	42	38	48	60						
	2mm	33	32	41	21						
	1.18mm	31	31	40	13						
	600µm	30	30	39	12						
	425µm	30	30	39	11						
	212 µm	30	29	39	10						
	150µm	29	29	38	10						
	75µm	27	25	36	9						
Atterberg Limits	LL (%)	35	32	33	54						
	PL (%)	19	16	18	24						
	PI (%)	16	16	15	30						
	LS (%)	9	9	7	14						
Moisture Content	%										
Particle Density	kg/m^3										
Bulk Density	kg/m^3										
Soil classification	BSCS										
Compactoin	MDD (kg/m^3)	1913	2045	2012	2140						
BS Heavy	MDD 95% (kg/m^3)	1817	1943	1911	2033						
BS Heavy	OMC (%)	11.7	9.6	7.8	6.8						
CBR (%)	95 % heavy DD										
(Unsoaked)	98 % heavy DD										
CBR (%)	100 % light DD										
(4 days soaked)	Swell (%)										
	95 % heavy DD	21	14	16	20						
	100 % heavy DD										
	Swell (%)	0.01	0.01	0.02	1.79						

TANZANIA NATIONAL ROADS AGENCY

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SUMMARY SHEET

Project: Bagamoyo - Talawanda road

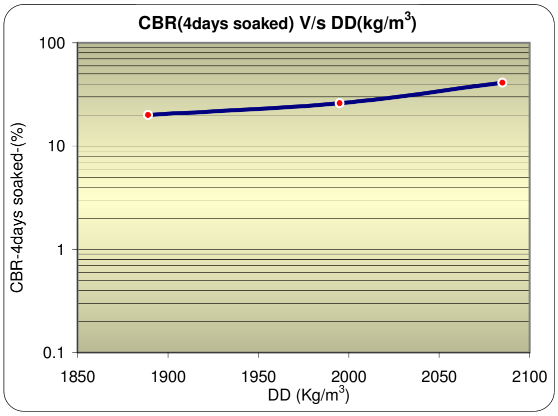
CML — CENTRAL MATERIALS LABORATORY

CH (km): 13+860 Borrow Pit 3	**Sample No. S 5**		**Offset:** 0+000
Client :	**TP**		**Depth** (m)
Contract No. 2010/2011/	**Date:** 3/2/2011		**Date:** 3/2/2011
Responsible Technician:	**Checked**		**Approved**

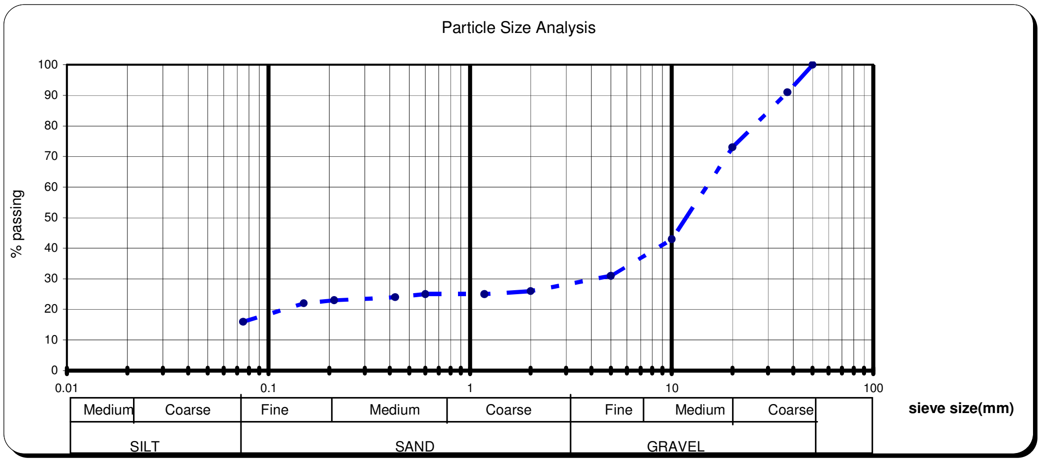
sieve size(mm)	%passing		
75			
63			
50	100		
37.5	91		
20	73		
10	43		
5	31		
2	26		
1.18	25		
0.600	25		
0.425	24		
0.212	23		
0.150	22		
0.075	16		

Atterberg Limits

Liquid Limit (%)	30		
Plastic Limit (%)	19		
Plasticity Index (%)	11		
Linear Shrinkage (%)	6		
GM	2.34		
MDD (Kg/m^3)	2069		
OMC (%)	8.7		
Field Moisture (%)			



	Data entry		autocalc	
Three Point CBR Values	DD (kg/m^3)	CBR (%)	%MDD	Swell (%)
(2,5 kg) 3 layers/62 blows	1889	20	91	
(4,5 kg) 5 layers/30 blows	1995	26	96	
(4,5 kg) 5 layers/62 blows	2085	41	101	0.24



TANZANIA NATIONAL ROADS AGENCY

TANROADS — Good roads for national development

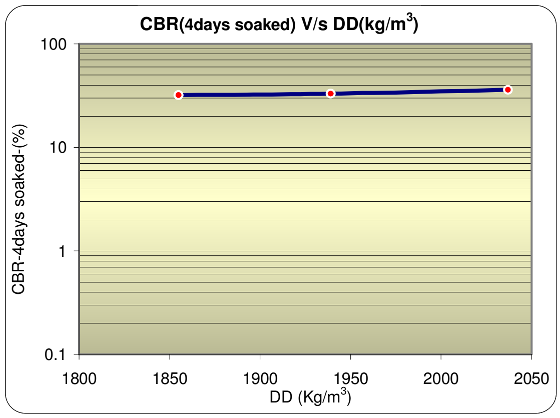
SUMMARY SHEET

Project: Bagamoyo - Talawanda road

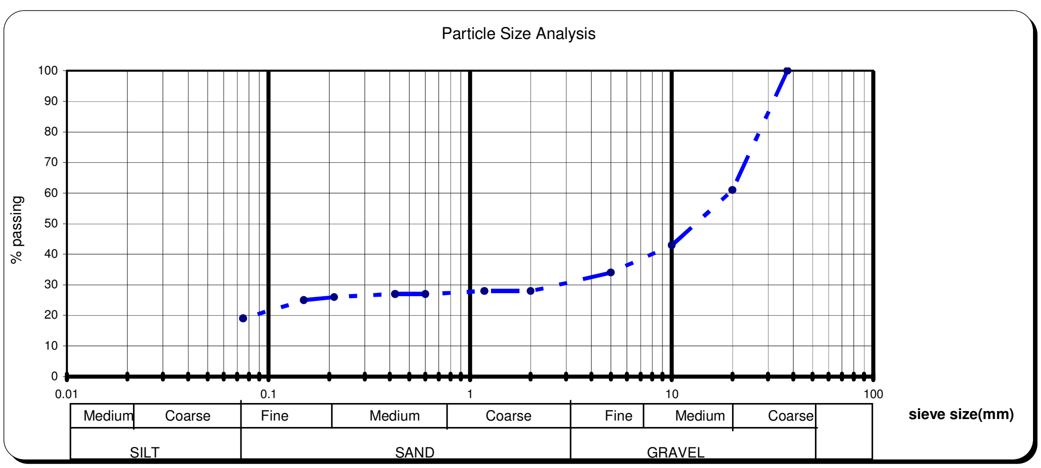
CML
CENTRAL MATERIALS LABORATORY

CH (km): 13+860 Borrow Pit 3		**Sample No. S 6**	**Offset:** 0+000
Client :		**TP**	**Depth** (m)
Contract No. 2010/2011/		**Date:** 3/2/2011	**Date:** 3/2/2011
Responsible Technician:		**Checked**	**Approved**

sieve size(mm)	%passing		
75			
63			
50			
37.5	100		
20	61		
10	43		
5	34		
2	28		
1.18	28		
0.600	27		
0.425	27		
0.212	26		
0.150	25		
0.075	19		
Atterberg Limits			
Liquid Limit (%)	30		
Plastic Limit (%)	16		
Plasticity Index (%)	14		
Linear Shrinkage (%)	9		
GM	2.26		
MDD (Kg/m^3)	2067		
OMC (%)	8.8		
Field Moisture (%)			



	Data entry		autocalc	
Three Point CBR Values	DD (kg/m^3)	CBR (%)	%MDD	Swell (%)
(2,5 kg) 3 layers/62 blows	1855	32	90	
(4,5 kg) 5 layers/30 blows	1939	33	94	
(4,5 kg) 5 layers/62 blows	2037	36	99	0.13



Borrow Pit 4 Test Results – 8 +000 km – Marly Limestone

TANZANIA NATIONAL ROADS AGENCY

TANROADS — Good roads for national development

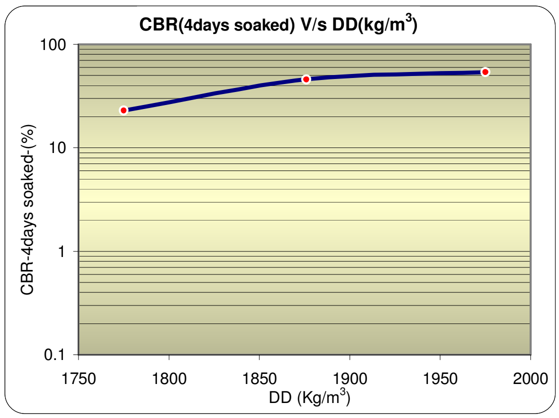
SUMMARY SHEET

Project: Bagamoyo - Talawanda road

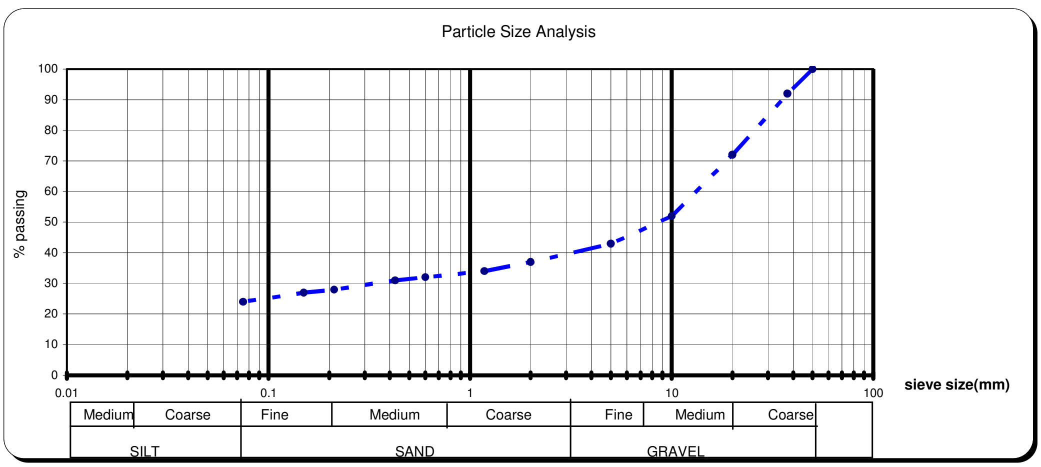
CML — CENTRAL MATERIALS LABORATORY

CH (km): Borrow Pit 4 - 8+000km	**Sample No. S 7**		**Offset:**
Client :	**8+000**		**Depth** (m)
Contract No. 2010/2011/	**Date:** 18/2/2011		**Date:** 18/2/2011
Responsible Technician:	**Checked**		**Approved**

sieve size(mm)	%passing		
75			
63			
50	100		
37.5	92		
20	72		
10	52		
5	43		
2	37		
1.18	34		
0.600	32		
0.425	31		
0.212	28		
0.150	27		
0.075	24		
Atterberg Limits			
Liquid Limit (%)	30		
Plastic Limit (%)	19		
Plasticity Index (%)	11		
Linear Shrinkage (%)	6		
GM	2.08		
MDD (Kg/m^3)	1980		
OMC (%)	11.5		
Field Moisture (%)			



	Data entry		autocalc	
Three Point CBR Values	DD (kg/m^3)	CBR (%)	%MDD	Swell (%)
(2,5 kg) 3 layers/62 blows	1775	23	90	
(4,5 kg) 5 layers/30 blows	1876	46	95	
(4,5 kg) 5 layers/62 blows	1975	54	100	0.1



Marly Limestone Test Results – Normal procedure and CBR after 1 month

TANZANIA NATIONAL ROADS AGENCY

TANROADS — Good roads for national development

SUMMARY SHEET

SOIL TESTS

CML

CENTRAL MATERIALS LABORATORY

Project: Bago - Talawanda Road	**Date:** May 06,/2011	**Date:** May 06,/2011
Client:	**Checked**	**Approved**
Contract No. 2010/2011/		
Responsible Technician:		

Location/ Chainage		SIDE	BOTTOM	TOP			SIDE	BOTTOM	TOP		
Sample No		B/PIT3	B/PIT3	B/PIT3	B/PIT4		B/PIT3	B/PIT3	B/PIT3	B/PIT4	
Remarks		**NORMAL PROCEDURE**					**CBR AFTER 1 MONTH**				
Grading	75mm										
	63mm		100								
	50mm		95	100	100						
	37.5mm		86	75	92						
	20mm		67	53	75						
	10mm	99	55	43	59						
	5mm	93	46	35	49						
	2mm	79	41	32	42						
	1.18mm	74	40	31	40						
	600µm	72	39	30	38						
	425µm	71	38	30	37						
	212 µm	70	36	29	33						
	150µm	69	34	28	32						
	75µm	65	28	25	30						
Atterberg Limits	LL (%)	32	29	30	32						
	PL (%)	18	14	18	19						
	PI (%)	14	15	12	13						
	LS (%)	9	6	9	9						
Moisture Content	%										
Particle Density	kg/m^3										
Bulk Density	kg/m^3										
Soil classification	BSCS										
Compactoin BS Light / Heavy	MDD (kg/m^3)	1990	2023	2070	2010		1990	2023	2070	2010	
	OMC (%)	11.2	10.4	9.3	10.7		11.2	10.4	9.3	10.7	
Field Density	FDD (kg/m^3)										
	FMC (%)	3.8	3.8	2.7	2.9		3.8	3.8	2.7	2.9	
CBR (%) (Unsoaked)	90 % heavy DD										
	95 % heavy DD										
	100 % heavy DD										
CBR (%) (4 days soaked)	90 % heavy DD										
	Swell (%)										
	95 % heavy DD										
	100 % heavy DD	14	30	22	58		18	35	35	77	
	Swell (%)	1.98	0.21	1.06	0.17		1.11	0.46	0.45	0.49	

Field Density Test Results

G60 Base Course

REGIONAL MANAGER`S OFFICE
TANROADS DAR ES SALAAM
MATERIALS TESTING LABORATORY SECTION

FIELD COMPACTION TEST (NUCLEAER METHOD- TROXILER)

Project: DEMONSTRATION SITE ALONG BAGO - TALAWANDA ROAD
Contractor: M/S DEL MONTE (T) LTD
Source of Materials: B/PIT NO: 4 (08.000 KM)
Location: BAGO - TALAWANDA ROAD
Layer: BASE COURSE OF NATURAL GRAVEL (60)
Date: 21-May-11

S/N	STATION/ CHAINAGE (Km)	OFFSET/ POSITION	LABORATORY COMPACTION OMC (%)	MDD kg/m3	NUCLEAR FIELD DENSITY WET DENSITY kg/m3	DRY DENSITY kg/m3	FMC (%)	COMP. (%)	REQUIRED COMP. (%)	DEPTH (mm)
1	0 + 030	CENTER	9.5	2094	2255	2084	8.2	**99.5**	98	100
2	0 + 080	RHS	9.5	2094	2285	2104	8.6	**100.5**	98	100
3	0 + 130	LHS	9.5	2094	2307	2138	7.9	**102.1**	98	100
4	0 + 200	CENTER	9.5	2094	2243	2079	7.9	**99.3**	98	100

MINIMUM AVERAGE VALUE (%)	100.3	*98.1*
MINIMUM - SINGLE TEST	99.3	*94.4*

Tested By: For: REGIONAL MANAGER TANROADS TANZANIA NATIONAL ROADS AGENCY P. O. Box 4838 DAR-ES-SALAAM Date: 21-May-11

CHecked By: .... Date: 24.5.2011

Approved by: .... Date: ....

REGIONAL MANAGER`S OFFICE
TANROADS DAR ES SALAAM
MATERIALS TESTING LABORATORY SECTION
FIELD COMPACTION TEST (NUCLEAER METHOD- TROXILER)

Project: DEMONSTRATION SITE ALONG BAGO - TALAWANDA ROAD
Contractor: M/S DEL MONTE (T) LTD
Source of Materials: B/PIT NO: 3
Location: (CH: 8 + 000 - 8 + 240) BAGO - TALAWANDA ROAD
Layer: NATURAL BASE COURSE (G60)
Date: 5-Jul-11

S/N	STATION/ CHAINAGE (Km)	OFFSET/ POSITION	LABORATORY COMPACTION OMC (%)	LABORATORY COMPACTION MDD kg/m3	NUCLEAR FIELD DENSITY WET DENSITY kg/m3	NUCLEAR FIELD DENSITY DRY DENSITY kg/m3	FMC (%)	COMP. (%)	REQUIRED COMP. (%)	DEPTH (mm)
1	8 + 000	CENTER	9.5	2094	2302	2153	6.9	**102.8**	98	150
2	8 + 080	RHS	9.5	2094	2210	2054	7.6	**98.1**	98	150
3	8 + 160	LHS	9.5	2094	2309	2164	6.7	**103.3**	98	150
4	8 + 240	CENTER	9.5	2094	2292	2142	7.0	**102.3**	98	150

MINIMUM AVERAGE VALUE (%)	101.6	*98.1*
MINIMUM - SINGLE TEST	98.1	*94.4*

Tested By: ADAM.M Date: 5-Jul-11

CHecked By: [signature] Date: 06/06/2011.

Approved by: For: REGIONAL MANAGER TANROADS TANZANIA NATIONAL ROADS AGENCY P. O. Box 4838 DAR-ES-SALAAM Date: ....

REGIONAL MANAGER`S OFFICE
TANROADS DAR ES SALAAM
MATERIALS TESTING LABORATORY SECTION
FIELD COMPACTION TEST (NUCLEAER METHOD- TROXILER)

Project: DEMONSTRATION SITE ALONG BAGO - TALAWANDA ROAD
Contractor: M/S DEL MONTE (T) LTD
Source of Materials: B/PIT NO: 4
Location: (CH: 11 + 200 - 11 + 390) BAGO - TALAWANDA ROAD
Layer: NATURAL BASE COURSE LAYER (G60)
Date: 29-Jun-11

S/N	STATION/ CHAINAGE (Km)	OFFSET/ POSITION	LABORATORY COMPACTION OMC (%)	LABORATORY COMPACTION MDD kg/m3	NUCLEAR FIELD DENSITY WET DENSITY kg/m3	NUCLEAR FIELD DENSITY DRY DENSITY kg/m3	FMC (%)	COMP. (%)	REQUIRED COMP. (%)	DEPTH (mm)
1	11 + 200	CENTER	9.5	2094	2322	2162	7.4	**103.2**	98	150
2	11 + 260	RHS	9.5	2094	2238	2068	8.2	**98.8**	98	150
3	11 + 320	LHS	9.5	2094	2256	2104	7.2	**100.5**	98	150
4	11 + 390	CENTER	9.5	2094	2226	2084	6.8	**99.5**	98	150

MINIMUM AVERAGE VALUE (%)	100.5	*98.1*
MINIMUM - SINGLE TEST	98.8	*94.4*

Tested By: ADAM.M Date: 29-Jun-11

CHecked By: [signature] Date: 30/06/2011.

Approved by: ………………… Date: ……………

FOR REGIONAL MANAGER
TANROADS
TANZANIA NATIONAL ROADS AGENCY
P. O. Box 4838
DAR-ES-SALAAM

REGIONAL MANAGER`S OFFICE
TANROADS DAR ES SALAAM
MATERIALS TESTING LABORATORY SECTION
FIELD COMPACTION TEST (NUCLEAER METHOD- TROXILER)

Project: DEMONSTRATION SITE ALONG BAGO - TALAWANDA ROAD
Contractor: M/S DEL MONTE (T) LTD
Source of Materials: B/PIT NO: 3
Location: (CH: 20 + 040 - 20 + 220) BAGO - TALAWANDA ROAD
Layer: NATURAL BASE COURSE LAYER (G60)
Date: 29-Jun-11

S/N	STATION/ CHAINAGE	OFFSET/ POSITION	LABORATORY COMPACTION		NUCLEAR FIELD DENSITY				REQUIRED COMP.	DEPTH
			OMC	MDD	WET DENSITY	DRY DENSITY	FMC	COMP.		
	(Km)		(%)	kg/m3	kg/m3	kg/m3	(%)	(%)	(%)	(mm)
1	20 + 040	CENTER	7.0	2090	2181	2077	5.0	**99.4**	98	150
2	20 + 100	RHS	7.0	2090	2170	2055	5.6	**98.3**	98	150
3	20 + 160	LHS	7.0	2090	2207	2082	6.0	**99.6**	98	150
4	20 + 220	CENTER	7.0	2090	2189	2069	5.8	**99.0**	98	150

MINIMUM AVERAGE VALUE (%)	99.1	*98.1*
MINIMUM - SINGLE TEST	98.3	*94.4*

Tested By: ADAM.M Date: 29-Jun-11

CHecked By: For: REGIONAL MANAGER....... Date: 30/06/2011

Approved by: TANROADS .... Date: ....

TANZANIA NATIONAL ROADS AGENCY
P. O. BOX 4836
DAR-ES-SALAAM

G45 Subbase

REGIONAL MANAGER`S OFFICE
TANROADS DAR ES SALAAM
MATERIALS TESTING LABORATORY SECTION
FIELD COMPACTION TEST (NUCLEAER METHOD- TROXILER)

Project: DEMONSTRATION SITE ALONG BAGO - TALAWANDA ROAD
Contractor: M/S DEL MONTE (T) LTD
Source of Materials: B/PIT NO: 4
Location: (CH: 8 + 000 - 8 + 160) BAGO - TALAWANDA ROAD
Layer: SUBBASE LAYER (G45)
Date: 29-Jun-11

S/N	STATION/ CHAINAGE (Km)	OFFSET/ POSITION	LABORATORY COMPACTION OMC (%)	LABORATORY COMPACTION MDD kg/m3	NUCLEAR FIELD DENSITY WET DENSITY kg/m3	NUCLEAR FIELD DENSITY DRY DENSITY kg/m3	FMC (%)	COMP. (%)	REQUIRED COMP. (%)	DEPTH (mm)
1	8 + 000	CENTER	9.5	2094	2296	2118	8.4	**101.2**	95	150
2	8 + 060	RHS	9.5	2094	2250	2062	9.1	**98.5**	95	150
3	8 + 110	LHS	9.5	2094	2158	1987	8.6	**94.9**	95	150
4	8 + 160	CENTER	9.5	2094	2269	2121	7.0	**101.3**	95	150

MINIMUM AVERAGE VALUE (%)	99.0	*95.2*
MINIMUM - SINGLE TEST	94.9	*91.4*

Tested By: ADAM.M Date: 29-Jun-11

CHecked By: For: REGIONAL MANAGER Date: 30/06/2011.

Approved by: .... Date: ....

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REGIONAL MANAGER`S OFFICE
TANROADS DAR ES SALAAM
MATERIALS TESTING LABORATORY SECTION

FIELD COMPACTION TEST (NUCLEAR METHOD- TROXILER)

Project: DEMONSTRATION SITE ALONG BAGO - TALAWANDA ROAD
Contractor: DEL-MONTE (T) LTD
Source of Materials: KIEMBE B/PIT (14KM)
Location: (CH: 10 + 000 - 10 + 680) - TALAWANDA ROAD
Layer: SUBBASE LAYER (G 45)
Date: 28 April 2011

S/N	STATION/ CHAINAGE	OFFSET/ POSITION	LABORATORY COMPACTION		NUCLEAR FIELD DENSITY				REQUIRED COMP.	DEPTH
			OMC	MDD	WET DENSITY	DRY DENSITY	FMC	COMP.		
	(Km)		(%)	kg/m3	kg/m3	kg/m3	(%)	(%)	(%)	(mm)
1	10 + 000	CENTER	7.0	2090	2308	2159	6.9	**103.3**	95	150
2	10 + 280	RHS	7.0	2090	2389	2216.1	7.8	**106.0**	95	150
3	10 + 380	LHS	7.0	2090	2230	2086.1	6.9	**99.8**	95	150
4	10 + 480	CENTER	7.0	2090	2306	2139.1	7.8	**102.4**	95	150
5	10 + 580	RHS	7.0	2090	2252	2128.5	5.8	**101.8**	95	150
6	10 + 680	LHS	7.0	2090	2314	2181	6.1	**104.4**	95	150
AVERAGE MINIMUM VALUE								102.9	*95.8*	
MINIMUM - SINGLE TEST								99.8	*91.0*	

Tested By: ADAM . M Date: 28 April 2011
CHecked By: [signature] Date: 3/5/2011
Approved by: Date:

For: REGIONAL MANAGER
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G15 Improved Subgrade Layer

REGIONAL MANAGER`S OFFICE
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MATERIALS TESTING LABORATORY SECTION

FIELD COMPACTION TEST (NUCLEAER METHOD- TROXILER)

Project: DEMONSTRATION SITE ALONG BAGO - TALAWANDA ROAD
Contractor: M/S DEL MONTE (T) LTD
Source of Materials: LUDIGA BORROW PIT NO - 3
Location: BAGO - TALAWANDA ROAD
Layer: FILL - G15
Date: 9-Apr-11

S/N	STATION/ CHAINAGE (Km)	OFFSET/ POSITION	LABORATORY COMPACTION OMC (%)	LABORATORY COMPACTION MDD kg/m3	NUCLEAR FIELD DENSITY WET DENSITY kg/m3	DRY DENSITY kg/m3	FMC (%)	COMP. (%)	REQUIRED COMP. (%)	DEPTH (mm)
1	5 + 500	CENTER	7	2090	2221	2023	9.8	**96.8**	95	150
2	5 + 660	LHS	7	2090	2215	2043	8.4	**97.8**	95	150
3	5 + 760	RHS	7	2090	2302	2141	7.5	**102.5**	95	150
4	5 + 860	CENTER	7	2090	2203	2042	7.9	**97.7**	95	150
5	5 + 980	LHS	7	2090	2241	2075	8.0	**99.3**	95	150
6	6 + 180	CENTER	7	2090	2237	2058	8.7	**98.5**	95	150
7	6 + 240	LHS	7	2090	2303	2146	7.3	**102.7**	95	150
8	6 + 390	RHS	7	2090	2207	2063	7	**98.7**	95	150
9	6 + 540	RHS	7	2090	2204	2054	7.3	**98.3**	95	150
10	6 + 670	CENTER	7	2090	2242	2064	8.6	**98.8**	95	150
11	6 + 810	LHS	7	2090	2215	2049	8.1	**98.0**	95	150
12	6 + 970	RHS	7	2090	2179	2010	8.4	**96.2**	95	150
13	7 + 120	CENTER	7	2090	2199	2065	6.5	**98.8**	95	150
14	7 + 340	CENTER	7	2090	2302	2124	8.4	**101.6**	95	150
15	7 + 440	RHS	7	2090	2280	2109	8.1	**100.9**	95	150
16	7 + 540	LHS	7	2090	2171	1988	9.2	**95.1**	95	150
17	7 + 640	CENTER	7	2090	2215	2023	9.5	**96.8**	95	150
18	7 + 740	LHS	7	2090	2286	2107	8.5	**100.8**	95	150

MINIMUM AVERAGE VALUE (%)	98.8	*96.3*
MINIMUM - SINGLE TEST	95.1	*90.7*

Tested By: ADAM.M Date: 9-Apr-11

CHecked By: [signature] Date: 11/4/2011.

Approved by: .... Date: ....

FOR REGIONAL MANAGER TANROADS TANZANIA NATIONAL ROADS AGENCY P. O. Box 4839 DAR-ES-SALAAM

REGIONAL MANAGER`S OFFICE
TANROADS DAR ES SALAAM
MATERIALS TESTING LABORATORY SECTION

FIELD COMPACTION TEST (NUCLEAER METHOD- TROXILER)

Project: DEMONSTRATION SITE ALONG BAGO - TALAWANDA ROAD
Contractor: M/S DEL MONTE (T) LTD
Source of Materials: LUDIGA BORROW PIT NO - 3
Location: BAGO - TALAWANDA ROAD
Layer: FILL - G15
Date: 9-Apr-11

S/N	STATION/ CHAINAGE (Km)	OFFSET/ POSITION	LABORATORY COMPACTION OMC (%)	LABORATORY COMPACTION MDD kg/m3	NUCLEAR FIELD DENSITY WET DENSITY kg/m3	NUCLEAR FIELD DENSITY DRY DENSITY kg/m3	NUCLEAR FIELD DENSITY FMC (%)	NUCLEAR FIELD DENSITY COMP. (%)	REQUIRED COMP. (%)	DEPTH (mm)
19	8 + 050	CENTER	7	2090	2254	2079	8.4	**99.5**	95	150
20	8 + 100	RHS	7	2090	2189	2010	8.9	**96.2**	95	150
21	8 + 160	LHS	7	2090	2302	2116	8.8	**101.2**	95	150
22	8 + 240	CENTER	7	2090	2230	2046	9.0	**97.9**	95	150
23	8 + 320	LHS	7	2090	2204	2037	8.2	**97.5**	95	150
24	8 + 520	CENTER	7	2090	2170	2002	8.4	**95.8**	95	150
25	8 + 620	RHS	7	2090	2233	2085	7.1	**99.8**	95	150
26	8 + 720	LHS	7	2090	2257	2111	6.9	**101.0**	95	150
27	8+ 820	CENTER	7	2090	2264	2098	7.9	**100.4**	95	150
28	9 + 980	CENTER	7	2090	2257	2100	7.5	**100.5**	95	150
29	10 + 080	LHS	7	2090	2199	2012	9.3	**96.3**	95	150
30	10 + 180	RHS	7	2090	2208	2018	9.4	**96.6**	95	150
31	10 + 280	CENTER	7	2090	2216	2069	7.1	**99.0**	95	150
32	10 + 380	CENTER	7	2090	2263	2088	8.4	**99.9**	95	150
33	10 + 480	RHS	7	2090	2215	2047	8.2	**97.9**	95	150
34	10+ 580	LHS	7	2090	2212	2024	9.3	**96.8**	95	150
35	11 + 200	CENTER	7	2090	2187	2006	9.0	**96.0**	95	150
36	11 + 250	LHS	7	2090	2174	1998	8.8	**95.6**	95	150
37	11+ 300	CENTER	7	2090	2179	2010	8.4	**96.2**	95	150
38	11 + 350	CENTER	7	2090	2155	1983	8.7	**94.9**	95	150
39	11 + 360	LHS	7	2090	2111	1942	8.7	**92.9**	95	150
40	11 + 400	CENTER	7	2090	2097	1935	8.4	**92.6**	95	150

MINIMUM AVERAGE VALUE (%)	97.5	*96.3*
MINIMUM - SINGLE TEST	92.6	*90.7*

Tested By: ADAM.M Date: 9-Apr-11

CHecked By: [signature] Date: 4/4/2011

Approved by: .... Date: ....

For REGIONAL MANAGER
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REGIONAL MANAGER`S OFFICE
TANROADS DAR ES SALAAM
MATERIALS TESTING LABORATORY SECTION

FIELD COMPACTION TEST (NUCLEAER METHOD- TROXILER)

Project: DEMONSTRATION SITE ALONG BAGO - TALAWANDA ROAD
Contractor: M/S DEL MONTE (T) LTD
Source of Materials: LUDIGA BORROW PIT NO - 3
Location: BAGO - TALAWANDA ROAD
Layer: FILL - G15
Date: 12-Apr-11

S/N	STATION/ CHAINAGE (Km)	OFFSET/ POSITION	LABORATORY COMPACTION OMC (%)	LABORATORY COMPACTION MDD kg/m3	NUCLEAR FIELD DENSITY WET DENSITY kg/m3	NUCLEAR FIELD DENSITY DRY DENSITY kg/m3	FMC (%)	COMP. (%)	REQUIRED COMP. (%)	DEPTH (mm)
1	12 + 580	CENTER	7	2090	2217	2097	5.7	**100.4**	95	150
2	12 + 500	LHS	7	2090	2096	1974	6.2	**94.4**	95	150
3	12 + 380	RHS	7	2090	2146	2019	6.3	**96.6**	95	150
4	12 + 240	CENTER	7	2090	2295	2159	6.3	**103.3**	95	150
5	11 + 390	CENTER	7	2090	2155	2018	6.8	**96.5**	95	150
6	11 + 340	LHS	7	2090	2156	2019	6.8	**96.6**	95	150
7	11 + 280	RHS	7	2090	2181	2058	6	**98.4**	95	150
8	11 + 220	CENTER	7	2090	2122	1987	6.8	**95.1**	95	150
9	5 + 500	LHS	7	2090	2097	1956	7.2	**93.6**	95	150
10	5 + 560	RHS	7	2090	2109	1973	6.9	**94.4**	95	150

MINIMUM AVERAGE VALUE (%)	96.9	*96.3*
MINIMUM - SINGLE TEST	93.6	*90.7*

Tested By: ADAM.M Date: 12-Apr-11

CHecked By: [signature] Date: 14/4/2011

Approved by: .... Date: ....

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REGIONAL MANAGER`S OFFICE
TANROADS DAR ES SALAAM
MATERIALS TESTING LABORATORY SECTION

FIELD COMPACTION TEST (NUCLEAR METHOD- TROXILER)

Project: DEMONSTRATION SITE ALONG BAGO - TALAWANDA ROAD

Contractor: DEL-MONTE (T) LTD
Source of Materials: KIEMBE B/PIT (14KM)
Location: **(CH: 5 + 340 - 5 + 490), (CH: 16 + 240 - 17 + 040) & (CH: 18 + 480 - 18 + 960)** BAGO - TALAWANDA ROAD
Layer: FILL LAYER - G 15
Date: 28 April 2011

S/N	STATION/ CHAINAGE (Km)	OFFSET/ POSITION	LABORATORY COMPACTION OMC (%)	LABORATORY COMPACTION MDD kg/m3	NUCLEAR FIELD DENSITY WET DENSITY kg/m3	NUCLEAR FIELD DENSITY DRY DENSITY kg/m3	FMC (%)	COMP. (%)	REQUIRED COMP. (%)	DEPTH (mm)
1	5 + 340	CENTER	7.0	2090	2172	2003.7	8.4	**95.9**	95	150
2	5 + 390	RHS	7.0	2090	2240	2085.7	7.4	**99.8**	95	150
3	5 + 440	LHS	7.0	2090	2207	2066.5	6.8	**98.9**	95	150
4	5 + 490	CENTER	7.0	2090	2204	2052.1	7.4	**98.2**	95	150
5	16 + 240	CENTER	7.0	2090	2298	2098.6	9.5	**100.4**	95	150
6	16 + 340	RHS	7.0	2090	2236	2029	10.2	**97.1**	95	150
7	16 + 440	LHS	7.0	2090	2330	2161.4	7.8	**103.4**	95	150
8	16 + 540	CENTER	7.0	2090	2362	2213.7	6.7	**105.9**	95	150
9	16 + 640	RHS	7.0	2090	2321	2181.4	6.4	**104.4**	95	150
10	16 + 740	LHS	7.0	2090	2310	2162.9	6.8	**103.5**	95	150
11	16 + 840	CENTER	7.0	2090	2256	2104.5	7.2	**100.7**	95	150
12	16 + 940	RHS	7.0	2090	2182	2001.8	9.0	**95.8**	95	150
13	17 + 040	LHS	7.0	2090	2360	2218	6.4	**106.1**	95	150
14	18 + 480	CENTER	7.0	2090	2252	2096.8	7.4	**100.3**	95	150
15	18 + 580	RHS	7.0	2090	2250	2079.5	8.2	**99.5**	95	150
16	18 + 680	LHS	7.0	2090	2320	2138.2	8.5	**102.3**	95	150
17	18 + 780	CENTER	7.0	2090	2188	2020.3	8.3	**96.7**	95	150
18	18 + 960	LHS	7.0	2090	2250	2073.7	8.5	**99.2**	95	150
	AVERAGE MINIMUM VALUE							100.4	***96.3***	
	MINIMUM - SINGLE TEST							95.8	***90.7***	

Tested By: ADAM . M — Date: 28 April 2011

CHecked By: [signature] — Date: 3/5/2011

Approved by: — Date:

For: REGIONAL MANAGER
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REGIONAL MANAGER`S OFFICE
TANROADS DAR ES SALAAM
MATERIALS TESTING LABORATORY SECTION

FIELD COMPACTION TEST (NUCLEAR METHOD- TROXILER)

Project: DEMONSTRATION SITE ALONG BAGO - TALAWANDA ROAD

Contractor: DEL-MONTE (T) LTD
Source of Materials: KIEMBE B/PIT (14KM)
Location: **(CH: 19 + 060 - 19 + 190) & (CH: 19 + 500 - 20 + 040)** BAGO - TALAWANDA ROAD
Layer: GRAVEL WEARING COURSE
Date: 28 April 2011

S/N	STATION/ CHAINAGE (Km)	OFFSET/ POSITION	LABORATORY COMPACTION OMC (%)	LABORATORY COMPACTION MDD kg/m3	NUCLEAR FIELD DENSITY WET DENSITY kg/m3	NUCLEAR FIELD DENSITY DRY DENSITY kg/m3	FMC (%)	COMP. (%)	REQUIRED COMP. (%)	DEPTH (mm)
1	19 + 060	CENTER	7.0	2090	2171	2008.3	8.1	**96.1**	95	150
2	19 + 110	RHS	7.0	2090	2369	2181.4	8.6	**104.4**	95	150
3	19 + 160	LHS	7.0	2090	2262	2092.5	8.1	**100.1**	95	150
4	19 + 190	CENTER	7.0	2090	2228	2066.8	7.8	**98.9**	95	150
5	19 + 500	RHS	7.0	2090	2145	2008.4	6.8	**96.1**	95	150
6	19 + 600	LHS	7.0	2090	2240	2085.7	7.4	**99.8**	95	150
7	19 + 700	CENTER	7.0	2090	2163	2000.9	8.1	**95.7**	95	150
8	19 + 800	RHS	7.0	2090	2235	2052.3	8.9	**98.2**	95	150
9	19 + 900	LHS	7.0	2090	2165	2002.8	8.1	**95.8**	95	150
10	20 + 040	CENTER	7.0	2090	2287	2121.5	7.8	**101.5**	95	150
	AVERAGE MINIMUM VALUE							98.7	*96.3*	
	MINIMUM - SINGLE TEST							95.7	*90.7*	

Tested By: ADAM . M Date: 28 April 2011

CHecked By: [signature] Date: 3/5/2011

Approved by: Date:

For: REGIONAL MANAGER
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G7 Improved Subgrade

REGIONAL MANAGER`S OFFICE
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MATERIALS TESTING LABORATORY SECTION

FIELD COMPACTION TEST (NUCLEAER METHOD- TROXILER)

Project: DEMONSTRATION SITE ALONG BAGO - TALAWANDA ROAD
Contractor: M/S DEL MONTE (T) LTD
Source of Materials: BORROW PIT NO - 2
Location: BAGO - TALAWANDA ROAD
Layer: FILL - G7
Date: 5-Mar-11

S/N	STATION/ CHAINAGE (Km)	OFFSET/ POSITION	LABORATORY COMPACTION OMC (%)	LABORATORY COMPACTION MDD kg/m3	NUCLEAR FIELD DENSITY WET DENSITY kg/m3	DRY DENSITY kg/m3	FMC (%)	COMP. (%)	REQUIRED COMP. (%)	DEPTH (mm)
1	0 + 030	RHS	8.6	2040	2176	2068	5.2	**101.4**	95	150
2	0 + 080	CENTER	8.6	2040	2033	1934	5.1	**94.8**	95	150
3	0 + 130	RHS	8.6	2040	2188	2076	5.4	**101.8**	95	150
4	0 + 180	LHS	8.6	2040	2083	1974	5.5	**96.8**	95	150
5	0 + 230	CENTER	8.6	2040	2059	1968	4.6	**96.5**	95	150
6	5 + 340	RHS	8.6	2040	2094	1977	5.9	**96.9**	95	150
7	5 + 420	LHS	8.6	2040	2169	2056	5.5	**100.8**	95	150
8	5 + 470	CENTER	8.6	2040	2183	2071	5.4	**101.5**	95	150
9	5 + 520	RHS	8.6	2040	2100	1987	5.7	**97.4**	95	150
10	8 + 000	LHS	8.6	2040	2030	1935	4.9	**94.9**	95	150
11	8 + 040	CENTER	8.6	2040	2120	2008	5.6	**98.4**	95	150
12	8 + 090	CENTER	8.6	2040	2173	2046	6.2	**100.3**	95	150
13	8 + 140	RHS	8.6	2040	2100	1976	6.3	**96.8**	95	150
14	8 + 190	LHS	8.6	2040	2157	2041	5.7	**100.0**	95	150
15	8 + 240	CENTER	8.6	2040	2097	1980	5.9	**97.1**	95	150
16	8 + 320	RHS	8.6	2040	2153	2041	5.5	**100.0**	95	150
17	8 + 420	LHS	8.6	2040	2160	2051	5.3	**100.6**	95	150
18	8 + 520	CENTER	8.6	2040	2205	2078	6.1	**101.9**	95	150
19	8 + 670	RHS	8.6	2040	2195	2073	5.9	**101.6**	95	150
20	8 + 720	LHS	8.6	2040	2211	2086	6.0	**102.2**	95	150
21	8 + 770	CENTER	8.6	2040	2181	2052	6.3	**100.6**	95	150
22	8 + 820	RHS	8.6	2040	2201	2074	6.1	**101.7**	95	150

MINIMUM AVERAGE VALUE (%)	99.3	*96.3*
MINIMUM - SINGLE TEST	94.8	*90.7*

Tested By: ADAM.M Date: 5-Mar-11

CHecked By: ....[signature]........ Date: 7/3/2011

Approved by: .... Date: ....

For REGIONAL MANAGER TANROADS ... P.O. Box 4598 DAR ES SALAAM

REGIONAL MANAGER`S OFFICE
TANROADS DER ES SALAAM
MATERIALS TESTING LABORATORY SECTION

FIELD COMPACTION TEST (NUCLEAER METHOD- TROXILER)

Project: DEMONSTRATION SITE ALONG BAGO - TALAWANDA ROAD
Contractor: M/S DEL MONTE (T) LTD
Source of Materials: BORROW PIT NO - 2
Location: BAGO - TALAWANDA ROAD
Layer: FILL - G7
Date: 10-Mar-11

S/N	STATION/ CHAINAGE (Km)	OFFSET/ POSITION	LABORATORY COMPACTION OMC (%)	MDD kg/m3	NUCLEAR FIELD DENSITY WET DENSITY kg/m3	DRY DENSITY kg/m3	FMC (%)	COMP. (%)	REQUIRED COMP. (%)	DEPTH (mm)
1	5 + 560	CENTER	8.6	2040	2158	2045	5.5	**100.3**	95	150
2	5 + 660	LHS	8.6	2040	2147	2043	5.1	**100.1**	95	150
3	5 + 760	RHS	8.6	2040	2189	2069	5.8	**101.4**	95	150
4	5 + 860	CENTER	8.6	2040	2048	1932	6.0	**94.7**	95	150
5	5 + 960	LHS	8.6	2040	2198	2054	7.0	**100.7**	95	150
6	6 + 060	RHS	8.6	2040	2094	1974	6.1	**96.7**	95	150
7	6 + 180	CENTER	8.6	2040	2120	1998	6.1	**97.9**	95	150
8	6 + 280	LHS	8.6	2040	2211	2094	5.6	**102.6**	95	150
9	6 + 380	RHS	8.6	2040	2113	2005	5.4	**98.3**	95	150
10	6 + 480	RHS	8.6	2040	1989	1873	6.2	**91.8**	95	150
11	6 + 580	CENTER	8.6	2040	2134	2013	6.0	**98.7**	95	150
12	6 + 680	LHS	8.6	2040	2051	1942	5.6	**95.2**	95	150
13	6 + 780	RHS	8.6	2040	2106	1981	6.3	**97.1**	95	150
14	6 + 880	CENTER	8.6	2040	2076	1979	4.9	**97.0**	95	150
15	6 + 980	RHS	8.6	2040	2116	1983	6.7	**97.2**	95	150
16	7 + 080	LHS	8.6	2040	2030	1931	5.1	**94.7**	95	150
17	7 + 320	CENTER	8.6	2040	2025	1898	6.7	**93.0**	95	150
18	7 + 420	RHS	8.6	2040	2112	1987	6.3	**97.4**	95	150
19	7 + 520	LHS	8.6	2040	2028	1928	5.2	**94.5**	95	150
20	7 + 620	CENTER	8.6	2040	2121	1995	6.3	**97.8**	95	150

MINIMUM AVERAGE VALUE (%)	97.4	*96.3*
MINIMUM - SINGLE TEST	91.2	*90.7*

Tested By: ADAM.M Date: 10-Mar-11

CHecked By: .... Date: 11/3/2011

Approved by: For REGIONAL MANAGER TANROADS P. O. Box 4238 DAR-ES-SALAAM Date: ....

REGIONAL MANAGER`S OFFICE
TANROADS DER ES SALAAM
MATERIALS TESTING LABORATORY SECTION

FIELD COMPACTION TEST (NUCLEAER METHOD- TROXILER)

Project: DEMONSTRATION SITE ALONG BAGO - TALAWANDA ROAD
Contractor: M/S DEL MONTE (T) LTD
Source of Materials: BORROW PIT NO - 3
Location: BAGO - TALAWANDA ROAD
Layer: FILL - G7
Date: 5-Mar-11

S/N	STATION/ CHAINAGE (Km)	OFFSET/ POSITION	LABORATORY COMPACTION OMC (%)	LABORATORY COMPACTION MDD kg/m3	NUCLEAR FIELD DENSITY WET DENSITY kg/m3	NUCLEAR FIELD DENSITY DRY DENSITY kg/m3	FMC (%)	COMP. (%)	REQUIRED COMP. (%)	DEPTH (mm)
1	16 + 240	CENTER	8.9	2000	1922	1824	5.4	**91.2**	95	150
2	16 + 300	LHS	8.9	2000	2037	1933	5.4	**96.6**	95	150
3	16 + 400	RHS	8.9	2000	2138	2021	5.8	**101.0**	95	150
4	16 + 500	CENTER	8.9	2000	2113	2001	5.6	**100.0**	95	150
5	16 + 600	LHS	8.9	2000	2136	2021	5.7	**101.0**	95	150
6	16 + 700	RHS	8.9	2000	2079	1967	5.7	**98.3**	95	150
7	16 + 800	CENTER	8.9	2000	2136	2017	5.9	**100.8**	95	150
8	16 + 900	LHS	8.9	2000	2106	1983	6.2	**99.2**	95	150
9	17 + 000	RHS	8.9	2000	2116	1992	6.2	**99.6**	95	150
10	17 + 100	CENTER	8.9	2000	2047	1931	6.0	**96.6**	95	150
11	18 + 500	LHS	8.9	2000	2105	2001	5.2	**100.0**	95	150
12	18 + 550	RHS	8.9	2000	2034	1945	4.6	**97.2**	95	150
13	18 + 600	CENTER	8.9	2000	2004	1910	4.9	**95.5**	95	150
14	18 + 650	RHS	8.9	2000	2063	1959	5.3	**98.0**	95	150
15	18 + 700	LHS	8.9	2000	2095	1984	5.6	**99.2**	95	150
16	18 + 750	CENTER	8.9	2000	2105	1977	6.5	**98.8**	95	150
17	18 + 800	RHS	8.9	2000	2073	1965	5.5	**98.2**	95	150
18	18 + 850	LHS	8.9	2000	2138	2030	5.3	**101.5**	95	150
19	18 + 900	CENTER	8.9	2000	2197	2104	4.4	**105.2**	95	150
20	18 + 950	RHS	8.9	2000	2139	2039	4.9	**102.0**	95	150
21	19 + 000	LHS	8.9	2000	1959	1862	5.2	**93.1**	95	150
22	20 + 040	CENTER	8.9	2000	2076	1942	6.9	**97.1**	95	150
23	20 + 110	RHS	8.9	2000	2086	1990	4.8	**99.5**	95	150
24	20 + 160	LHS	8.9	2000	2144	2038	5.2	**101.9**	95	150
25	20 + 210	CENTER	8.9	2000	2042	1956	4.4	**97.8**	95	150
26	20 + 260	RHS	8.9	2000	1938	1828	6.0	**91.4**	95	150

MINIMUM AVERAGE VALUE (%)	98.5	*96.3*
MINIMUM - SINGLE TEST	91.2	*90.7*

Tested By: ADAM.M Date: 5-Mar-11

CHecked By: ....[signature].... Date: 7/3/2011

Approved by: .... Date: ....

For: REGIONAL MANAGER
TANROADS
P. O. Box 4838
DAR-ES-SALAAM

Roadbed

REGIONAL MANAGER`S OFFICE
TANROADS DER ES SALAAM
MATERIALS TESTING LABORATORY SECTION

FIELD COMPACTION TEST (NUCLEAER METHOD- TROXILER)

Project: DEMONSTRATION SITE ALONG BAGO - TALAWANDA ROAD
Contractor: M/S DEL MONTE (T) LTD
Source of Materials: EXISTING MATERIAL
Location: BAGO - TALAWANDA
Layer: ROADBED
Date: 4-Dec-10

S/N	STATION/ CHAINAGE (Km)	OFFSET/ POSITION	LABORATORY COMPACTION OMC (%)	LABORATORY COMPACTION MDD kg/m3	NUCLEAR FIELD DENSITY WET DENSITY kg/m3	NUCLEAR FIELD DENSITY DRY DENSITY kg/m3	FMC (%)	COMP. (%)	REQUIRED COMP. (%)	DEPTH (mm)
1	0 + 020	CENTER	7.2	2040	1981	1925	2.9	94.4	93	150
2	0 + 070	RHS	7.2	2040	1976	1909	3.5	93.6	93	150
3	0 + 120	LHS	7.2	2040	1993	1907	4.5	93.5	93	150
4	0 + 170	CENTER	7.2	2040	1937	1836	5.5	90.0	93	150
5	0 + 220	RHS	7.2	2040	1903	1795	6.0	88.0	93	150
6	1 + 170	CENTER	7.2	2040	2060	1934	6.5	94.8	93	150

MINIMUM AVERAGE VALUE (%)	92.4	93.8
MINIMUM - SINGLE TEST	88.0	87.4

Tested By: ELISONY M Date: 4-Dec-10

CHecked By: Date: 10-12-2010

Approved by: .... Date: ....

REGIONAL MANAGER`S OFFICE
TANROADS DER ES SALAAM
MATERIALS TESTING LABORATORY SECTION

FIELD COMPACTION TEST (NUCLEAER METHOD- TROXILER)

Project: DEMONSTRATION SITE ALONG BAGO - TALAWANDA ROAD
Contractor: M/S DEL MONTE (T) LTD
Source of Materials: EXISTING MATERIAL
Location: 5+340 - 5+600 BLACK COTTON SOIL
Layer: ROADBED
Date: 4-Dec-10

S/N	STATION/ CHAINAGE (Km)	OFFSET/ POSITION	LABORATORY COMPACTION OMC (%)	MDD kg/m3	NUCLEAR FIELD DENSITY WET DENSITY kg/m3	DRY DENSITY kg/m3	FMC (%)	COMP. (%)	REQUIRED COMP. (%)	DEPTH (mm)
1	5 + 340	CENTER	15.7	1708	1685	1494	12.8	87.5	93	150
2	5 + 390	RHS	15.7	1708	1598	1423	12.3	83.3	93	150
3	5 + 440	LHS	15.7	1708	1652	1427	15.8	83.5	93	150
4	5 + 470	CENTER	15.7	1708	1695	1483	14.3	86.8	93	150
5	5+ 600	LHS	15.7	1708	1710	1516	12.8	88.8	93	150

MINIMUM AVERAGE VALUE (%)	86.0	93.6
MINIMUM - SINGLE TEST	83.3	87.6

Tested By: ELISONY M. Date: 4-Dec-10

CHecked By: Date: 10/12/2010

Approved by: .... Date: ....

REGIONAL MANAGER`S OFFICE
TANROADS DER ES SALAAM
MATERIALS TESTING LABORATORY SECTION

FIELD COMPACTION TEST (NUCLEAER METHOD- TROXILER)

Project: DEMONSTRATION SITE ALONG BAGO - TALAWANDA ROAD
Contractor: M/S DEL MONTE (T) LTD
Source of Materials: EXISTING MATERIAL
Location: 5 + 560 - 6+ 780
Layer: ROADBED
Date: 4-Dec-10

S/N	STATION/ CHAINAGE (Km)	OFFSET/ POSITION	LABORATORY COMPACTION OMC (%)	LABORATORY COMPACTION MDD kg/m3	NUCLEAR FIELD DENSITY WET DENSITY kg/m3	DRY DENSITY kg/m3	FMC (%)	COMP. (%)	REQUIRED COMP. (%)	DEPTH (mm)
1	5 + 560	CENTER	15.7	1708	1858	1741	6.7	102.0	93	150
2	5 + 660	RHS	15.7	1708	1810	1722	5.1	100.8	93	150
3	5 + 760	LHS	16.7	1708	1814	1741	4.2	101.9	93	150
4	5 + 860	CENTER	16.7	1708	1896	1774	6.9	103.8	93	150
5	5 + 960	RHS	17.7	1708	1800	1674	7.5	98.0	93	150
6	6 +080	LHS	17.7	1708	1945	1844	5.5	107.9	93	150
7	6 + 180	CENTER	18.7	1708	1685	1552	8.6	90.8	93	150
8	6 + 220	RHS	18.7	1708	1708	1509	13.2	88.3	93	150
9	6 +280	LHS	19.7	1708	1765	1515	16.5	88.7	93	150
10	6 + 380	CENTER	19.7	1708	1801	1531	17.6	89.7	93	150
11	6 + 480	RHS	20.7	1708	1802	1541	16.9	90.3	93	150
12	6 +580	LHS	20.7	1708	1685	1451	16.1	85.0	93	150
13	6 + 680	CENTER	21.7	1708	1812	1538	17.8	90.1	93	150
14	6 + 780	RHS	21.7	1708	1955	1694	15.4	99.2	93	150

MINIMUM AVERAGE VALUE (%)	95.5	94.3
MINIMUM - SINGLE TEST	88.7	86.9

Tested By: ELISONY M. [signature] Date: 4-Dec-10

CHecked By: [signature] Date: 10/12/2010

Approved by: .... Date: ....

REGIONAL MANAGER`S OFFICE
TANROADS DER ES SALAAM
MATERIALS TESTING LABORATORY SECTION

FIELD COMPACTION TEST (NUCLEAER METHOD- TROXILER)

Project: DEMONSTRATION SITE ALONG BAGO - TALAWANDA ROAD
Contractor: M/S DEL MONTE (T) LTD
Source of Materials: EXISTING MATERIAL
Location: 6 + 800 - 8+ 820
Layer: ROADBED
Date: 4-Dec-10

S/N	STATION/ CHAINAGE (Km)	OFFSET/ POSITION	LABORATORY COMPACTION		NUCLEAR FIELD DENSITY				REQUIRED COMP. (%)	DEPTH (mm)
			OMC (%)	MDD kg/m3	WET DENSITY kg/m3	DRY DENSITY kg/m3	FMC (%)	COMP. (%)		
1	6 + 880	CENTER	18	1688	1858	1613	15.2	**95.5**	93	150
2	6 + 980	RHS	18	1688	1810	1602	13.0	**94.9**	93	150
3	7 + 010	LHS	18	1688	1814	1605	13	**95.1**	93	150
4	7 + 100	CENTER	18	1688	1896	1693	12.0	**100.3**	93	150
5	7 + 200	RHS	18	1688	1875	1656	13.2	**98.1**	93	150
6	7 +300	LHS	18	1688	1945	1786	8.9	**105.8**	93	150
7	7 + 400	CENTER	18	1688	1789	1596	12.1	**94.5**	93	150
8	7 + 540	RHS	18	1688	1790	1581	13.2	**93.7**	93	150
9	7 +680	LHS	18	1688	1865	1601	16.5	**94.8**	93	150
10	7 + 800	CENTER	18	1688	1801	1597	12.8	**94.6**	93	150
11	8 + 000	RHS	18	1688	1802	1577	14.3	**93.4**	93	150
12	8 +100	LHS	18	1688	1789	1580	13.2	**93.6**	93	150
13	8 + 200	CENTER	18	1688	1812	1572	15.3	**93.1**	93	150
14	8 + 300	RHS	18	1688	1955	1694	15.4	**100.4**	93	150
15	8 +400	CENTER	18	1688	1902	1683	13	**99.7**	93	150
16	8 + 520	CENTER	18	1688	1898	1716	10.6	**101.7**	93	150
17	8 + 620	RHS	18	1688	1910	1673	14.2	**99.1**	93	150
18	8 +720	CENTER	18	1688	1872	1648	13.6	**97.6**	93	150
19	8 + 820	CENTER	18	1688	1935	1722	12.4	**102.0**	93	150
MINIMUM AVERAGE VALUE (%)								97.3	*94.3*	
MINIMUM - SINGLE TEST								93.1	***86.9***	

Tested By: ELISONY M. Date: 4-Dec-10

CHecked By: .... Date: 10/12/2010

Approved by: .... Date: ....

REGIONAL MANAGER`S OFFICE
TANROADS DER ES SALAAM
MATERIALS TESTING LABORATORY SECTION

FIELD COMPACTION TEST (NUCLEAER METHOD- TROXILER)

Project: DEMONSTRATION SITE ALONG BAGO - TALAWANDA ROAD
Contractor: M/S DEL MONTE (T) LTD
Source of Materials: EXISTING MATERIAL
Location: BAGO - TALAWANDA
Layer: ROADBED
Date: 4-Dec-10

S/N	STATION/ CHAINAGE (Km)	OFFSET/ POSITION	LABORATORY COMPACTION OMC (%)	MDD kg/m3	NUCLEAR FIELD DENSITY WET DENSITY kg/m3	DRY DENSITY kg/m3	FMC (%)	COMP. (%)	REQUIRED COMP. (%)	DEPTH (mm)
1	9 + 980	CENTER	7.2	1688	1935	1864	3.8	**110.4**	93	150
2	10 + 080	RHS	7.2	1688	1944	1891	2.8	**112.0**	93	150
3	10 + 180	LHS	7.2	1688	1859	1826	1.8	**108.2**	93	150
4	10 + 280	CENTER	7.2	1688	1911	1877	1.8	**111.2**	93	150
5	10 + 380	RHS	7.2	1850	1881	1819	3.4	**98.3**	93	150
6	10 + 480	LHS	7.2	1850	1722	1680	2.5	**90.8**	93	150
7	10 + 580	CENTER	7.2	1850	1858	1814	2.4	**98.1**	93	150
8	10 + 680	RHS	7.2	1850	1929	1882	2.5	**101.7**	93	150

MINIMUM AVERAGE VALUE (%)	103.9	*94.2*
MINIMUM - SINGLE TEST	88.0	*87.0*

Tested By: ELISONY M. [signature] Date: 4-Dec-10

CHecked By: [signature] Date: 10/12/2010

Approved by: .... Date: ....

For REGIONAL MANAGER TANROADS P. O. BOX ... DAR-ES-SALAAM

REGIONAL MANAGER'S OFFICE
TANROADS DER ES SALAAM
MATERIALS TESTING LABORATORY SECTION

FIELD COMPACTION TEST (NUCLEAER METHOD- TROXILER)

Project: DEMONSTRATION SITE ALONG BAGO - TALAWANDA ROAD
Contractor: M/S DEL MONTE (T) LTD
Source of Materials: EXISTING MATERIAL
Location: 11+200 - 11+400
Layer: ROADBED
Date: 4-Dec-10

S/N	STATION/ CHAINAGE (Km)	OFFSET/ POSITION	LABORATORY COMPACTION OMC (%)	LABORATORY COMPACTION MDD kg/m3	NUCLEAR FIELD DENSITY WET DENSITY kg/m3	NUCLEAR FIELD DENSITY DRY DENSITY kg/m3	NUCLEAR FIELD DENSITY FMC (%)	NUCLEAR FIELD DENSITY COMP. (%)	REQUIRED COMP. (%)	DEPTH (mm)
1	11 + 200	CENTER	9	2040	2038	1941	5.0	**95.1**	93	150
2	11 + 250	RHS	9	2040	2024	1942	4.2	**95.2**	93	150
3	11 + 300	LHS	9	2040	1942	1876	3.5	**92.0**	93	150
4	11 + 350	CENTER	9	2040	1927	1871	3.0	**91.7**	93	150
5	11 + 400	RHS	9	2040	2041	1961	4.1	**96.1**	93	150

MINIMUM AVERAGE VALUE (%)	94.0	*93.6*
MINIMUM - SINGLE TEST	91.7	*87.6*

Tested By: ELISONY M. [signature] Date: 4-Dec-10

CHecked By: [signature] Date: 10/12/2010

Approved by: .... Date: ....

REGIONAL MANAGER TANROADS BOX 4036 DAR ES SALAAM

REGIONAL MANAGER`S OFFICE
TANROADS DER ES SALAAM
MATERIALS TESTING LABORATORY SECTION

FIELD COMPACTION TEST (NUCLEAER METHOD- TROXILER)

Project: DEMONSTRATION SITE ALONG BAGO - TALAWANDA ROAD
Contractor: M/S DEL MONTE (T) LTD
Source of Materials: EXISTING MATERIAL
Location: BAGO - TALAWANDA (CH: 12 + 200 - 17 + 100)
Layer: ROADBED
Date: 22-Jan-11

S/N	STATION/ CHAINAGE (Km)	OFFSET/ POSITION	LABORATORY COMPACTION OMC (%)	LABORATORY COMPACTION MDD kg/m3	NUCLEAR FIELD DENSITY WET DENSITY kg/m3	DRY DENSITY kg/m3	FMC (%)	COMP. (%)	REQUIRED COMP. (%)	DEPTH (mm)
1	12 + 200	CENTER	15.7	1708	1768	1626	8.7	**95.2**	93	150
2	12 + 300	RHS	15.7	1708	1798	1613	11.5	**94.4**	93	150
3	12 + 400	LHS	15.7	1708	1822	1661	9.7	**97.2**	93	150
4	12 + 520	CENTER	15.7	1708	1801	1645	9.5	**96.3**	93	150
5	16 + 240	RHS	15.7	1708	1737	1599	8.6	**93.6**	93	150
6	16 + 300	LHS	15.7	1708	1714	1587	8.0	**92.9**	93	150
7	16 + 400	CENTER	15.7	1708	1766	1620	9.0	**94.9**	93	150
8	16 + 500	RHS	15.7	1708	1792	1662	7.8	**97.3**	93	150
9	16 + 600	LHS	15.7	1708	1784	1677	6.4	**98.2**	93	150
10	16 + 700	CENTER	15.7	1708	1646	1524	8	**89.2**	93	150
11	16 + 820	RHS	15.7	1708	1656	1571	5.4	**92.0**	93	150
12	16 + 900	LHS	15.7	1708	1747	1642	6.4	**96.1**	93	150
13	17 + 000	CENTER	15.7	1708	1743	1649	5.7	**96.5**	93	150
14	17 + 100	RHS	15.7	1708	1811	1710	5.9	**100.1**	93	150

MINIMUM AVERAGE VALUE (%)	95.3	*94.3*
MINIMUM - SINGLE TEST	89.2	*86.9*

Tested By: ADAM.M Date: 22-Jan-11

CHecked By: [signature] Date: 24/01/2011

Approved by: .... Date: ....

For: REGIONAL MANAGER
TANROADS
TANZANIA NATIONAL ROADS AGENCY
P. O. Box 4838
DAR-ES-SALAAM

REGIONAL MANAGER`S OFFICE
TANROADS DER ES SALAAM
MATERIALS TESTING LABORATORY SECTION

FIELD COMPACTION TEST (NUCLEAER METHOD- TROXILER)

Project: DEMONSTRATION SITE ALONG BAGO - TALAWANDA ROAD
Contractor: M/S DEL MONTE (T) LTD
Source of Materials: EXISTING MATERIAL
Location: BAGO - TALAWANDA (CH: 18 + 480 - 20 + 260)
Layer: ROADBED
Date: 22-Jan-11

S/N	STATION/ CHAINAGE (Km)	OFFSET/ POSITION	LABORATORY COMPACTION OMC (%)	LABORATORY COMPACTION MDD kg/m3	NUCLEAR FIELD DENSITY WET DENSITY kg/m3	NUCLEAR FIELD DENSITY DRY DENSITY kg/m3	FMC (%)	COMP. (%)	REQUIRED COMP. (%)	DEPTH (mm)
15	18 + 480	CENTER	15.7	1708	1758	1676	4.9	**98.1**	93	150
16	18 + 580	RHS	15.7	1708	1669	1583	5.4	**92.7**	93	150
17	18 + 680	LHS	15.7	1708	1746	1638	6.6	**95.9**	93	150
18	18 + 800	CENTER	15.7	1708	1734	1633	6.2	**95.6**	93	150
19	18 + 900	RHS	15.7	1708	1744	1612	8.2	**94.4**	93	150
20	19 + 000	LHS	15.7	1708	1765	1673	5.5	**97.9**	93	150
21	19 + 100	CENTER	15.7	1708	1721	1605	7.2	**94.0**	93	150
22	19 + 200	RHS	15.7	1708	1724	1617	6.6	**94.7**	93	150
23	19 + 520	LHS	15.7	1708	1750	1636	7.0	**95.8**	93	150
24	19 + 600	CENTER	15.7	1708	1673	1581	5.8	**92.6**	93	150
25	19 + 700	RHS	15.7	1708	1754	1636	7.2	**95.8**	93	150
26	19 + 800	LHS	15.7	1708	1756	1658	5.9	**97.1**	93	150
27	19 + 900	CENTER	15.7	1708	1736	1632	6.4	**95.5**	93	150
28	20 + 040	RHS	15.7	1708	1837	1745	5.3	**102.1**	93	150
29	20 + 100	LHS	15.7	1708	1792	1667	7.5	**97.6**	93	150
30	20 + 180	CENTER	15.7	1708	1813	1696	6.9	**99.3**	93	150
31	20 + 260	RHS	15.7	1708	1811	1680	7.8	**98.4**	93	150

MINIMUM AVERAGE VALUE (%)	96.3	*94.3*
MINIMUM - SINGLE TEST	92.6	*86.9*

Tested By: ADAM.M Date: 22-Jan-11

CHecked By: .... Date: 24/1/2011

Approved by: .... Date: ....

For: REGIONAL MANAGER
TANROADS
TANZANIA NATIONAL ROADS AGENCY
P. O. Box 4836
DAR-ES-SALAAM

Gravel Wearing Course

REGIONAL MANAGER`S OFFICE
TANROADS DAR ES SALAAM
MATERIALS TESTING LABORATORY SECTION

FIELD COMPACTION TEST (NUCLEAER METHOD- TROXILER)

Project: DEMONSTRATION SITE ALONG BAGO - TALAWANDA ROAD
Contractor: M/S DEL MONTE (T) LTD
Source of Materials: B/PIT NO: 3 (14.000 KM)
Location: BAGO - TALAWANDA ROAD
Layer: GRAVEL WEARING COURSE
Date: 21-May-11

S/N	STATION/ CHAINAGE (Km)	OFFSET/ POSITION	LABORATORY COMPACTION OMC (%)	LABORATORY COMPACTION MDD kg/m3	NUCLEAR FIELD DENSITY WET DENSITY kg/m3	NUCLEAR FIELD DENSITY DRY DENSITY kg/m3	FMC (%)	COMP. (%)	REQUIRED COMP. (%)	DEPTH (mm)
1	8 + 840	CENTER	9.5	2090	2154	1991	8.2	**95.3**	95	100
2	8 + 940	RHS	9.5	2090	2163	2033	6.4	**97.3**	95	100
3	9 + 040	LHS	9.5	2090	2232	2069	7.9	**99.0**	95	100
4	9 + 040	CENTER	9.5	2090	2160	2000	8.0	**95.7**	95	100
5	9 + 140	RHS	9.5	2090	2178	2032	7.2	**97.2**	95	100
6	9 + 240	LHS	9.5	2090	2206	2043	8.0	**97.7**	95	100
7	9 + 340	CENTER	9.5	2090	2215	2041	8.5	**97.7**	95	100
8	9 + 440	RHS	9.5	2090	2160	2004	7.8	**95.9**	95	100
9	9 + 540	LHS	9.5	2090	2196	2033	8.0	**97.3**	95	100
10	9 + 640	CENTER	9.5	2090	2176	2009	8.3	**96.1**	95	100
11	9 + 740	RHS	9.5	2090	2205	2045	7.8	**97.9**	95	100
12	9 + 840	LHS	9.5	2090	2198	2043	7.6	**97.7**	95	100
13	9 + 940	CENTER	9.5	2090	2190	2026	8.1	**96.9**	95	100

MINIMUM AVERAGE VALUE (%)	97.0	*96.3*
MINIMUM - SINGLE TEST	95.3	*90.7*

Tested By: ADAM M — Date: 21-May-11

CHecked By: For: REGIONAL MANAGER TANROADS TANZANIA NATIONAL ROADS P. O. Box [illegible] DAR [illegible] — Date: 24/5/2011

Approved by: .... — Date: ....

REGIONAL MANAGER`S OFFICE
TANROADS DAR ES SALAAM
MATERIALS TESTING LABORATORY SECTION
FIELD COMPACTION TEST (NUCLEAER METHOD- TROXILER)

Project: DEMONSTRATION SITE ALONG BAGO - TALAWANDA ROAD
Contractor: M/S DEL MONTE (T) LTD
Source of Materials: B/PIT NO: 3
Location: (CH: 8 + 000 - 8 + 240) BAGO - TALAWANDA ROAD
Layer: GRAVEL WEARING COURSE
Date: 5-Jul-11

S/N	STATION/ CHAINAGE (Km)	OFFSET/ POSITION	LABORATORY COMPACTION OMC (%)	LABORATORY COMPACTION MDD kg/m3	NUCLEAR FIELD DENSITY WET DENSITY kg/m3	NUCLEAR FIELD DENSITY DRY DENSITY kg/m3	NUCLEAR FIELD DENSITY FMC (%)	NUCLEAR FIELD DENSITY COMP. (%)	REQUIRED COMP. (%)	DEPTH (mm)
1	17 + 120	CENTER	7.0	2090	2194	2102	4.4	**100.6**	95	100
2	17 + 220	RHS	7.0	2090	2163	2052	5.4	**98.2**	95	100
3	8 + 160	LHS	7.0	2090	2130	2023	5.3	**96.8**	95	100
4	8 + 240	CENTER	7.0	2090	2259	2162	4.5	**103.4**	95	100
5	9 + 080	RHS	7.0	2090	2106	2039	3.3	**97.5**	95	100
6	9 + 160	LHS	7.0	2090	2168	2067	4.9	**98.9**	95	100
7	9 + 240	CENTER	7.0	2090	2086	1992	4.7	**95.3**	95	100
8	10 + 080	RHS	7.0	2090	2144	2038	5.2	**97.5**	95	100
9	10 + 160	LHS	7.0	2090	2182	2064	5.7	**98.8**	95	100
10	10 + 240	CENTER	7.0	2090	2069	1974	4.8	**94.5**	95	100
11	11 + 080	RHS	7.0	2090	2172	2074	4.7	**99.3**	95	100
12	11 + 160	LHS	7.0	2090	2125	2026	4.9	**96.9**	95	100
13	11 + 240	CENTER	7.0	2090	2092	2010	4.1	**96.2**	95	100
14	12 + 080	RHS	7.0	2090	2098	1987	5.6	**95.1**	95	100

MINIMUM AVERAGE VALUE (%)	97.8	*95.2*
MINIMUM - SINGLE TEST	94.5	*91.4*

Tested By: ADAM.M — Date: 5-Jul-11

CHecked By: [signature] — Date: 06/06/2011.

Approved by: For: REGIONAL MANAGER TANROADS TANZANIA NATIONAL ROADS AGENCY P. O. Box 4838 DAR-ES-SALAAM — Date: ....

REGIONAL MANAGER`S OFFICE
TANROADS DAR ES SALAAM
MATERIALS TESTING LABORATORY SECTION

FIELD COMPACTION TEST (NUCLEAER METHOD- TROXILER)

Project: DEMONSTRATION SITE ALONG BAGO - TALAWANDA ROAD
Contractor: M/S DEL MONTE (T) LTD
Source of Materials: B/PIT NO: 3 (14.000 KM)
Location: BAGO - TALAWANDA ROAD
Layer: GRAVEL WEARING COURSE
Date: 21-May-11

S/N	STATION/ CHAINAGE (Km)	OFFSET/ POSITION	LABORATORY COMPACTION OMC (%)	LABORATORY COMPACTION MDD kg/m3	NUCLEAR FIELD DENSITY WET DENSITY kg/m3	NUCLEAR FIELD DENSITY DRY DENSITY kg/m3	NUCLEAR FIELD DENSITY FMC (%)	NUCLEAR FIELD DENSITY COMP. (%)	REQUIRED COMP. (%)	DEPTH (mm)
1	11 + 420	CENTER	9.5	2090	2088	1946	7.3	**93.1**	95	100
2	11 + 520	RHS	9.5	2090	2272	2125	6.9	**101.7**	95	100
3	11 + 620	LHS	9.5	2090	2156	2021	6.7	**96.7**	95	100
4	11 + 720	CENTER	9.5	2090	2180	2035	7.1	**97.4**	95	100
5	11 + 820	RHS	9.5	2090	2200	2060	6.8	**98.6**	95	100
6	11 + 920	LHS	9.5	2090	2165	2033	6.5	**97.3**	95	100
7	12 + 020	CENTER	9.5	2090	2158	2017	7.0	**96.5**	95	100
8	12 +120	RHS	9.5	2090	2200	2047	7.5	**97.9**	95	100
9	12 + 220	LHS	9.5	2090	2210	2048	7.9	**98.0**	95	100
10	12 +600	CENTER	9.5	2090	2190	2049	6.9	**98.0**	95	100
11	12 +700	RHS	9.5	2090	2196	2056	6.8	**98.4**	95	100
12	12 +800	LHS	9.5	2090	2186	2039	7.2	**97.6**	95	100
13	12 +900	CENTER	9.5	2090	2203	2057	7.1	**98.4**	95	100
14	13 +000	RHS	9.5	2090	2191	2050	6.9	**98.1**	95	100
15	13 +100	LHS	9.5	2090	2175	2027	7.3	**97.0**	95	100
16	13 +200	CENTER	9.5	2090	2168	2015	7.6	**96.4**	95	100
17	13 +300	RHS	9.5	2090	2179	2040	6.8	**97.6**	95	100
18	13 +400	LHS	9.5	2090	2200	2050	7.3	**98.1**	95	100
19	13 +500	CENTER	9.5	2090	2190	2056	6.5	**98.4**	95	100

MINIMUM AVERAGE VALUE (%)	97.6	***96.3***
MINIMUM - SINGLE TEST	95.4	***90.7***

Tested By: ADAM M. Date: 21-May-11
CHecked By: Date: 24/5/2011
Approved by: Date: ....

For: REGIONAL MANAGER
TANROADS
TANZANIA NATIONAL ROADS AGENCY
P. O. Box 4838
DAR-ES-SALAAM

Field Quality Control for Bitumen Spraying and Aggregate Spreading Rate

WORK SHEET

FIELD QUALITY CONTROL FOR BITUMEN SPRAYING AND AGGREGATE SPRADING RATE

CLIENT: EXECUTIVE DIRECTOR BAGAMOYO DISTRICT
CONSULTANT: EXECUTIVE DIRECTOR BAGAMOYO DISTRICT
PROJECT: DEMOSTRATION SITE ALONG BAGO - TALAWANDA ROAD

CONTRACTOR: M/S DEL-MONTE (T) LTD
MATERIAL: BITUMEN PRAYING RATE MC -30
LOCATION: BAGO - TALAWANDA
SAMPLE DATE 5-Jul-11
TEST DATE 5-Jul-11

DETERMINATION OF BINDER CONTENT		TEST 1	TEST 2	
CHAINAGE	KM			
WEIGHT OF TRA'	g	587.6	415.2	
WEIGHT OF TRAY + BITUMEN	g	627.8	490.2	
WEIGHT OF BITUMEN	g	40.2	75	
DENSITY OF BITUMEN	g/CC	1.025	1.025	
VOLUME OF BITUMEN	C.C	0.0392	0.0732	
SURFACE AREA OF BITUMEN TRAY	M^2	0.024	0.0567	
SPRAYING RATE	L/m^2	1.63	1.29	
AVERAGE SPRAYING RATE	L/m^2		1.5	

Tested By:
ADAM MAPALA

Contractors Representative

Date:

Date: ....

REMARKS:

TANROADS
TANZANIA NATIONAL ROADS AGENCY
REGIONAL MANAGERS OFFICE
MATERIALS LABORATORY

For: REGIONAL MANAGER
TANROADS
TANZANIA NATIONAL ROADS AGENCY
P. O. Box 4838
DAR-ES-SALAAM

P.O.BOX 4838
PHONE 255 22 2450185
FAX: 255 22 2450626
DAR ES SALAAM.

Concrete Cube Results

Mix Designs for 20 MPa and 30 MPa Concrete – 7 day results

TANZANIA NATIONAL ROADS AGENCY

TANROADS — Good roads for national development

SUMMARY SHEET

CONCRETE TEST

CML

Project: BAGO-TALAWANDA RD	**Location**: BAGAMOYO	**Date**:4/10/2010
Client:	**Lab no**:	**Date:**
Responsible technician:	**Checked**:	**Approved**:

Contractor: Jansons Construction Co. Ltd				Construction part:	
SLUMP		Pore Volume (%)	Air temp. (ºC)	Concrete Temp.(ºC)	Sampling
Measured (cm)	Design (cm)				
Cement type :				Aggregates :	

Lab No.	Marking	Cube dimensions W X D X H (mm X mm X mm)	Density (g/cm^3)	Date made	Date tested	Age of cube (days)	Compressive Strength individual (Mpa)	Compressive Strength Average (Mpa)
A	C30	150 x 150 x 150	2.553	27/09/2010	10/04/2010	7	27.1	
A	C20	150 x 150 x 150	2.589	27/09/2010	10/04/2010	7	18.1	

Mix Designs for 20 MPa and 30 MPa Concrete – 28 day results

TANZANIA NATIONAL ROADS AGENCY

Good roads for national development

SUMMARY SHEET

CONCRETE TEST

CML

Project: BAGO-TALAWANDA RD	**Location**: BAGAMOYO	**Date**:25/10/2010
Client:	**Lab no**:	**Date:**
Responsible technician:	**Checked**:	**Approved**:

Contractor:				Construction part:	
SLUMP		Pore Volume (%)	Air temp. (ºC)	Concrete Temp.(ºC)	Sampling
Measured (cm)	Design (cm)				
Cement type :				Aggregates :	

Lab No.	Marking	Cube dimensions W X D X H (mm X mm X mm)	Density (g/cm^3)	Date made	Date tested	Age of cube (days)	Compressive Strength individual (Mpa)	Compressive Strength Average (Mpa)
B	C30	150 x 150 x 150	2.555	27/09/2010	25/10/2010	28	36.2	
C	C30	150 x 150 x 150	2.555	27/09/2010	25/10/2010	28	41.2	
B	C20	150 x 150 x 150	2.614	27/09/2010	25/10/2010	28	21.5	
C	C20	150 x 150 x 150	2.579	27/09/2010	25/10/2010	28	27.1	

Concrete Cube Results for Concrete Strips

MATERIALS LABORATORY SECTION

Field and Laboratory Control of Concrete Works

Contractor:	DELMONTE (T) LTD	Project:	DEMOSTRATION SITE ALONG BAGO - TALAWANDA ROAD
CLIENT:	EXECUTIVE DIRECTOR BAGAMOYO DISRICT	SITE ID:	
Job Type:	CONCRETE STRIPS	Location:	SECTION - 07
Aggregate Size (mm):	20	Multiplication Factor:	0.9923

Field Work				Laboratory Testing Work												
Mark	Casting Date	Slump	Nominal Mix	Curing Age	Testing Date	Cube Size (cm)			Nominal Grade	Cement Class	Wt. After Curing	Gross Density	Area	Ultimate Load	Corrected Load	Compressive Strength
No.		mm	Ratio	Days		L	W	H			(g)	kg/m³	Sq.mm	kN	KN	N/mm2
				(CH: 10 + 170 - 10 + 240) LHS												
	16-May-11	N/A	1:02:04	28	13-Jun-11	15	15	15	20	42.5R	8396.2	2488	22500	500	496	22.1
				(CH: 10 + 240 - 10 + 380) LHS												
	17-May-11	N/A	1:02:04	28	14-Jun-11	15	15	15	20	42.5R	8370.6	2480	22500	490	486	21.6
				(CH: 10 + 440 - 10 + 520) LHS												
	19-May-11	N/A	1:02:04	28	16-Jun-11	15	15	15	20	42.5R	8340.0	2471	22500	480	476	21.2
				(CH: 10 + 520 - 10 + 670) LHS												
	20-May-11	N/A	1:02:04	28	17-Jun-11	15	15	15	20	42.5R	8410.4	2492	22500	506	502	22.3
				(CH: 10 + 170 - 10 + 310) RHS												
	21-May-11	N/A	1:02:04	28	18-Jun-11	15	15	15	20	42.5R	8420.2	2495	22500	480	476	21.2
				(CH: 10 + 310 - 10 + 440) RHS												
	24-May-11	N/A	1:02:04	28	21-Jun-11	15	15	15	20	42.5R	8450.4	2504	22500	498	494	22.0
				(CH: 10 + 440 - 10 + 580) RHS												
	26-May-11	N/A	1:02:04	28	23-Jun-11	15	15	15	20	42.5R	8396.0	2488	22500	510	506	22.5
				(CH: 10 + 580 - 10 + 670) RHS												
	27-May-11	N/A	1:02:04	28	24-Jun-11	15	15	15	20	42.5R	8412.6	2493	22500	492	488	21.7

Field Technician

For: REGIONAL MANAGER
TANROADS
TANZANIA NATIONAL ROADS AGENCY
P. O. Box 4838,
DAR-ES-SALAAM

EMANUEL.H
Laboratory Technician

Materials Engineer/Supervisor

30/05/2011.
Date

Remarks:

TANROADS — Good roads for national development

MATERIALS LABORATORY SECTION

Field and Laboratory Control of Concrete Works

Contractor: DELMONTE (T) LTD	**Project:** DEMOSTRATION SITE ALONG BAGO - TALAWANDA ROAD	
CLIENT: EXECUTIVE DIRECTOR BAGAMOYO DISRICT	**SITE ID:**	
Job Type: CONCRETE STRIPS	**Location:** SECTION - 07	
Aggregate Size (mm): 20	**Multiplication Factor:**	0.9923

Field Work				Laboratory Testing Work												
Mark No.	Casting Date	Slump mm	Nominal Mix Ratio	Curing Age Days	Testing Date	Cube Size (cm) L	W	H	Nominal Grade	Cement Class	Wt. After Curing (g)	Gross Density kg/m^3	Area Sq.mm	Ultimate Load kN	Corrected Load KN	Compressive Strength N/mm2
				(CH: 9 + 980 - 10 + 020) LHS												
	7-May-11	N/A	1:02:04	28	04-Jun-11	15	15	15	20	42.5R	8386.2	2485	22500	480	476	21.2
				(CH: 10 + 020 - 10 + 080) LHS												
	8-May-11	N/A	1:02:04	28	05-Jun-11	15	15	15	20	42.5R	8450.6	2504	22500	502	498	22.1
				(CH: 10 + 080 - 10 + 120) LHS												
	9-May-11	N/A	1:02:04	28	06-Jun-11	15	15	15	20	42.5R	8467.4	2509	22500	506	502	22.3
				(CH: 10 + 120 - 10 + 160) LHS												
	10-May-11	N/A	1:02:04	28	07-Jun-11	15	15	15	20	42.5R	8537.8	2530	22500	510	506	22.5
				(CH: 9 + 980 - 10 + 020) RHS												
	11-May-11	N/A	1:02:04	28	08-Jun-11	15	15	15	20	42.5R	8510.4	2522	22500	500	496	22.1
				(CH: 10 + 020 - 10 + 120) RHS												
	12-May-11	N/A	1:02:04	28	09-Jun-11	15	15	15	20	42.5R	8478.2	2512	22500	496	492	21.9
				(CH: 10 + 120 - 10 + 160) RHS												
	13-May-11	N/A	1:02:04	28	10-Jun-11	15	15	15	20	42.5R	8477.8	2512	22500	494	490	21.8

Field Technician

For: REGIONAL MANAGER
TANROADS
TANZANIA NATIONAL ROADS AGENCY
P. O. Box 4838
DAR-ES-SALAAM

EMANUEL.H
Laboratory Technician

Materials Engineer/Supervisor

16/05/2011.
Date

Remarks:

7 Day Cube Test Results for Concrete Drifts

REGIONAL MANAGER OFFICE-TANROADS DAR ES SALAAM

TANROADS

MATERIALS LABORATORY SECTION

Field and Laboratory Control of Concrete Works

Contractor:	M/S DELMONTE (T) LTD	Project:	DEMONSTRATION SITE ALONG BAGO -TALAWANDA ROAD
Client:	TANROADS	CEMENT:	ORDINARY PORTILAND CEMENT 42.2R
Job Type:	DRIFT CONCRETE	Location:	(CH: 0 + 475) & (CH: 3 + 820)
Aggregate Size (mm):	20	Multiplication Factor:	0.9923

Field Work				Laboratory Testing Work													
Mark	Casting Date	Slump	Nominal Mix	Curing Age	Testing Date	Cube Size (cm)			Nominal	Cement Class	Wt. After Curing	Gross Density	Area	Ultimate Load	Corrected Load	Compressive Strength
No.		mm	Ratio	Days		L	W	H			(g)	kg/m3	Sq.cm	kN	KN	N/mm2
1	5-Jan-11	N/A	1:01:02	7	12-Jan-11	15	15	15	30	42.2R	8627.0	2556	225	630	625	27.8
2	5-Jan-11	N/A	1:01:02	7	12-Jan-11	15	15	15	30	42.2R	8495.0	2517	225	590	585	26.0
3	5-Jan-11	N/A	1:01:02	7	12-Jan-11	15	15	15	30	42.2R	8264.0	2449	225	620	615	27.3
														AVERAGE		26.9
1	6-Jan-11	N/A	1:01:02	7	13-Jan-11	15	15	15	30	42.2R	8298.0	2459	225	610	605	26.9
2	6-Jan-11	N/A	1:01:02	7	13-Jan-11	15	15	15	30	42.2R	8240.0	2441	225	600	595	26.5
3	6-Jan-11	N/A	1:01:02	7	13-Jan-11	15	15	15	30	42.2R	8347.0	2473	225	580	576	25.6
														AVERAGE		26.7

Field Technician

ADAM MAPALA
Laboratory Technician

DBR.CE. Eng. E. Mlay
Materials Engineer/Supervisor

13/01/2011
Date

Remarks:

For: REGIONAL MANAGER
TANROADS
TANZANIA NATIONAL ROADS AGENCY
P. O. Box 4836
DAR-ES-SALAAM

REGIONAL MANAGER OFFICE-TANROADS DAR ES SALAAM

TANROADS

MATERIALS LABORATORY SECTION

Field and Laboratory Control of Concrete Works

Contractor:	M/S DELMONTE (T) LTD	Project:	DEMONSTRATION SITE ALONG BAGO -TALAWANDA ROAD
Client:	TANROADS	CEMENT:	ORDINARY PORTLAND CEMENT 42.2R
Job Type:	DRIFT CONCRETE	Location:	(CH: 9 + 310) & (CH: 9 + 570)
Aggregate Size (mm):	20	Multiplication Factor:	0.9923

Field Work				Laboratory Testing Work												
Mark	Casting Date	Slump	Nominal Mix	Curing Age	Testing Date	Cube Size (cm)			Nominal	Cement Class	Wt. After Curing	Gross Density	Area	Ultimate Load	Corrected Load	Compressive Strength
						L	W	H								
No.		mm	Ratio	Days							(g)	kg/m3	Sq.cm	kN	KN	N/mm2
1	10-Jan-11	N/A	1:01:02	7	17-Jan-11	15	15	15	30	42.2R	8468.4	2509	225	580	576	25.6
2	10-Jan-11	N/A	1:01:02	7	17-Jan-11	15	15	15	30	42.2R	8416.0	2494	225	590	585	26.0
3	10-Jan-11	N/A	1:01:02	7	17-Jan-11	15	15	15	30	42.2R	8511.8	2522	225	570	566	25.1
														AVERAGE		25.8
1	11-Jan-11	N/A	1:01:02	7	18-Jan-11	15	15	15	30	42.2R	8312.6	2463	225	590	585	26.0
2	11-Jan-11	N/A	1:01:02	7	18-Jan-11	15	15	15	30	42.2R	8520.2	2525	225	570	566	25.1
3	11-Jan-11	N/A	1:01:02	7	18-Jan-11	15	15	15	30	42.2R	8512.4	2522	225	580	576	25.6
														AVERAGE		25.6

Field Technician

ADAM MAPALA
Laboratory Technician

Materials Engineer/Supervisor

18/01/11
Date

Remarks:

For: REGIONAL MANAGER
TANROADS
TANZANIA NATIONAL ROADS AGENCY
P. O. Box 4838
DAR-ES-SALAAM

REGIONAL MANAGER OFFICE-TANROADS DAR ES SALA

MATERIALS LABORATORY SECTION

Field and Laboratory Control of Concrete Works

Contractor:	M/S DELMONTE (T) LTD	Project:	DEMONSTRATION SITE ALONG BAGO -TALAWANDA ROAD
Client:	TANROADS	CEMENT:	ORDINARY PORTLAND CEMENT 42.2R
Job Type:	DRIFT CONCRETE	Location:	(CH: 15 + 640)
Aggregate Size (mm):	20	Multiplication Factor:	0.9923

Field Work				Laboratory Testing Work												
Mark	Casting Date	Slump	Nominal Mix	Curing Age	Testing Date	Cube Size (cm)			Nominal	Cement Class	Wt. After Curing	Gross Density	Area	Ultimate Load	Corrected Load	Compressive Strength
No.		mm	Ratio	Days		L	W	H			(g)	kg/m3	Sq.cm	kN	KN	N/mm2
1	13-Jan-11	N/A	1:01:02	7	20-Jan-11	15	15	15	30	42.2R	8626.0	2556	225	580	576	25.6
2	13-Jan-11	N/A	1:01:02	7	20-Jan-11	15	15	15	30	42.2R	8594.6	2547	225	600	595	26.5
3	13-Jan-11	N/A	1:01:02	7	20-Jan-11	15	15	15	30	42.2R	8585.4	2544	225	590	585	26.0
														AVERAGE		26.0

....
Field Technician

ADAM MAPALA
Laboratory Technician

Materials Engineer/Supervisor

20/01/2011
Date

Remarks:

For: REGIONAL MANAGER
TANROADS
TANZANIA NATIONAL ROADS AGENCY
P. O. Box 4638
DAR-ES-SALAAM

28 Day Cube Results for Concrete Drifts

REGIONAL MANAGER OFFICE-TANROADS DAR ES SALAAM

Good roads for national development

MATERIALS LABORATORY SECTION

Field and Laboratory Control of Concrete Works

Contractor:	M/S DELMONTE (T) LTD	**Project:**	DEMONSTRATION SITE ALONG BAGO -TALAWANDA ROAD
Client:	EXECUTIVE DIRECTOR BAGAMOYO DISRICT	**CEMENT:**	ORDINARY PORTILAND CEMENT **42.2R**
Job Type:	DRIFT CONCRETE	**Location:**	(CH: 5 + 540)
Aggregate Size (mm):	20	**Multiplication Factor:**	0.9923

Field Work				Laboratory Testing Work											
Mark	Casting Date	Slump	Nominal Mix	Curing Age	Testing Date	Cube Size (cm)			Nominal	Cement Class	Wt. After Curing	Gross Density	Area	Ultimate Load	Corrected Load	Compressive Strength
No.		mm	Ratio	Days		L	W	H			(g)	kg/m3	Sq.cm	kN	KN	N/mm2
1	30-May-11	N/A	1:01:02	28	27-Jun-11	15	15	15	30	42.2R	8490.2	2516	225	730	724	32.2
2	30-May-11	N/A	1:01:02	28	27-Jun-11	15	15	15	30	42.2R	8468.8	2509	225	740	734	32.6
3	30-May-11	N/A	1:01:02	28	27-Jun-11	15	15	15	30	42.2R	8512.6	2522	225	720	714	31.8
														AVERAGE		32.2

Field Technician

EMANUEL .H
Laboratory Technician

For: REGIONAL MANAGER
TANROADS
TANZANIA NATIONAL ROADS AGENCY
P. O. Box 4838
DAR-ES-SALAAM

Materials Engineer/Supervisor

28/06/2011.
Date

REGIONAL MANAGER OFFICE-TANROADS DAR ES SALAAM

MATERIALS LABORATORY SECTION

Field and Laboratory Control of Concrete Works

Contractor:	M/S DELMONTE (T) LTD	Project:	DEMONSTRATION SITE ALONG BAGO -TALAWANDA ROAD
Client:	EXECUTIVE DIRECTOR BAGAMOYO DISRICT	CEMENT:	ORDINARY PORTLAND CEMENT 42.2R
Job Type:	DRIFT CONCRETE	Location:	(CH: 15 + 095)
Aggregate Size (mm):	20	Multiplication Factor:	0.9923

Field Work				Laboratory Testing Work												
Mark	Casting Date	Slump	Nominal Mix	Curing Age	Testing Date	Cube Size (cm)			Nominal	Cement Class	Wt. After Curing	Gross Density	Area	Ultimate Load	Corrected Load	Compressive Strength
No.		mm	Ratio	Days		L	W	H			(g)	kg/m3	Sq.cm	kN	KN	N/mm2
1	13-Jan-11	N/A	1:01:02	28	10-Feb-11	15	15	15	30	42.2R	8452.4	2504	225	685	680	30.2
2	13-Jan-11	N/A	1:01:02	28	10-Feb-11	15	15	15	30	42.2R	8619.0	2554	225	705	700	31.1
3	13-Jan-11	N/A	1:01:02	28	10-Feb-11	15	15	15	30	42.2R	8463.2	2508	225	690	685	30.4
														AVERAGE		30.7

Field Technician

ADAM MAPALA
Laboratory Technician

Materials Engineer/Supervisor

Date

Remarks:

REGIONAL MANAGER OFFICE-TANROADS DAR ES SALAAM

MATERIALS LABORATORY SECTION

Field and Laboratory Control of Concrete Works

Contractor:	M/S DELMONTE (T) LTD	Project:	DEMONSTRATION SITE ALONG BAGO -TALAWANDA ROAD
Client:	EXECUTIVE DIRECTOR BAGAMOYO DISRICT	CEMENT:	ORDINARY PORTILAND CEMENT 42.2R
Job Type:	DRIFT CONCRETE	Location:	(CH: 8 + 940)
Aggregate Size (mm):	20	Multiplication Factor:	0.9923

Field Work				Laboratory Testing Work												
Mark	Casting Date	Slump	Nominal Mix	Curing Age	Testing Date	Cube Size (cm)			Nominal	Cement Class	Wt. After Curing	Gross Density	Area	Ultimate Load	Corrected Load	Compressive Strength
No.		mm	Ratio	Days		L	W	H			(g)	kg/m3	Sq.cm	kN	KN	N/mm2
1	21-Jan-11	N/A	1:01:02	28	18-Feb-11	15	15	15	30	42.2R	8512.6	2522	225	690	685	30.4
2	21-Jan-11	N/A	1:01:02	28	18-Feb-11	15	15	15	30	42.2R	8602.0	2549	225	710	705	31.3
3	21-Jan-11	N/A	1:01:02	28	18-Feb-11	15	15	15	30	42.2R	8420.7	2495	225	695	690	30.7
														AVERAGE		30.9

Field Technician

ADAM MAPALA
Laboratory Technician

Materials Engineer/Supervisor

Date

Remarks:

For REGIONAL MANAGER TANROADS P.O. BOX DAR-ES-SALAAM

REGIONAL MANAGER OFFICE-TANROADS DAR ES SALA

TANROADS

MATERIALS LABORATORY SECTION

Field and Laboratory Control of Concrete Works

Contractor:	M/S DELMONTE (T) LTD	Project:	DEMONSTRATION SITE ALONG BAGO -TALAWANDA ROAD
Client:	EXECUTIVE DIRECTOR BAGAMOYO DISRICT	CEMENT:	ORDINARY PORTLAND CEMENT 42.2R
Job Type:	DRIFT CONCRETE	Location:	(CH: 8 + 580)
Aggregate Size (mm):	20	Multiplication Factor:	0.9923

Field Work				Laboratory Testing Work												
Mark	Casting Date	Slump	Nominal Mix	Curing Age	Testing Date	Cube Size (cm)			Nominal	Cement Class	Wt. After Curing	Gross Density	Area	Ultimate Load	Corrected Load	Compressive Strength
No.		mm	Ratio	Days		L	W	H			(g)	kg/m3	Sq.cm	kN	KN	N/mm2
1	26-Feb-11	N/A	1:01:02	28	26-Mar-11	15	15	15	30	42.2R	8412.4	2493	225	850	843	37.5
2	26-Feb-11	N/A	1:01:02	28	26-Mar-11	15	15	15	30	42.2R	8326.4	2467	225	642	637	28.3
3	26-Feb-11	N/A	1:01:02	28	26-Mar-11	15	15	15	30	42.2R	7730.8	2291	225	810	804	35.7
														AVERAGE		32.9

Field Technician

FAUSTINE
Laboratory Technician

Eng. F. Mlay
Materials Engineer/Supervisor

26/03/2011
Date

Remarks: Passed.

For: REGIONAL MANAGER
TANROADS
TANZANIA NATIONAL ROADS AGENCY
P. O. Box 4838
DAR-ES-SALAAM

REGIONAL MANAGER OFFICE-TANROADS DAR ES SAL

MATERIALS LABORATORY SECTION

Field and Laboratory Control of Concrete Works

Contractor:	M/S DELMONTE (T) LTD
Client:	EXECUTIVE DIRECTOR BAGAMOYO DISRICT
Job Type:	DRIFT CONCRETE
Aggregate Size (mm):	20
Project:	DEMONSTRATION SITE ALONG BAGO -TALAWANDA ROAD
CEMENT:	ORDINARY PORTILAND CEMENT 42.2R
Location:	(CH: 8 + 660)
Multiplication Factor:	0.9923

Field Work				Laboratory Testing Work												
Mark	Casting Date	Slump	Nominal Mix	Curing Age	Testing Date	Cube Size (cm)			Nominal	Cement Class	Wt. After Curing	Gross Density	Area	Ultimate Load	Corrected Load	Compressive Strength
No.		mm	Ratio	Days		L	W	H			(g)	kg/m3	Sq.cm	kN	KN	N/mm2
1	25-Feb-11	N/A	1:01:02	28	25-Mar-11	15	15	15	30	42.2R	8656.4	2565	225	794	788	35.0
2	25-Feb-11	N/A	1:01:02	28	25-Mar-11	15	15	15	30	42.2R	8641.8	2561	225	802	796	35.4
3	25-Feb-11	N/A	1:01:02	28	25-Mar-11	15	15	15	30	42.2R	8611.8	2552	225	882	875	38.9
														AVERAGE		35.2

Field Technician

ADAM MAPALA / FAUSTINE
Laboratory Technician

Eng. F. Mlay
Materials Engineer/Supervisor

25/03/2011
Date

Remarks:

For: REGIONAL MANAGER
TANROADS
TANZANIA NATIONAL ROADS AGENCY
P. O. Box 4838
DAR-ES-SALAAM

REGIONAL MANAGER OFFICE-TANROADS DAR ES SA AM

Tanzania National Roads Agency — TANROADS — Good roads for national development

MATERIALS LABORATORY SECTION

Field and Laboratory Control of Concrete Works

Contractor:	M/S DELMONTE (T) LTD	Project:	DEMONSTRATION SITE ALONG BAGO -TALAWANDA ROAD
Client:	EXECUTIVE DIRECTOR BAGAMOYO DISRICT	CEMENT:	ORDINARY PORTILAND CEMENT 42.2R
Job Type:	DRIFT CONCRETE	Location:	~~(CH. 8 + 580)~~ CH: 10+170
Aggregate Size (mm):	20	Multiplication Factor:	0.9923

Field Work				Laboratory Testing Work												
Mark No.	Casting Date	Slump mm	Nominal Mix Ratio	Curing Age Days	Testing Date	Cube Size (cm) L	W	H	Nominal	Cement Class	Wt. After Curing (g)	Gross Density kg/m3	Area Sq.cm	Ultimate Load kN	Corrected Load KN	Compressive Strength N/mm2
1	3-Mar-11	N/A	1:01:02	28	31-Mar-11	15	15	15	30	42.2R	0.6	0	225	760	754	33.5
2	3-Mar-11	N/A	1:01:02	28	31-Mar-11	15	15	15	30	42.2R	8458.4	2506	225	750	744	33.1
3	3-Mar-11	N/A	1:01:02	28	31-Mar-11	16	15	15	30	42.2R	8521.0	2525	225	700	695	30.9
														AVERAGE		33.3

Field Technician

FAUSTINE
Laboratory Technician

Eng. E. Mlay
Materials Engineer/Supervisor

31/04/2011
Date

Remarks:

For REGIONAL MANAGER
TANROADS
TANZANIA NATIONAL ROADS AGENCY
P. O. Box 4830
DAR-ES-SALAAM

APPENDIX D – WHOLE LIFE ECONOMIC ANALYSIS DATA

Without Project Alternative (Gravel Wearing Course) Annual Data

Year	Road Work Costs (M$)			Road User Costs (M$)	Total Society Costs (M$)	CO_2 Emissions (tons)
	Capital Costs	Recurrent Costs	Total Costs			
1	0.020	0.004	0.024	0.031	0.055	22.040
2	0.000	0.004	0.004	0.034	0.037	23.609
3	0.000	0.004	0.004	0.036	0.040	25.302
4	0.000	0.004	0.004	0.039	0.043	27.035
5	0.000	0.004	0.004	0.042	0.046	28.737
6	0.000	0.004	0.004	0.046	0.050	30.579
7	0.000	0.004	0.004	0.050	0.054	32.505
8	0.000	0.004	0.004	0.055	0.059	34.868
9	0.000	0.004	0.004	0.063	0.067	38.475
10	0.000	0.013	0.013	0.054	0.068	37.399
11	0.000	0.004	0.004	0.058	0.062	39.522
12	0.000	0.004	0.004	0.064	0.067	42.331
13	0.000	0.004	0.004	0.069	0.073	45.026
14	0.000	0.004	0.004	0.077	0.080	48.283
15	0.000	0.004	0.004	0.085	0.089	52.337
16	0.000	0.004	0.004	0.095	0.099	57.493
17	0.000	0.004	0.004	0.108	0.112	64.205
18	0.000	0.013	0.013	0.092	0.105	59.184
19	0.000	0.004	0.004	0.099	0.103	62.961
20	0.000	0.004	0.004	0.109	0.113	68.061
Salvage			-0.008		-0.008	
Total	0.020	0.094	0.106	1.308	1.414	839.952
PV 6%	0.020	0.055	0.072	0.701	0.773	
PV 10%	0.020	0.041	0.060	0.500	0.559	

Otta Seal with Sand Seal Annual Data

Year	Road Work Costs (M$)			Road User Costs (M$)	Total Society Costs (M$)	CO_2 Emissions (tons)
	Capital Costs	Recurrent Costs	Total Costs			
1	0.096	0.000	0.096	0.028	0.124	19.265
2	0.000	0.000	0.000	0.030	0.030	20.344
3	0.000	0.000	0.000	0.031	0.031	21.495
4	0.000	0.000	0.000	0.033	0.033	22.719
5	0.000	0.000	0.000	0.035	0.035	24.024
6	0.000	0.000	0.000	0.038	0.038	25.486
7	0.000	0.000	0.000	0.041	0.041	27.013
8	0.000	0.013	0.013	0.041	0.054	28.265
9	0.000	0.000	0.000	0.044	0.044	29.909
10	0.000	0.000	0.000	0.047	0.047	31.681
11	0.000	0.000	0.000	0.052	0.052	33.573
12	0.000	0.013	0.013	0.052	0.065	35.243
13	0.000	0.000	0.000	0.056	0.056	37.280
14	0.000	0.000	0.000	0.060	0.060	39.495
15	0.000	0.000	0.000	0.066	0.066	41.704
16	0.000	0.013	0.013	0.067	0.079	43.985
17	0.000	0.000	0.000	0.071	0.071	46.504
18	0.000	0.000	0.000	0.076	0.076	49.152
19	0.000	0.000	0.000	0.082	0.082	51.852
20	0.000	0.013	0.013	0.090	0.102	53.805
Salvage			-0.048		-0.048	
Total	0.096	0.051	0.146	1.041	1.187	682.795
PV 6%	0.096	0.025	0.120	0.564	0.684	
PV 10%	0.096	0.016	0.105	0.405	0.510	

Comparison between Otta Seal with Sand Seal and GWC

Year	Road Work Costs Decrease (M$)			Road User Costs Decrease (M$)	Total Society Costs Decrease (M$)	CO2 Emissions Decrease (tons)
	Capital Costs	Recurrent Costs	Total Costs			
1	-0.076	0.004	-0.072	0.003	-0.069	2.776
2	0.000	0.004	0.004	0.004	0.008	3.266
3	0.000	0.004	0.004	0.005	0.009	3.807
4	0.000	0.004	0.004	0.006	0.010	4.316
5	0.000	0.004	0.004	0.007	0.011	4.713
6	0.000	0.004	0.004	0.008	0.012	5.093
7	0.000	0.004	0.004	0.009	0.013	5.492
8	0.000	-0.009	-0.009	0.014	0.005	6.603
9	0.000	0.004	0.004	0.019	0.023	8.566
10	0.000	0.013	0.013	0.007	0.020	5.718
11	0.000	0.004	0.004	0.007	0.011	5.949
12	0.000	-0.009	-0.009	0.011	0.002	7.087
13	0.000	0.004	0.004	0.014	0.017	7.746
14	0.000	0.004	0.004	0.016	0.020	8.788
15	0.000	0.004	0.004	0.019	0.023	10.633
16	0.000	-0.009	-0.009	0.029	0.020	13.508
17	0.000	0.004	0.004	0.037	0.041	17.702
18	0.000	0.013	0.013	0.015	0.029	10.031
19	0.000	0.004	0.004	0.017	0.021	11.109
20	0.000	-0.009	-0.009	0.019	0.011	14.256
Salvage	0.000	0.000	0.040	0.000	0.040	0.000
Net Present Value (M$) at			6%		0.104	
			10%		0.049	
Internal Rate of Return (%)					17.1%	
Emissions Decrease (tons)						157.2

Hand Packed Stone Annual Data

Year	Road Work Costs (M$)			Road User Costs (M$)	Total Society Costs (M$)	CO_2 Emissions (tons)
	Capital Costs	Recurrent Costs	Total Costs			
1	0.077	0.000	0.077	0.032	0.109	19.476
2	0.000	0.000	0.000	0.034	0.034	20.516
3	0.000	0.000	0.000	0.036	0.036	21.583
4	0.000	0.000	0.000	0.039	0.039	22.521
5	0.000	0.004	0.004	0.040	0.044	24.218
6	0.000	0.000	0.000	0.043	0.043	25.520
7	0.000	0.000	0.000	0.046	0.046	26.873
8	0.000	0.000	0.000	0.049	0.049	28.293
9	0.000	0.000	0.000	0.053	0.053	29.834
10	0.000	0.004	0.004	0.053	0.057	31.816
11	0.000	0.000	0.000	0.057	0.057	33.810
12	0.000	0.000	0.000	0.061	0.061	35.320
13	0.000	0.000	0.000	0.065	0.065	37.254
14	0.000	0.000	0.000	0.071	0.071	39.432
15	0.000	0.004	0.004	0.071	0.075	42.207
16	0.000	0.000	0.000	0.076	0.076	44.860
17	0.000	0.000	0.000	0.082	0.082	47.658
18	0.000	0.000	0.000	0.089	0.089	50.369
19	0.000	0.000	0.000	0.097	0.097	53.501
20	0.000	0.004	0.004	0.108	0.112	57.855
Salvage			-0.031		-0.031	
Total	0.077	0.016	0.062	1.201	1.263	692.916
PV 6%	0.077	0.009	0.076	0.650	0.726	
PV 10%	0.077	0.006	0.079	0.466	0.545	

Comparison between Hand Packed Stone and GWC

Year	Road Work Costs Decrease (M$)			Road User Costs Decrease (M$)	Total Society Costs Decrease (M$)	CO_2 Emissions Decrease (tons)
	Capital Costs	Recurrent Costs	Total Costs			
1	-0.057	0.004	-0.053	-0.001	-0.054	2.564
2	0.000	0.004	0.004	0.000	0.003	3.093
3	0.000	0.004	0.004	0.000	0.004	3.720
4	0.000	0.004	0.004	0.000	0.004	4.514
5	0.000	0.000	0.000	0.002	0.002	4.519
6	0.000	0.004	0.004	0.003	0.007	5.059
7	0.000	0.004	0.004	0.004	0.008	5.632
8	0.000	0.004	0.004	0.006	0.010	6.574
9	0.000	0.004	0.004	0.010	0.014	8.641
10	0.000	0.009	0.009	0.001	0.010	5.583
11	0.000	0.004	0.004	0.002	0.005	5.712
12	0.000	0.004	0.004	0.003	0.007	7.010
13	0.000	0.004	0.004	0.004	0.008	7.772
14	0.000	0.004	0.004	0.006	0.009	8.851
15	0.000	0.000	0.000	0.014	0.014	10.130
16	0.000	0.004	0.004	0.020	0.024	12.632
17	0.000	0.004	0.004	0.027	0.030	16.547
18	0.000	0.013	0.013	0.003	0.016	8.815
19	0.000	0.004	0.004	0.002	0.006	9.460
20	0.000	0.000	0.000	0.001	0.001	10.206
Salvage	0.000	0.000	0.023	0.000	0.023	0.000
Net Present Value (M$) at			6%		0.048	
			10%		0.014	
Internal Rate of Return (%)					12.7%	
Emissions Decrease (tons)						147.0

Concrete Strips Reinforced Annual Data

Year	Road Work Costs (M$)			Road User Costs (M$)	Total Society Costs (M$)	CO_2 Emissions (tons)
	Capital Costs	Recurrent Costs	Total Costs			
1	0.077	0.000	0.077	0.029	0.106	19.541
2	0.000	0.000	0.000	0.031	0.031	20.667
3	0.000	0.000	0.000	0.033	0.033	21.863
4	0.000	0.000	0.000	0.035	0.035	23.174
5	0.000	0.004	0.004	0.036	0.040	24.382
6	0.000	0.000	0.000	0.039	0.039	25.819
7	0.000	0.000	0.000	0.041	0.041	27.350
8	0.000	0.000	0.000	0.044	0.044	29.096
9	0.000	0.000	0.000	0.047	0.047	30.864
10	0.000	0.004	0.004	0.049	0.053	32.636
11	0.000	0.000	0.000	0.052	0.052	34.619
12	0.000	0.000	0.000	0.055	0.055	36.709
13	0.000	0.000	0.000	0.059	0.059	38.918
14	0.000	0.000	0.000	0.064	0.064	41.166
15	0.000	0.004	0.004	0.065	0.069	43.694
16	0.000	0.000	0.000	0.069	0.069	46.336
17	0.000	0.000	0.000	0.074	0.074	49.128
18	0.000	0.000	0.000	0.080	0.080	52.038
19	0.000	0.000	0.000	0.085	0.085	54.701
20	0.000	0.004	0.004	0.093	0.097	57.290
Salvage			-0.039		-0.039	
Total	0.077	0.016	0.055	1.082	1.136	709.990
PV 6%	0.077	0.009	0.074	0.586	0.660	
PV 10%	0.077	0.006	0.077	0.421	0.499	

Comparison between Concrete Strips Reinforced and GWC

Year	Road Work Costs Decrease (M$)			Road User Costs Decrease (M$)	Total Society Costs Decrease (M$)	CO_2 Emissions Decrease (tons)
	Capital Costs	Recurrent Costs	Total Costs			
1	-0.057	0.004	-0.053	0.002	-0.051	2.500
2	0.000	0.004	0.004	0.003	0.007	2.942
3	0.000	0.004	0.004	0.004	0.007	3.440
4	0.000	0.004	0.004	0.004	0.008	3.861
5	0.000	0.000	0.000	0.006	0.006	4.354
6	0.000	0.004	0.004	0.007	0.011	4.760
7	0.000	0.004	0.004	0.009	0.013	5.155
8	0.000	0.004	0.004	0.011	0.015	5.772
9	0.000	0.004	0.004	0.016	0.019	7.611
10	0.000	0.009	0.009	0.006	0.015	4.763
11	0.000	0.004	0.004	0.006	0.010	4.903
12	0.000	0.004	0.004	0.008	0.012	5.621
13	0.000	0.004	0.004	0.010	0.014	6.108
14	0.000	0.004	0.004	0.012	0.016	7.117
15	0.000	0.000	0.000	0.020	0.020	8.643
16	0.000	0.004	0.004	0.026	0.030	11.157
17	0.000	0.004	0.004	0.034	0.038	15.077
18	0.000	0.013	0.013	0.012	0.025	7.146
19	0.000	0.004	0.004	0.014	0.018	8.260
20	0.000	0.000	0.000	0.016	0.016	10.772
Salvage	0.000	0.000	0.031	0.000	0.031	0.000
Net Present Value (M$) at			6%		0.113	
			10%		0.060	
Internal Rate of Return (%)					20.5%	
Emissions Decrease (tons)						130.0

Concrete Strips Unreinforced Annual Data

Year	Road Work Costs (M$)			Road User Costs (M$)	Total Society Costs (M$)	CO_2 Emissions (tons)
	Capital Costs	Recurrent Costs	Total Costs			
1	0.063	0.000	0.063	0.029	0.092	19.541
2	0.000	0.000	0.000	0.031	0.031	20.667
3	0.000	0.000	0.000	0.033	0.033	21.863
4	0.000	0.000	0.000	0.035	0.035	23.174
5	0.000	0.003	0.003	0.036	0.039	24.382
6	0.000	0.000	0.000	0.039	0.039	25.819
7	0.000	0.000	0.000	0.041	0.041	27.350
8	0.000	0.000	0.000	0.044	0.044	29.096
9	0.000	0.000	0.000	0.047	0.047	30.864
10	0.000	0.003	0.003	0.049	0.051	32.636
11	0.000	0.000	0.000	0.052	0.052	34.619
12	0.000	0.000	0.000	0.055	0.055	36.709
13	0.000	0.000	0.000	0.059	0.059	38.918
14	0.000	0.000	0.000	0.064	0.064	41.166
15	0.000	0.003	0.003	0.065	0.068	43.694
16	0.000	0.000	0.000	0.069	0.069	46.336
17	0.000	0.000	0.000	0.074	0.074	49.128
18	0.000	0.000	0.000	0.080	0.080	52.038
19	0.000	0.000	0.000	0.085	0.085	54.701
20	0.000	0.003	0.003	0.093	0.096	57.290
Salvage			-0.031		-0.031	
Total	0.063	0.011	0.042	1.082	1.124	709.990
PV 6%	0.063	0.006	0.059	0.586	0.645	
PV 10%	0.063	0.004	0.062	0.421	0.484	

Comparison between Concrete Strips Unreinforced and GWC

Year	Road Work Costs Decrease (M$)			Road User Costs Decrease (M$)	Total Society Costs Decrease (M$)	CO_2 Emissions Decrease (tons)
	Capital Costs	Recurrent Costs	Total Costs			
1	-0.043	0.004	-0.039	0.002	-0.037	2.500
2	0.000	0.004	0.004	0.003	0.007	2.942
3	0.000	0.004	0.004	0.004	0.007	3.440
4	0.000	0.004	0.004	0.004	0.008	3.861
5	0.000	0.001	0.001	0.006	0.007	4.354
6	0.000	0.004	0.004	0.007	0.011	4.760
7	0.000	0.004	0.004	0.009	0.013	5.155
8	0.000	0.004	0.004	0.011	0.015	5.772
9	0.000	0.004	0.004	0.016	0.019	7.611
10	0.000	0.011	0.011	0.006	0.016	4.763
11	0.000	0.004	0.004	0.006	0.010	4.903
12	0.000	0.004	0.004	0.008	0.012	5.621
13	0.000	0.004	0.004	0.010	0.014	6.108
14	0.000	0.004	0.004	0.012	0.016	7.117
15	0.000	0.001	0.001	0.020	0.021	8.643
16	0.000	0.004	0.004	0.026	0.030	11.157
17	0.000	0.004	0.004	0.034	0.038	15.077
18	0.000	0.013	0.013	0.012	0.025	7.146
19	0.000	0.004	0.004	0.014	0.018	8.260
20	0.000	0.001	0.001	0.016	0.017	10.772
Salvage	0.000	0.000	0.024	0.000	0.024	0.000
Net Present Value (M$) at			6%		0.128	
			10%		0.076	
Internal Rate of Return (%)					26.8%	
Emissions Decrease (tons)						130.0

Concrete Geocells Annual Data

Year	Road Work Costs (M$)			Road User Costs (M$)	Total Society Costs (M$)	CO_2 Emissions (tons)
	Capital Costs	Recurrent Costs	Total Costs			
1	0.075	0.000	0.075	0.029	0.104	19.541
2	0.000	0.000	0.000	0.031	0.031	20.667
3	0.000	0.000	0.000	0.033	0.033	21.863
4	0.000	0.000	0.000	0.035	0.035	23.174
5	0.000	0.003	0.003	0.036	0.040	24.382
6	0.000	0.000	0.000	0.039	0.039	25.819
7	0.000	0.000	0.000	0.041	0.041	27.350
8	0.000	0.000	0.000	0.044	0.044	29.096
9	0.000	0.000	0.000	0.047	0.047	30.864
10	0.000	0.003	0.003	0.049	0.052	32.636
11	0.000	0.000	0.000	0.052	0.052	34.619
12	0.000	0.000	0.000	0.055	0.055	36.709
13	0.000	0.000	0.000	0.059	0.059	38.918
14	0.000	0.000	0.000	0.064	0.064	41.166
15	0.000	0.003	0.003	0.065	0.068	43.694
16	0.000	0.000	0.000	0.069	0.069	46.336
17	0.000	0.000	0.000	0.074	0.074	49.128
18	0.000	0.000	0.000	0.080	0.080	52.038
19	0.000	0.000	0.000	0.085	0.085	54.701
20	0.000	0.003	0.003	0.093	0.096	57.290
Salvage			-0.030		-0.030	
Total	0.075	0.013	0.058	1.082	1.140	709.990
PV 6%	0.075	0.007	0.073	0.586	0.659	
PV 10%	0.075	0.005	0.076	0.421	0.497	

Comparison between Concrete Geocells and GWC

Year	Road Work Costs Decrease (M$)			Road User Costs Decrease (M$)	Total Society Costs Decrease (M$)	CO_2 Emissions Decrease (tons)
	Capital Costs	Recurrent Costs	Total Costs			
1	-0.055	0.004	-0.052	0.002	-0.049	2.500
2	0.000	0.004	0.004	0.003	0.007	2.942
3	0.000	0.004	0.004	0.004	0.007	3.440
4	0.000	0.004	0.004	0.004	0.008	3.861
5	0.000	0.000	0.000	0.006	0.006	4.354
6	0.000	0.004	0.004	0.007	0.011	4.760
7	0.000	0.004	0.004	0.009	0.013	5.155
8	0.000	0.004	0.004	0.011	0.015	5.772
9	0.000	0.004	0.004	0.016	0.019	7.611
10	0.000	0.010	0.010	0.006	0.016	4.763
11	0.000	0.004	0.004	0.006	0.010	4.903
12	0.000	0.004	0.004	0.008	0.012	5.621
13	0.000	0.004	0.004	0.010	0.014	6.108
14	0.000	0.004	0.004	0.012	0.016	7.117
15	0.000	0.000	0.000	0.020	0.021	8.643
16	0.000	0.004	0.004	0.026	0.030	11.157
17	0.000	0.004	0.004	0.034	0.038	15.077
18	0.000	0.013	0.013	0.012	0.025	7.146
19	0.000	0.004	0.004	0.014	0.018	8.260
20	0.000	0.000	0.000	0.016	0.017	10.772
Salvage	0.000	0.000	0.022	0.000	0.022	0.000
Net Present Value (M$) at			6%		0.114	
			10%		0.062	
Internal Rate of Return (%)					21.3%	
Emissions Decrease (tons)						130.0

Double Surface Dressing Annual Data

Year	Road Work Costs (M$)			Road User Costs (M$)	Total Society Costs (M$)	CO_2 Emissions (tons)
	Capital Costs	Recurrent Costs	Total Costs			
1	0.109	0.000	0.109	0.030	0.139	19.603
2	0.000	0.000	0.000	0.031	0.031	20.725
3	0.000	0.000	0.000	0.033	0.033	21.917
4	0.000	0.000	0.000	0.035	0.035	23.199
5	0.000	0.000	0.000	0.038	0.038	24.515
6	0.000	0.013	0.013	0.039	0.052	25.856
7	0.000	0.000	0.000	0.041	0.041	27.380
8	0.000	0.000	0.000	0.045	0.045	29.126
9	0.000	0.000	0.000	0.048	0.048	30.865
10	0.000	0.000	0.000	0.052	0.052	32.438
11	0.000	0.000	0.000	0.054	0.054	34.642
12	0.000	0.013	0.013	0.057	0.070	36.686
13	0.000	0.000	0.000	0.061	0.061	38.577
14	0.000	0.000	0.000	0.066	0.066	40.540
15	0.000	0.000	0.000	0.071	0.071	42.778
16	0.000	0.000	0.000	0.073	0.073	45.534
17	0.000	0.000	0.000	0.078	0.078	48.147
18	0.000	0.013	0.013	0.084	0.097	50.396
19	0.000	0.000	0.000	0.091	0.091	53.320
20	0.000	0.000	0.000	0.099	0.099	56.189
Salvage			-0.055		-0.055	
Total	0.109	0.038	0.093	1.126	1.219	702.431
PV 6%	0.109	0.021	0.113	0.607	0.720	
PV 10%	0.109	0.015	0.116	0.434	0.550	

Comparison between Double Surface Dressing and GWC

Year	Road Work Costs Decrease (M$)			Road User Costs Decrease (M$)	Total Society Costs Decrease (M$)	CO_2 Emissions Decrease (tons)
	Capital Costs	Recurrent Costs	Total Costs			
1	-0.090	0.004	-0.086	0.002	-0.084	2.438
2	0.000	0.004	0.004	0.002	0.006	2.885
3	0.000	0.004	0.004	0.003	0.007	3.385
4	0.000	0.004	0.004	0.004	0.008	3.836
5	0.000	0.004	0.004	0.005	0.008	4.222
6	0.000	-0.009	-0.009	0.007	-0.002	4.724
7	0.000	0.004	0.004	0.008	0.012	5.125
8	0.000	0.004	0.004	0.011	0.014	5.742
9	0.000	0.004	0.004	0.015	0.019	7.610
10	0.000	0.013	0.013	0.003	0.016	4.961
11	0.000	0.004	0.004	0.005	0.008	4.880
12	0.000	-0.009	-0.009	0.006	-0.002	5.644
13	0.000	0.004	0.004	0.008	0.012	6.449
14	0.000	0.004	0.004	0.011	0.015	7.743
15	0.000	0.004	0.004	0.014	0.018	9.559
16	0.000	0.004	0.004	0.022	0.026	11.958
17	0.000	0.004	0.004	0.030	0.034	16.058
18	0.000	0.001	0.001	0.007	0.008	8.788
19	0.000	0.004	0.004	0.008	0.012	9.642
20	0.000	0.004	0.004	0.010	0.014	11.873
Salvage	0.000	0.000	0.047	0.000	0.047	0.000
Net Present Value (M$) at			6%		0.054	
			10%		0.009	
Internal Rate of Return (%)					11.2%	
Emissions Decrease (tons)						137.5

Double Sand Seal Annual Data

Year	Road Work Costs (M$)			Road User Costs (M$)	Total Society Costs (M$)	CO_2 Emissions (tons)
	Capital Costs	Recurrent Costs	Total Costs			
1	0.089	0.000	0.089	0.028	0.117	19.315
2	0.000	0.000	0.000	0.030	0.030	20.436
3	0.000	0.000	0.000	0.032	0.032	21.659
4	0.000	0.000	0.000	0.034	0.034	22.973
5	0.000	0.000	0.000	0.036	0.036	24.355
6	0.000	0.013	0.013	0.037	0.051	25.650
7	0.000	0.000	0.000	0.040	0.040	27.207
8	0.000	0.000	0.000	0.043	0.043	29.005
9	0.000	0.000	0.000	0.047	0.047	30.838
10	0.000	0.013	0.013	0.048	0.062	32.598
11	0.000	0.000	0.000	0.052	0.052	34.604
12	0.000	0.000	0.000	0.056	0.056	36.720
13	0.000	0.000	0.000	0.060	0.060	38.875
14	0.000	0.013	0.013	0.062	0.076	41.245
15	0.000	0.000	0.000	0.067	0.067	43.715
16	0.000	0.000	0.000	0.072	0.072	46.232
17	0.000	0.000	0.000	0.078	0.078	48.228
18	0.000	0.013	0.013	0.080	0.093	51.994
19	0.000	0.000	0.000	0.085	0.085	54.416
20	0.000	0.000	0.000	0.093	0.093	57.249
Salvage			-0.045		-0.045	
Total	0.089	0.053	0.098	1.080	1.178	707.313
PV 6%	0.089	0.029	0.104	0.582	0.686	
PV 10%	0.089	0.020	0.103	0.416	0.519	

Comparison between Double Sand Seal and GWC

Year	Road Work Costs Decrease (M$)			Road User Costs Decrease (M$)	Total Society Costs Decrease (M$)	CO_2 Emissions Decrease (tons)
	Capital Costs	Recurrent Costs	Total Costs			
1	-0.069	0.004	-0.066	0.003	-0.062	2.725
2	0.000	0.004	0.004	0.004	0.008	3.173
3	0.000	0.004	0.004	0.005	0.009	3.643
4	0.000	0.004	0.004	0.006	0.009	4.062
5	0.000	0.004	0.004	0.006	0.010	4.382
6	0.000	-0.010	-0.010	0.008	-0.001	4.929
7	0.000	0.004	0.004	0.010	0.014	5.298
8	0.000	0.004	0.004	0.012	0.016	5.863
9	0.000	0.004	0.004	0.016	0.020	7.637
10	0.000	0.000	0.000	0.006	0.006	4.801
11	0.000	0.004	0.004	0.007	0.010	4.918
12	0.000	0.004	0.004	0.008	0.012	5.611
13	0.000	0.004	0.004	0.009	0.013	6.151
14	0.000	-0.010	-0.010	0.014	0.005	7.038
15	0.000	0.004	0.004	0.019	0.022	8.622
16	0.000	0.004	0.004	0.023	0.027	11.261
17	0.000	0.004	0.004	0.030	0.034	15.977
18	0.000	0.000	0.000	0.011	0.012	7.190
19	0.000	0.004	0.004	0.014	0.018	8.545
20	0.000	0.004	0.004	0.016	0.020	10.813
Salvage	0.000	0.000	0.037	0.000	0.037	0.000
Net Present Value (M$) at			6%		0.087	
			10%		0.040	
Internal Rate of Return (%)					16.5%	
Emissions Decrease (tons)						132.6

Slurry Seal Annual Data

Year	Road Work Costs (M$)			Road User Costs (M$)	Total Society Costs (M$)	CO_2 Emissions (tons)
	Capital Costs	Recurrent Costs	Total Costs			
1	0.078	0.000	0.078	0.029	0.107	19.541
2	0.000	0.000	0.000	0.031	0.031	20.705
3	0.000	0.012	0.012	0.033	0.045	21.832
4	0.000	0.000	0.000	0.035	0.035	23.153
5	0.000	0.000	0.000	0.038	0.038	24.516
6	0.000	0.012	0.012	0.039	0.051	25.829
7	0.000	0.000	0.000	0.041	0.041	27.374
8	0.000	0.000	0.000	0.045	0.045	29.128
9	0.000	0.012	0.012	0.046	0.058	30.795
10	0.000	0.000	0.000	0.049	0.049	32.685
11	0.000	0.000	0.000	0.053	0.053	34.651
12	0.000	0.012	0.012	0.056	0.068	36.715
13	0.000	0.000	0.000	0.060	0.060	38.905
14	0.000	0.000	0.000	0.065	0.065	40.653
15	0.000	0.012	0.012	0.067	0.079	43.701
16	0.000	0.000	0.000	0.072	0.072	46.278
17	0.000	0.000	0.000	0.077	0.077	48.287
18	0.000	0.012	0.012	0.080	0.092	52.006
19	0.000	0.000	0.000	0.085	0.085	54.401
20	0.000	0.000	0.000	0.094	0.094	56.643
Salvage			-0.039		-0.039	
Total	0.078	0.074	0.113	1.094	1.207	707.799
PV 6%	0.078	0.044	0.110	0.592	0.702	
PV 10%	0.078	0.033	0.105	0.425	0.530	

Comparison between Slurry Seal and GWC

Year	Road Work Costs Decrease (M$)			Road User Costs Decrease (M$)	Total Society Costs Decrease (M$)	CO_2 Emissions Decrease (tons)
	Capital Costs	Recurrent Costs	Total Costs			
1	-0.058	0.004	-0.054	0.002	-0.052	2.500
2	0.000	0.004	0.004	0.003	0.006	2.904
3	0.000	-0.009	-0.009	0.004	-0.005	3.470
4	0.000	0.004	0.004	0.004	0.008	3.881
5	0.000	0.004	0.004	0.005	0.008	4.221
6	0.000	-0.009	-0.009	0.007	-0.001	4.750
7	0.000	0.004	0.004	0.009	0.012	5.131
8	0.000	0.004	0.004	0.010	0.014	5.740
9	0.000	-0.009	-0.009	0.017	0.008	7.679
10	0.000	0.013	0.013	0.005	0.018	4.714
11	0.000	0.004	0.004	0.005	0.009	4.871
12	0.000	-0.009	-0.009	0.008	-0.001	5.616
13	0.000	0.004	0.004	0.010	0.013	6.121
14	0.000	0.004	0.004	0.012	0.016	7.629
15	0.000	-0.009	-0.009	0.018	0.010	8.635
16	0.000	0.004	0.004	0.024	0.028	11.215
17	0.000	0.004	0.004	0.031	0.035	15.918
18	0.000	0.001	0.001	0.012	0.013	7.178
19	0.000	0.004	0.004	0.014	0.018	8.561
20	0.000	0.004	0.004	0.015	0.019	11.419
Salvage	0.000	0.000	0.031	0.000	0.031	0.000
Net Present Value (M$) at			6%		0.071	
			10%		0.029	
Internal Rate of Return (%)					14.8%	
Emissions Decrease (tons)						132.2

APPENDIX E - PHOTOGRAPHS DETAILING MONITORING METHODS

Monitoring Methods	
	1: Monitoring Beacon
	2: Surface Profile Measurement
	3: Surface Rut Measurement
Photograph	**Description**

Monitoring Methods	
	4: Surface Roughness Meaurement (MERLIN)
	5: Surface Texture Measurement
Photograph	**Description**

APPENDIX F - TRAFFIC COUNT DATA

Before Construction

Traffic Counting Data (Bago village; Ch. 0+640)							
Day No.	Pedestrian	Bicycle	Motorcycle	Saloon Car	Pick up/ 4WD	2-axle truck/ bus	3-axle truck
Day 1	470	215	140	1	6	5	0
Day 2	492	438	254	3	14	25	0
Day 3	370	341	229	4	9	15	0
Day 4	298	282	174	2	1	4	0
Day 5	279	270	303	2	8	20	0
Day 6	347	335	223	0	11	2	0
Day 7	408	305	234	2	6	11	0
Total	2664	2186	1557	14	55	82	0

Traffic Counting Data (Ludiga village; Ch. 11+040)							
Day No.	Pedestrian	Bicycle	Motorcycle	Saloon Car	Pick up/ 4WD	2-axle truck/ bus	3-axle truck
Day 1	242	174	29	1	0	0	0
Day 2	153	174	42	0	1	0	0
Day 3	118	144	40	0	5	0	0
Day 4	114	158	41	2	5	0	0
Day 5	138	135	38	0	10	0	0
Day 6	404	217	57	1	8	0	0
Day 7	241	222	45	1	5	0	0
Total	1410	1224	292	5	34	0	0

After Construction

Traffic Counting Data (Bago village; Ch. 0+640)							
Day No.	Pedestrian	Bicycle	Motorcycle	Saloon Car	Pick up/ 4WD	2-axle truck/ bus	3-axle truck
Day 1	178	304	219	6	1	2	0
Day 2	169	211	181	4	28	0	0
Day 3	126	197	165	6	6	0	0
Day 4	132	275	323	2	16	0	0
Day 5	121	228	144	2	15	0	0
Day 6	190	217	204	4	8	0	0
Day 7	256	288	235	4	20	0	0
Total	1172	1720	1471	28	94	2	0

Traffic Counting Data (Ludiga village; Ch. 11+040)							
Day No.	Pedestrian	Bicycle	Motorcycle	Saloon Car	Pick up/ 4WD	2-axle truck/ bus	3-axle truck
Day 1	131	142	90	3	5	0	0
Day 2	148	146	124	3	1	0	0
Day 3	187	166	147	0	7	1	0
Day 4	113	122	104	2	4	1	0
Day 5	150	175	140	0	4	0	0
Day 6	184	266	198	1	4	0	0
Day 7	209	286	242	2	5	0	0
Total	1122	1303	1045	11	30	2	0

APPENDIX G - SCHEDULE OF DRAINAGE STRUCTURES

Schedule of Drainage Structures

Type of Structure	Diameter (mm)	Pipe Length (m)	Total Span of Drift (m)	Chainage (km)	Direction of Water Flow	Other
Drift	-	-	12	0+475	←	-
Culvert	600	7.3	-	0+795	←	Skewed
Culvert	600	7.3	-	1+170	-	Access
Culvert	600	7.3	-	1+580	-	Access
Culvert	600	7.3	-	1+650	-	Access
Culvert	600	7.3	-	1+700	-	Access
Culvert	600	5.5	-	1+890	→	90°
Culvert	600	5.5	-	2+190	→	90°
Culvert	600	7.3	-	2+715	-	Access
Drift	-	-	13	3+830	←	-
Culvert	600	7.3	-	3+980	←	Skewed
Drift	-	-	26	5+540	←	-
Culvert	600	5.5	-	5+835	←	90°
Culvert	600	5.5	-	5+835	←	90°
Culvert	600	7.3	-	6+180	-	Skewed
Culvert	600	7.3	-	6+355	←	Skewed
Culvert	600	7.3	-	6+500	←	Skewed
Culvert	600	7.3	-	6+690	←	Skewed
Culvert	600	7.3	-	6+920	←	Skewed
Culvert	600	5.5	-	7+340	→	90°
Culvert	600	5.5	-	8+150	→	90°
Drift	-	-	6	8+580	→	90°
Drift	-	-	11	8+670	← ←	-
Drift	-	-	11	8+945	←	-
Culvert	600	5.5	-	9+190	←	90°
Drift	-	-	10	9+310	←	-
Drift	-	-	10	9+560	←	-
Drift	-	-	14	10+160	←	-
Culvert	600	5.5	-	11+020	→	90°
Culvert	600	7.3	-	11+400	→	Skewed
Culvert	600	7.3	-	11+510	→	Skewed
Culvert	600	7.3	-	11+700	-	Access
Culvert	600	5.5	-	11+850	→	90°
Culvert	600	5.5	-	12+030	→	90°
Culvert	600	5.5	-	12+500	←	90°
Culvert	600	5.5	-	12+920	→	90°
Culvert	600	5.5	-	13+375	←	90°
Culvert	600	5.5	-	14+355	←	90°
Culvert	600	7.3	-	14+550	→	Skewed
Culvert	600	7.3	-	14+855	→	Skewed
Culvert	600	7.3	-	14+920	→	Skewed
Drift	-	-	10	15+095	→	-
Culvert	600	5.5	-	15+305	→	90°
Culvert	600	5.5	-	15+480	→	90°
Culvert	600	5.5	-	15+560	→	90°
Drift	-	-	10	15+640	→	-

Schedule of Drainage Structures						
Culvert	600	5.5	-	15+830	→	90°
Culvert	600	5.5	-	15+910	→	90°
Culvert	600	5.5	-	16+100	→	90°
Culvert	600	5.5	-	16+260	→	90°
Culvert	600	7.3	-	16+550	-	Skewed
Culvert	600	5.5	-	16+690	→	90°
Culvert	600	5.5	-	16+760	→	90°
Drift	-	-	10	16+885	→	-
Culvert	600	5.5	-	17+065	→	90°
Culvert	600	5.5	-	17+580	→	90°
Culvert	600	5.5	-	17+640	→	90°
Culvert	600	5.5	-	17+680	→	90°
Culvert	600	5.5	-	17+905	→	90°
Culvert	600	5.5	-	18+060	→	90°
Culvert	600	7.3	-	18+340	←	Skewed
Culvert	-	5.5	-	18+550	←	90°
Culvert	600	7.3	-	18+920	→	Skewed
Drift	-	-	15	19+490	←	-
Culvert	600	5.5	-	19+820	→	90°
Culvert	600	5.5	-	19+960	→	90°

APPENDIX H – MONITORING FIELD SHEETS

VISUAL INSPECTION FIELD SHEET

AFCAP 8 Date: .... Monitor: ....

Tanzania Surface: From: To:

Section: Length:

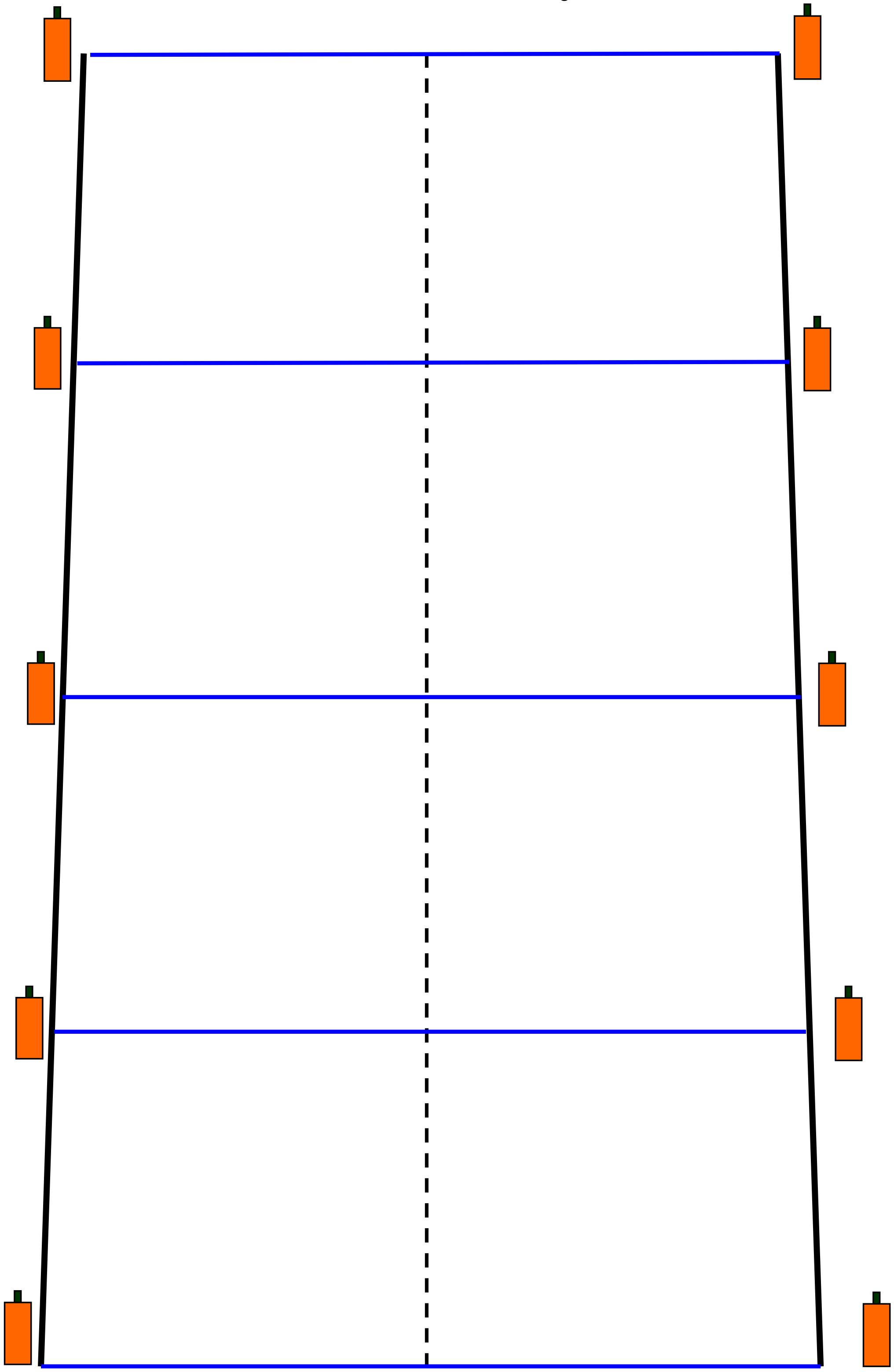
CH:

CH:

CH:

CH:

CH:



Traffic Count Survey **AFCAP 8**

Count Station: Date:

From (Time): **6h00** To (Time): **7h00**

Category		Counts						Total	Counts						Total
Direction		Towards Talawanda							Away from Talawanda						
1	Predestrian-Male	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
2	Predestrian-Female	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
3	Predestrian Load-Male	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
4	Predestrian Load-Female	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
5	Bicycles	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
6	Animal Cart/ Hand Cart	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
7	Motor Cycle	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
8	Saloon Car	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
9	4WD; Pickup; Minibus	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
10	Tractor, Utility Truck	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
11	Bus; 2-axle truck	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
12	3-axle truck	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	

From (Time): **7h00** To (Time): **8h00**

Category		Counts						Total	Counts						Total
Direction		Towards Talawanda							Away from Talawanda						
1	Predestrian-Male	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
2	Predestrian-Female	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
3	Predestrian Load-Male	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
4	Predestrian Load-Female	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
5	Bicycles	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
6	Animal Cart/ Hand Cart	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
7	Motor Cycle	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
8	Saloon Car	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
9	4WD; Pickup; Minibus	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
10	Tractor, Utility Truck	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
11	Bus; 2-axle truck	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
12	3-axle truck	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	

		65	70	75	80	85	90		65	70	75	80	85	90	

From (Time): **8h00** To (Time): **9h00**

	Category	Counts						Total	Counts						Total
	Direction	Towards Talawanda							Away from Talawanda						
1	Predestrian-Male	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
2	Predestrian-Female	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
3	Predestrian Load-Male	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
4	Predestrian Load-Female	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
5	Bicycles	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
6	Animal Cart/ Hand Cart	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
7	Motor Cycle	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
8	Saloon Car	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
9	4WD; Pickup; Minibus	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
10	Tractor, Utility Truck	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
11	Bus; 2-axle truck	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
12	3-axle truck	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	

From (Time): **9h00** To (Time): **10h00**

	Category	Counts						Total	Counts						Total
	Direction	Towards Talawanda							Away from Talawanda						
1	Predestrian-Male	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
2	Predestrian-Female	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
3	Predestrian Load-Male	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
4	Predestrian Load-Female	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
5	Bicycles	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
6	Animal Cart/ Hand Cart	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
7	Motor Cycle	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
8	Saloon Car	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
9	4WD; Pickup; Minibus	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
10	Tractor, Utility Truck	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
11	Bus; 2-axle truck	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
12	3-axle truck	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	

From (Time): **10h00** To (Time): **11h00**

	Category	Counts						Total	Counts						Total
	Direction	**Towards Talawanda**							**Away from Talawanda**						
1	**Predestrian-Male**	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
2	**Predestrian-Female**	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
3	**Predestrian Load-Male**	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
4	**Predestrian Load-Female**	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
5	**Bicycles**	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
6	**Animal Cart/ Hand Cart**	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
7	**Motor Cycle**	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
8	**Saloon Car**	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
9	**4WD; Pickup; Minibus**	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
10	**Tractor, Utility Truck**	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
11	**Bus; 2-axle truck**	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
12	**3-axle truck**	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	

From (Time): **11h00** To (Time): **12h00**

	Category	Counts						Total	Counts						Total
	Direction	**Towards Talawanda**							**Away from Talawanda**						
1	**Predestrian-Male**	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
2	**Predestrian-Female**	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
3	**Predestrian Load-Male**	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
4	**Predestrian Load-Female**	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
5	**Bicycles**	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
6	**Animal Cart/ Hand Cart**	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
7	**Motor Cycle**	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
8	**Saloon Car**	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
9	**4WD; Pickup; Minibus**	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
10	**Tractor, Utility Truck**	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
11	**Bus; 2-axle truck**	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
12	**3-axle truck**	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	

From (Time): **12h00** To (Time): **13h00**

Category		Counts						Total	Counts						Total
Direction		Towards Talawanda							Away from Talawanda						
1	Predestrian-Male	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
2	Predestrian-Female	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
3	Predestrian Load-Male	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
4	Predestrian Load-Female	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
5	Bicycles	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
6	Animal Cart/ Hand Cart	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
7	Motor Cycle	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
8	Saloon Car	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
9	4WD; Pickup; Minibus	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
10	Tractor, Utility Truck	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
11	Bus; 2-axle truck	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
12	3-axle truck	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	

From (Time): **13h00** To (Time): **14h00**

Category		Counts						Total	Counts						Total
Direction		Towards Talawanda							Away from Talawanda						
1	Predestrian-Male	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
2	Predestrian-Female	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
3	Predestrian Load-Male	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
4	Predestrian Load-Female	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
5	Bicycles	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
6	Animal Cart/ Hand Cart	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
7	Motor Cycle	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
8	Saloon Car	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
9	4WD; Pickup; Minibus	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
10	Tractor, Utility Truck	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
11	Bus; 2-axle truck	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
12	3-axle truck	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	

From (Time): 14h00 To (Time): 15h00

Category		Counts						Total	Counts						Total
Direction		Towards Talawanda							Away from Talawanda						
1	Predestrian-Male	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
2	Predestrian-Female	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
3	Predestrian Load-Male	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
4	Predestrian Load-Female	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
5	Bicycles	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
6	Animal Cart/ Hand Cart	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
7	Motor Cycle	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
8	Saloon Car	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
9	4WD; Pickup; Minibus	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
10	Tractor, Utility Truck	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
11	Bus; 2-axle truck	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
12	3-axle truck	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	

From (Time): 15h00 To (Time): 16h00

Category		Counts						Total	Counts						Total
Direction		Towards Talawanda							Away from Talawanda						
1	Predestrian-Male	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
2	Predestrian-Female	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
3	Predestrian Load-Male	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
4	Predestrian Load-Female	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
5	Bicycles	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
6	Animal Cart/ Hand Cart	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
7	Motor Cycle	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
8	Saloon Car	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
9	4WD; Pickup; Minibus	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
10	Tractor, Utility Truck	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
11	Bus; 2-axle truck	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
12	3-axle truck	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	

From (Time): 16h00 To (Time): 17h00

	Category	Counts						Total	Counts						Total
	Direction	Towards Talawanda							Away from Talawanda						
1	Predestrian-Male	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
2	Predestrian-Female	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
3	Predestrian Load-Male	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
4	Predestrian Load-Female	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
5	Bicycles	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
6	Animal Cart/ Hand Cart	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
7	Motor Cycle	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
8	Saloon Car	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
9	4WD; Pickup; Minibus	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
10	Tractor, Utility Truck	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
11	Bus; 2-axle truck	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
12	3-axle truck	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	

From (Time): 17h00 To (Time): 18h00

	Category	Counts						Total	Counts						Total
	Direction	Towards Talawanda							Away from Talawanda						
1	Predestrian-Male	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
2	Predestrian-Female	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
3	Predestrian Load-Male	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
4	Predestrian Load-Female	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
5	Bicycles	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
6	Animal Cart/ Hand Cart	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
7	Motor Cycle	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
8	Saloon Car	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
9	4WD; Pickup; Minibus	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
10	Tractor, Utility Truck	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
11	Bus; 2-axle truck	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
12	3-axle truck	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	

From (Time): **18h00** To (Time): **19h00**

	Category	Counts						Total	Counts						Total
	Direction	Towards Talawanda							Away from Talawanda						
1	Predestrian-Male	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
2	Predestrian-Female	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
3	Predestrian Load-Male	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
4	Predestrian Load-Female	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
5	Bicycles	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
6	Animal Cart/ Hand Cart	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
7	Motor Cycle	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
8	Saloon Car	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
9	4WD; Pickup; Minibus	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
10	Tractor, Utility Truck	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
11	Bus; 2-axle truck	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
12	3-axle truck	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	

From (Time): **19h00** To (Time): **20h00**

	Category	Counts						Total	Counts						Total
	Direction	Towards Talawanda							Away from Talawanda						
1	Predestrian-Male	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
2	Predestrian-Female	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
3	Predestrian Load-Male	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
4	Predestrian Load-Female	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
5	Bicycles	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
6	Animal Cart/ Hand Cart	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
7	Motor Cycle	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
8	Saloon Car	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
9	4WD; Pickup; Minibus	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
10	Tractor, Utility Truck	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
11	Bus; 2-axle truck	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
12	3-axle truck	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	

From (Time): **20h00** To (Time): **21h00**

	Category	Counts						Total	Counts						Total
	Direction	Towards Talawanda							Away from Talawanda						
1	Predestrian-Male	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
2	Predestrian-Female	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
3	Predestrian Load-Male	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
4	Predestrian Load-Female	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
5	Bicycles	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
6	Animal Cart/ Hand Cart	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
7	Motor Cycle	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
8	Saloon Car	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
9	4WD; Pickup; Minibus	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
10	Tractor, Utility Truck	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
11	Bus; 2-axle truck	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
12	3-axle truck	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	

From (Time): **21h00** To (Time): **22h00**

	Category	Counts						Total	Counts						Total
	Direction	Towards Talawanda							Away from Talawanda						
1	Predestrian-Male	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
2	Predestrian-Female	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
3	Predestrian Load-Male	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
4	Predestrian Load-Female	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
5	Bicycles	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
6	Animal Cart/ Hand Cart	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
7	Motor Cycle	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
8	Saloon Car	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
9	4WD; Pickup; Minibus	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
10	Tractor, Utility Truck	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
11	Bus; 2-axle truck	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
12	3-axle truck	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	

From (Time): **22h00** To (Time): **23h00**

	Category	Counts						Total	Counts						Total
	Direction	Towards Talawanda							Away from Talawanda						
1	Predestrian-Male	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
2	Predestrian-Female	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
3	Predestrian Load-Male	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
4	Predestrian Load-Female	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
5	Bicycles	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
6	Animal Cart/ Hand Cart	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
7	Motor Cycle	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
8	Saloon Car	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
9	4WD; Pickup; Minibus	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
10	Tractor, Utility Truck	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
11	Bus; 2-axle truck	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
12	3-axle truck	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	

From (Time): **23h00** To (Time): **24h00**

	Category	Counts						Total	Counts						Total
	Direction	Towards Talawanda							Away from Talawanda						
1	Predestrian-Male	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
2	Predestrian-Female	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
3	Predestrian Load-Male	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
4	Predestrian Load-Female	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
5	Bicycles	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
6	Animal Cart/ Hand Cart	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
7	Motor Cycle	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
8	Saloon Car	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
9	4WD; Pickup; Minibus	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
10	Tractor, Utility Truck	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
11	Bus; 2-axle truck	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	
12	3-axle truck	5	10	15	20	25	30		5	10	15	20	25	30	
		35	40	45	50	55	60		35	40	45	50	55	60	
		65	70	75	80	85	90		65	70	75	80	85	90	

Africa Community Access Programme (AFCAP)

Research Consultant to Support the Design, Construction and Monitoring

of Demonstration Sites for District Road Improvement in Tanzania

Bago-Talawanda Road

Measurement of the Road Profile

Supervisor: ______________________ Date: ______________________

Trial Section:

Chainage (km)	Profile Location	BS	IS	FS	HC	RL	Remarks

AFCAP 8 - Bago-Talawana , Tanzania
Consultant: Roughton International

SAND PATCH TEST FORM

Access Road No.: Type of Pavement:

Tested by: Checked by: Date:

Location	Diametre (mm)					Texture depth (mm)
(KM)	D1	D2	D3	D4	Average	63660/D^2

Surface Rut Measurements		
Section:	Pavement Type:	
Chainage from:		Date:
Chainage to:		
Chainage (km)	LHS From CL	RHS From CL

Roughton International

Test Section: ....

Wheel-path: ....

Date: ....

Operator: ....

Road Maintenance Management System for the Republic of Seychelles

MERLIN Roughness Calibration Sheet

a Machine for Evaluating Roughness using Low-cost InstrumentatioN

1	2	3	4	5	6	7	8	9	10
11	12	13	14	15	16	17	18	19	20
21	22	23	24	25	26	27	28	29	30
31	32	33	34	35	36	37	38	39	40
41	42	43	44	45	46	47	48	49	50
51	52	53	54	55	56	57	58	59	60
61	62	63	64	65	66	67	68	69	70
71	72	73	74	75	76	77	78	79	80
81	82	83	84	85	86	87	88	89	90
91	92	93	94	95	96	97	98	99	100
101	102	103	104	105	106	107	108	109	110
111	112	113	114	115	116	117	118	119	120
121	122	123	124	125	126	127	128	129	130
131	132	133	134	135	136	137	138	139	140
141	142	143	144	145	146	147	148	149	150
151	152	153	154	155	156	157	158	159	160
161	162	163	164	165	166	167	168	169	170
171	172	173	174	175	176	177	178	179	180
181	182	183	184	185	186	187	188	189	190
191	192	193	194	195	196	197	198	199	200

DCP Field Worksheet

Project: Tested By: Chainage:

Location: Date: Offset:

BLOW No	READING mm	DN mm/blow	BLOW No	READING mm	DN mm/blow
0 (zero reading)			190		
5			195		
10			200		
15			205		
20			210		
25			215		
30			220		
35			225		
40			230		
45			235		
50			240		
55			245		
60			250		
65			255		
70			260		
75			265		
80			270		
85			275		
90			280		
95			285		
100			290		
105			295		
110			300		
115			305		
120			310		
125			315		
130			320		
135			325		
140			330		
145			335		
150			340		
155			345		
160			350		
165			355		
170			360		
175			365		
180			370		
185			375		

APPENDIX I - MONITORING DATABASE COMPACT DISC