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Baseline Survey Report for 11 Low-Volume Sealed Roads in Kenya

Final Report

By: Across Africa Consultants Ltd.

Prepared for Kenya Materials Testing and Research Department (MTRD)

AFCAP Project

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Cover Photo:
Across Africa staff carrying out rut depth measurements along road number D382 near Nyahururu.

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Abstract

The baseline survey was conducted on 11 roads. The survey spanned for over six months. The initial measurements of road roughness carried out on all the roads had to be redone in June 2017. This was due to the errors in the vehicle suspension of the survey vehicle. The vehicle suspension system was corrected and the machine was recalibrated before re-doing the survey.

The roads showed very low base course CBR values and will thus provide a good opportunity in determining threshold values of the base course CBR for low volume sealed roads after, provided monitoring is carried out for a number of years.

The deflection/stiffness of the pavements was highly variable along the section lengths. This was attributed to the variable grading of the base course materials on some of the roads – especially as regards the particle size distribution. Some of the bases, for example on D435 contain a large amount of oversize materials.

The surfacing on all the roads is cold mix asphalt. They show varied performance with the majority performing very well and others showing cracks and ravelling.

Key words

Monitoring, Research, Pavements, Performance, Kenya, Road Sections, Setting Up, Trends, Measurements, Baseline

RESEARCH FOR COMMUNITY ACCESS PARTNERSHIP (ReCAP)

Safe and sustainable transport for rural communities

ReCAP is a research programme, funded by UK Aid, with the aim of promoting safe and sustainable transport for rural communities in Africa and Asia. ReCAP comprises the Africa Community Access Partnership (AfCAP) and the Asia Community Access Partnership (AsCAP). These partnerships support knowledge sharing between participating countries in order to enhance the uptake of low cost, proven solutions for rural access that maximise the use of local resources. The ReCAP programme is managed by Cardno Emerging Markets (UK) Ltd.

Acknowledgements

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Acronyms, Units and Currencies

$	United States Dollar (US$ 1.00 ≈ 92KShs)
AfCAP	Africa Community Access Partnership
AsCAP	Asia Community Access Partnership
CBR	California Bearing Ratio
DfID	Department for International Development
DCP	Dynamic Cone Penetrometer
DN	DCP Number (mm/blow)
DSN800	DCP Structural Number at 800 mm
FMC	Field Moisture Content (In-situ Moisture Content)
FWD	Falling Weight Deflectometer
GPS	Global positioning system
IRI	International Roughness Index
IWL	Inner Wheel Path Left Hand Side
IWR	Inner Wheel Path Right Hand Side
LHS	Left Hand Side
LVSR	Low Volume Sealed Road
MoTI	Ministry of Transport and Infrastructure
MTRD	Materials Testing and Research Division
OMC	Optimum Moisture Content
OWL	Outer Wheel Path Left Hand Side
OWR	Outer Wheel Path Right Hand Side
PSR	Present Serviceability Rating
ReCAP	Research for Community Access Partnership
RHS	Right Hand Side
TRL	Transport Research Laboratory
UK	United Kingdom (of Great Britain and Northern Ireland)
UKAid	United Kingdom Aid (Department for International Development, UK)

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1 Executive Summary

The baseline survey sought to investigate 11 trial sections to determine the performance of the nonstandard construction materials used on the roads. The roads under study are spread across four counties in Central Region of Kenya namely: Kiambu County (D379); Murang'a County (D415, D419, D420, D421, E511); Nyeri County (D435, E579) and Nyandarua County (D381, D382, D388). All these are low volume sealed roads serving rural populations, mostly consisting of small scale farmers. Construction on most of the roads was completed in 2014.

For each of the eleven roads, a number of tests and activities were carried out in a predetermined sequence. These included: Traffic counts; Axle load surveys; Visual Condition Surveys; Deflection tests; Roughness measurements; Rut depth measurements; DCP tests; Relative moisture content determination; Recording rainfall amounts; and trial pit sampling for laboratory tests. All the data from these tests was analysed using the appropriate methods and the results used to make valid conclusions on the reasons behind the current state of the road pavements.

The major defects on each of the roads were noted and examined closely to determine the extent of the defects. Such defects included pothole formation, delamination of pavement layers, longitudinal, transverse and crocodile cracking, encroachment of vegetation onto the carriageway and aggregate stone loss. Each of the eleven roads had its own specific dominating defects, arising from the construction materials used, the prevailing weather conditions and the roads' usage.

One common problem cutting across all the roads is poor carriageway drainage. Despite the roads having been constructed with adequate side drains, the use of the roads by heavy vehicles has led to formation of ruts along both the outer and inner wheel paths, which leads to accumulation of water on the pavement. This water slowly finds its way into the base material, forming weak points which fail when subjected to pressure by the wheels of the vehicles. Thus a pothole develops and because of the average 20 mm thick surfacing, the pothole widens fast as the surfacing crumbles easily at the edge of the pothole.
Edge break is also common for all the roads because of the failure to seal the access roads. At the point where the earth access roads join the sealed roads, edge breaks are most severe, and are expected to get worse unless remedied

2 Introduction

2.1 Project Background

The Africa Community Access Partnership (AfCAP) is a research programme funded by the UK Government's Department for International Development (DFID). The programme is aimed at promoting safe and sustainable rural access in Africa by use of low cost, proven solutions that maximize the use of local resources.

Kenya is one amongst the several AfCAP participating countries. The Government of Kenya (GoK) is on a mission to upgrade the majority of the low volume rural roads to paved standard. This may prove an expensive venture due to the increasing scarcity of good construction materials in many areas, which translates to long haulage distances. Therefore, AfCAP has been asked by the Ministry of Transport and

Infrastructure (MoTI) through the Materials Testing and Research Department (MTRD) and the Kenya Rural Roads Authority (KeRRA) to support research on utilization of non-standard materials for Low Volume Sealed Road (LVSR) pavements. As part of this process trial sections have been constructed on roads in various locations in Kenya for research purposes.

2.2 Report Structure

This report contains a detailed account of all the investigative tests that were carried out to measure the performance of the eleven roads. These include traffic surveys, rut depth measurements, deflection measurements, DCP tests, moisture content determination, roughness measurements, trial pit sampling and standard soils tests, and visual condition assessment. A brief description is made on how each of the above tests was done. This is followed by the results, mostly presented in tables and graphs. The challenges encountered during the exercise are also discussed. Conclusions are thereafter made and the necessary recommendations given. Each road is discussed under a different chapter, numbered 3 to 13.

2.3 Monitoring Period

The monitoring of the roads took place between June and December 2016. The monitoring period started just after the long rains, through the dry season between the rainy seasons, and extended through to the short rains. Therefore, the baseline survey cannot be regarded as either wet or dry. The rainfall data collected during the baseline period will be used to decide whether the survey was in the wet or the dry season after further data is obtained in the future. Table 2-1 is a timetable of the dates over which the baseline surveys were conducted on each road. Specific dates for specific activities on each road are shown in Table 2-2.

Table 2-1: Timetable of survey dates

Roads	Start date	Completion date
D379	16-05-2016	13-11-2016
D381	19-05-2016	09-11-2016
D382	19-05-2016	10-11-2016
D388	19-05-2016	10-11-2016
D415	16-05-2016	13-11-2016
D419	17-05-2016	12-11-2016
D420	17-05-2016	12-11-2016
D421	17-05-2016	12-11-2016
D435	18-05-2016	11-11-2016
E511	20-05-2016	13-11-2016
E579	18-05-2016	11-11-2016

Precise dates when the various surveys were conducted on each site are shown in

Table 2-2: Baseline survey dates per site

Road Name	Road Number	Deflection/ Stiffness	Rut Depth	DCP	Axle Load Surveys	Traffic Counts	Test Pits	Visual Condition Assessment	Roughness
Wamwangi - Karatu	D379	08/08/2016	07/08/2016	01/09/2016	06/08/2016 – 09/08/2016	31/08/2016 – 06/09/2016	27/10/2016 – 28/10/2016	13/11/2016	12/06/2017 – 20/06/2017
Total – Kona Mbaya	D381	09/08/2016	11/08/2016	26/09/2016	04/09/2016 – 07/09/2016	14/09/2016 – 20/09/2016	05/11/2016	09/11/2016	12/06/2017 – 20/06/2017
Lord – Kona Bahati	D382	09/08/2016	11/08/2016	27/09/2016	31/08/2016 – 03/09/2016	14/09/2016 – 20/09/2016	07/11/2016	09/11/2016	12/06/2017 – 20/06/2017
Mairo Inya - Kaheho	D388	09/08/2016	11/08/2016	27/09/2016	08/09/2016 – 11/09/2016	14/09/2016 – 20/09/2016	03/11/2016 – 04/11/2016	10/11/2016	12/06/2017 – 20/06/2017
Muruka - Kandara	D415	11/08/2016	08/08/2016	01/09/2016	10/08/2016 – 13/08/2016	31/08/2016 – 06/09/2016	28/10/2016	13/11/2016	12/06/2017 – 20/06/2017
Maragua – Gakoigo Jn	D419	11/08/2016	09/08/2016	06/09/2016	22/08/2016 – 25/08/2016	07/09/2016 – 13/09/2016	03/11/2016	12/11/2016	12/06/2017 – 20/06/2017
Karega – Gathara - Ithumbi	D420	11/08/2016	09/08/2016	03/09/2016	18/08/2016 – 21/08/2016	07/09/2016 – 13/09/2016	31/10/2016	12/11/2016	12/06/2017 – 20/06/2017
Gakoigo Jn – Maragua River	D421	11/08/2016	08/08/2016	04/09/2016	26/08/2016 – 29/08/2016	07/09/2016 – 13/09/2016	01/11/2016	12/11/2016	12/06/2017 – 20/06/2017
Muthuaini -	D435	10/08/2016	12/08/2016	08/09/2016	12/09/2016 –	09/09/2016 –	03/11/2016	11/11/2016	12/06/2017 –

Mununga ini					15/09/2016	15/09/2016			20/06/2017
Kangari - Kinyona	E511	11/08/2016	08/08/2016	02/09/2016	14/08/2016 – 17/08/2016	31/08/2016 – 06/09/2016	29/10/2016	12/11/2016	12/06/2017 – 20/06/2017
Ruring'u - Kinunga	E579	10/08/2016	08/08/2016	08/09/2016	16/09/2016 – 19/09/2016	09/09/2016 – 15/09/2016	02/11/2016	X	12/06/2017 – 20/06/2017

3 Wamwangi-Karatu Road D379

3.1 Site Description

Road D379 is located in Kiambu County. It starts at Wamwangi town centre, about 3km north of Gatundu town. The sealed section is 400 m long, but the road goes up to Karatu. This road was constructed in the year 2012. Figure 3-1 is a truncated map showing its location.

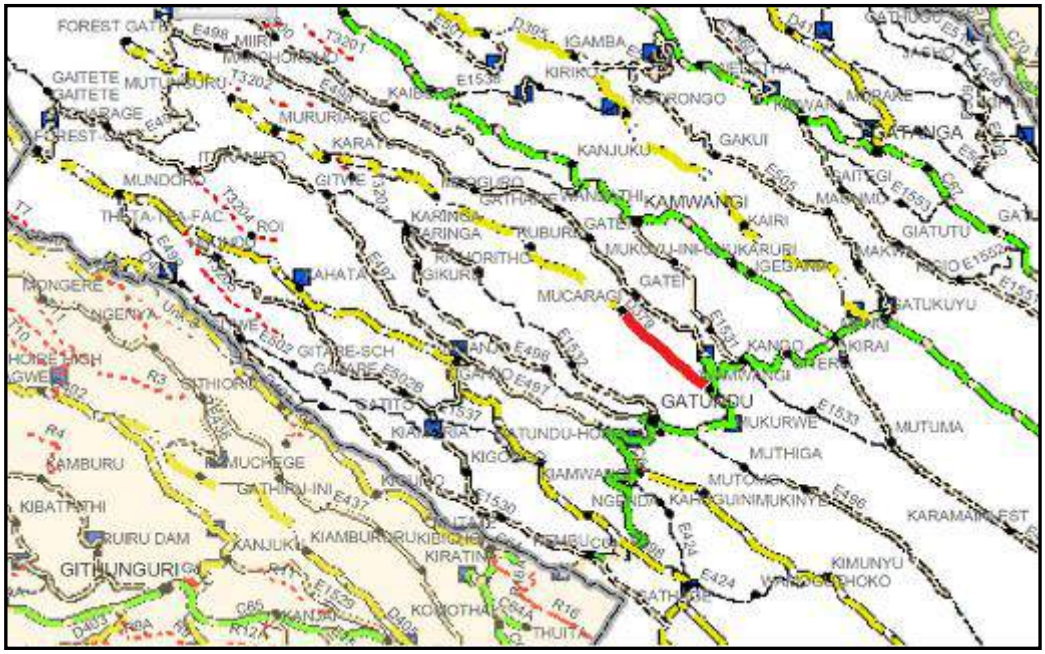


Figure 3-1: Map showing location of Wamwangi – Karatu Road D379 (marked in red)

3.2 Pavement Description

Figure 3-2 shows the designed pavement structure.

20 mm Cold Mix Asphalt	
160 mm Neat laterite base	
220 mm Granular subbase	
Subgrade	

Figure 3-2: Designed pavement structure (D379)

3.3 Traffic Survey

3.3.1 Classified Traffic Counts

Traffic data for the road was collected over five 12-hour periods and two 24 hour periods. The count was done manually by enumerators seated strategically by the roadside, each one counting vehicles of a specific type heading to a given direction. Table 3-1 below shows the classified traffic count analysed results.

Table 3-1: Classified Traffic Count Summary (D379)

Vehicle Type	Daily Volume (vpd)
Motorcycles	320
Cars	164
Minibus	10
Bus[1]	0
Light Goods Vehicle	17
Medium Goods Vehicle	5
Heavy Goods Vehicle	1
ADT	**517**

Note 1: Only one bus used the route during the 7-day survey. Therefore, when a 7 day average is taken, this appears 0.

The highest traffic category on this road is motorcycles, averaging to 320 per day.

No major event was encountered during the 7 days counting period which could significantly affect the traffic volumes at the time of counting.

3.3.2 Axle Load Survey

Table 3-2 shows the summary of ESA by vehicle type, and computed ESA/day

Table 3-2: Traffic ESA (D379)

Vehicle Type	ESA/day
Bus[1]	0.06
Medium Goods Vehicles	4.54
Heavy Goods Vehicles	1.76
Articulated Heavy Goods Vehicles	0.00
Total ESA/day	**6.36**

Note 1: Only one bus used the route during the survey.

NB: The axle load survey and traffic counts were done in different weeks, thus the slight variation in the traffic ESA and Average Daily Traffic.

3.4 Rutting

Rut depth was measured by use of a 3 m long straight edge and a wedge. The straight edge was placed on one side of the road, followed by the other side, in one continuous transverse profile. The rut depths were measured in both outer and inner wheel paths.

Table 3-3 shows the maximum rut depth left and right of each chainage point. The green shaded rows represent measurements taken in the LTPP section. This convention is used throughout this document.

The average rut depth for both the left and right hand side is approximately 10 mm. This is considered slight rutting, which poses no major deterrence to traffic flow.

Table 3-3: Rut Depth (D379)

Chainage	LHS Rut in mm	RHS Rut in mm
0+000	8	12
0+025	8	4
0+040	13	12
0+055	7	9
0+070	12	12
0+085	11	10

0+100	8	12
0+115	10	10
0+130	12	12
0+145	12	11
0+160	6	12
0+175	12	7
0+200	7	12
0+250	12	12
0+300	4	15
0+350	3	18
Average	**9**	**11**

3.5 Deflection/Stiffness

Defection was measured using the Falling Weight Deflectometer (FWD) at 50 m intervals along the road, alternating between the outer wheel path and the inner wheel path. A large circular weight was used to transmit a pressure of 566 kPa to the pavement. The load imparted on the pavement therefore was measured and the stiffness parameters calculated. Table 3-4 show the deflection of the pavement at D_0 and the base, sub-base and subgrade stiffness measured at each point. Lane 1 represents the outer LHS wheel path, Lane 2 represents the outer RHS wheel path, Lane 3 represents the inner LHS wheel path and Lane 4 represents the inner RHS wheel path. This convention is used throughout this document.

Table 3-4: Deflection and stiffness (D379)

Chainage (m)	Lane No.	Stiffness			Normalized Deflections at Geophone Locations (µm) D_0
		EBase (MPa)	ESubbase (MPa)	ESubgrade(MPa)	
0+000	1	162	125	128	727
0+017	1	9549	13706	18	598
0+030	1	416	51	115	799
0+045	1	1653	300	127	429
0+060	1	207	152	102	756
0+075	1	269	184	96	697
0+090	1	300	200	93	664
0+106	1	471	62	97	792
0+120	1	576	98	101	708
0+128	1	131	110	100	941
0+135	1	352	36	125	855
0+150	1	326	39	116	923
0+155	1	143	126	99	937
0+165	1	406	76	135	836
0+170	1	106	93	98	875
0+180	1	163	125	114	796

0+185	1	192	145	127	719
0+194	1	171	140	108	878
0+195	1	154	119	111	849
0+225	1	137	113	108	795
0+251	1	422	44	169	695
0+275	1	300	200	141	531
0+300	1	422	62	116	762
0+325	1	158	125	133	654
0+350	1	634	46	169	590
0+000	4	211	155	103	789
0+009	4	198	148	91	829
0+025	4	211	154	96	786
0+040	4	256	183	77	861
0+053	4	229	171	77	870
0+070	4	1234	210	97	819
0+085	4	183	146	86	903
0+101	4	160	129	101	876
0+115	4	270	185	96	708

Figure 3-3 shows a graphical representation of the central deflection by chainage. The values are highly variable for each lane along the road.

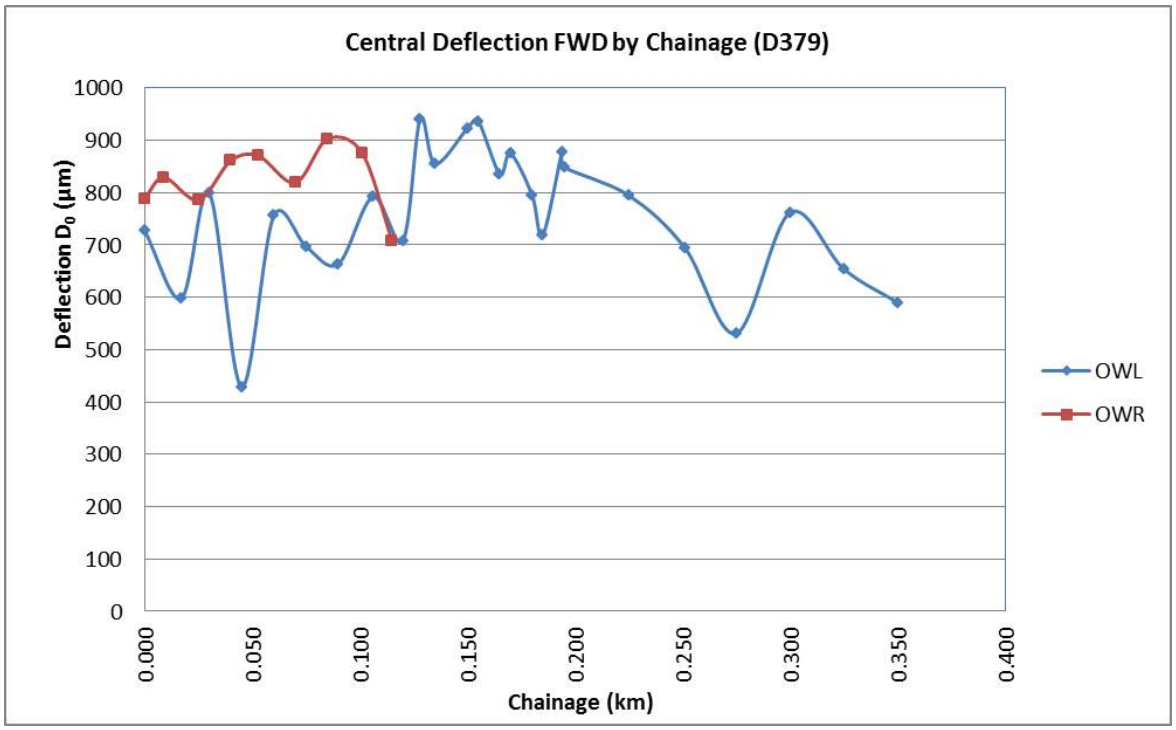


Figure 3-3: Central deflection by chainage (D379)

3.6 DCP Measurements

These were taken to average depths of 800 mm on both the outer and inner wheel paths. At the LTPP, DCP measurements were taken at two cross-sections, each cross-section with 5 test points. Table 3-5 shows the DN and DSN by layer for each test point. The maroon shaded rows represent measurements taken at the test pit excavated at the LTPP. This convention is used throughout the document.

Table 3-5: DSN and DN values (D379)

Chainage (m)	Specifications	≤3.2	≤6.0	≤12	≤19	≤25	DSN800
	Position	0-150	150-300	300-450	450-600	600-800	≥100
0+010	OWR	6.2	10.6	19.6	28.6	27.3	64
0+010	IWR	2.7	3.9	8.9	8.7	7.3	171
0+010	IWL	3.5	2.7	8.8	11.6	19.3	175
0+010	OWL	3.5	3.5	5.2	10.1	14.5	156
0+010	CL	5.7	7.2	12.2	11.8	13.9	95
0+012	RHS	7.6	9.8	17.7	28.2	38.1	58
0+186	CL	3.3	3.2	5.7	9.0	10.6	168
0+186	OWL	2.9	2.7	5.8	10.3	15.9	191
0+186	IWL	2.6	3.4	5.1	8.8	12.5	200
0+186	IWR	4.3	3.2	6.7	11.5	25.6	142
0+186	OWR	9.8	11.6	20.5	38.3	34.6	50
0+194	CL	1.9	2.5	3.6	4.2	2.0	396
0+250	RHS	6.5	11.6	9.7	18.1	25.1	72
0+300	CL	8.1	8.7	9.8	14.1	18.1	83
0+350	RHS	1.9	2.0	4.2	8.8	10.9	271

The DCP measurements were done at the same points as the FWD tests to get a correlation between the two tests.

3.7 Roughness Measurements

The roughness measurements are shown in

Table 3-6 and Table 3-7. The values are as would be expected for low volume sealed roads in their early life. Figure 3-4 shows the roughness of each lane along the road section.

Table 3-6: Roughness values including humps (D379)

Wamwangi – Karatu Road (D379)			
LHS		RHS	
Chainage	IRI	Chainage	IRI
0+000-0+017	3.2	0+000-0+009	3.2
0+017-0+045	3.2	0+009-0+025	3.2
0+045-0+075	2.4	0+025-0+053	3.2
0+075-0+128	2.4	0+053-0+070	3.2

0+128-0+155	2.4	0+070-0+085	3.2
0+155-0+194	2.4		
0+194-0+300	1.7		
0+300-0+350	1.7		

Table 3-7: Roughness values excluding humps (D379)

Wamwangi – Karatu Road (D379)			
LHS		RHS	
Chainage	IRI	Chainage	IRI
0+000-0+017	2.1	0+000-0+009	2.1
0+017-0+045	2.1	0+009-0+025	2.1
0+045-0+075	2.1	0+025-0+053	2.1
0+075-0+128	2.1	0+053-0+070	2.1
0+128-0+155	2.1	0+070-0+085	2.1
0+155-0+194	2.1		
0+194-0+300	2.7		
0+300-0+350	2.7		

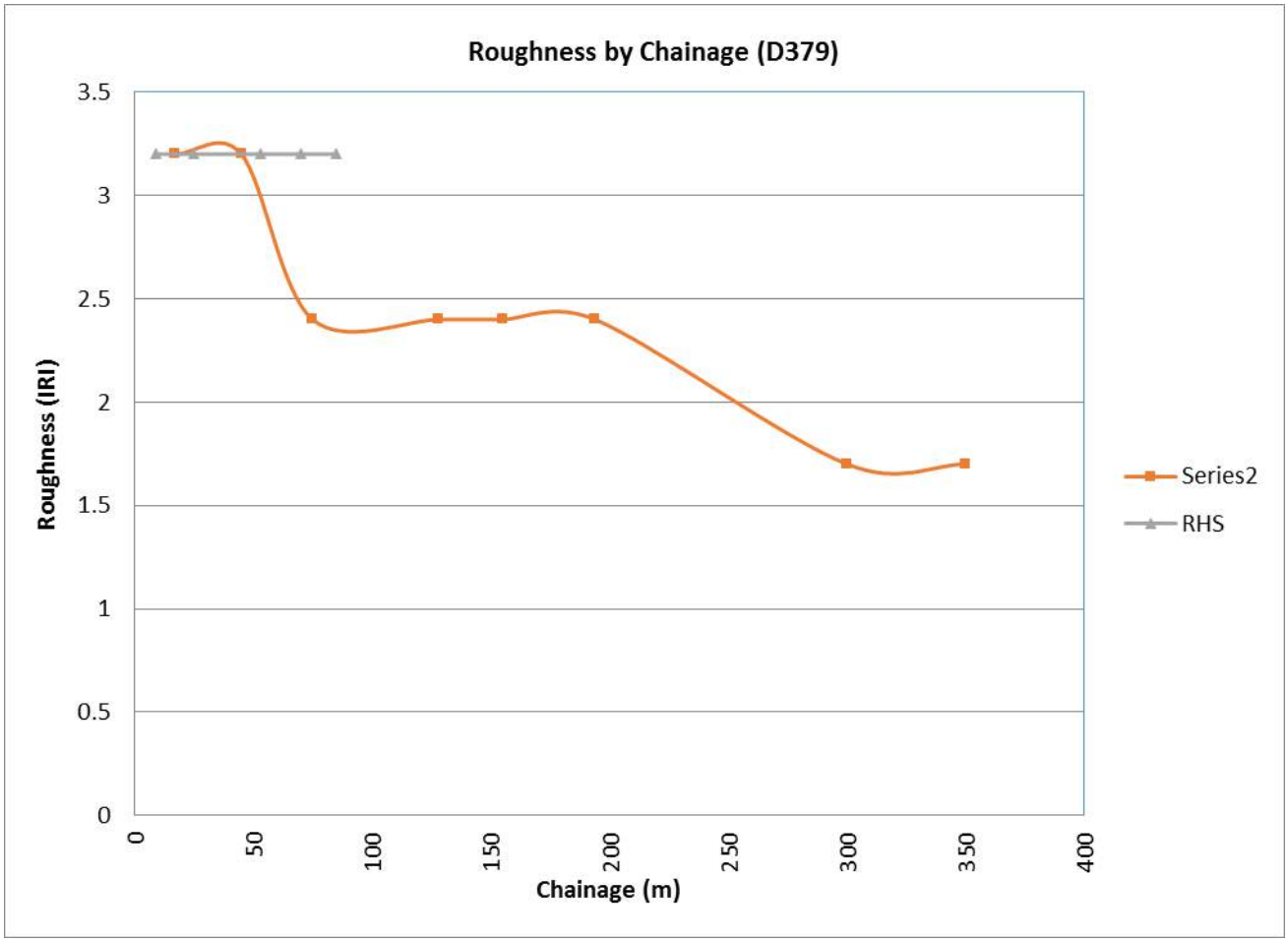


Figure 3-4: Roughness values including humps by chainage (D379)

3.8 Test Pits

3.8.1 DN Values

Table 3-8 shows the DN values of each layer in the structure measured before excavation of the test pit. The values do not meet the recommended specifications.

Table 3-8: DN Values at test pits (D381)

Depth (mm)	DN values (mm/blow)		
	Specifications	Pit A @ 0+012	Pit B @ 0+194
0 – 150	≤3.2	7.6	1.9
150 – 300	≤6.0	9.8	2.5
300 – 450	≤12	17.7	3.6
450 – 600	≤19	28.2	4.2
600 – 800	≤25	38.1	2.0
DSN800	≥100	58	396

The other DCP test details are presented in the Appendix section of the report.

3.8.2 Layer Thicknesses

Figure 3-5 shows the measured layer thicknesses for the two test pit and description of the pavement materials.

Test Pit A, km 0+012		Test Pit B, km 0+194
20 mm Cold Mix Asphalt		20 mm Cold Mix Asphalt
160 mm Neat Laterite base		150 mm Neat laterite base
220 mm Granular subbase		160 mm Granular subbase
Subgrade		Subgrade

Figure 3-5: Layer thicknesses at test pit (D379)

3.8.3 Densities and Moisture Content

Table 3-9 shows the dry density, the MDD, the in-situ moisture content and the OMC for each layer for the two test pits, including the subgrade. AASHTO T180 test method was employed for base/subbase and AAHTO T99 for the subgrade. The in-situ moisture contents are close to the OMC.

Table 3-9: Density and Moisture Content at Test Pits (D379)

Location	Wheel Path	Layer	MDD (kg/m^3)	In-situ Moisture Content: FMC (%)	OMC (%)	Relative Moisture Content (FMC/OMC)
Panel A	**OWP**	**Base**	1845	12.4	17.2	0.72
		Sub-base	1540	22.7	20.3	1.12
		Subgrade	1320	30.8	32.0	0.94
	IWP	**Base**	1880	11.9	13.5	0.88
		Sub-base	1500	24.1	21.5	1.12
		Subgrade	1300	30.3	33.2	0.91
Panel B	**OWP**	**Base**	1685	15.9	18.3	0.87
		Sub-base	1530	20.7	29.6	0.70
		Subgrade	1210	31.2	34.4	0.91
	IWP	**Base**	1775	14.1	16.9	0.83
		Sub-base	1475	20.3	23.3	0.87
		Subgrade	1320	28.7	33.2	0.86

3.8.4 Particle Size Distribution

Figure 3-6, Figure 3-7, and Figure 3-8 are plots showing the particle size distribution for each layer. The base materials all fit into the specification envelope.

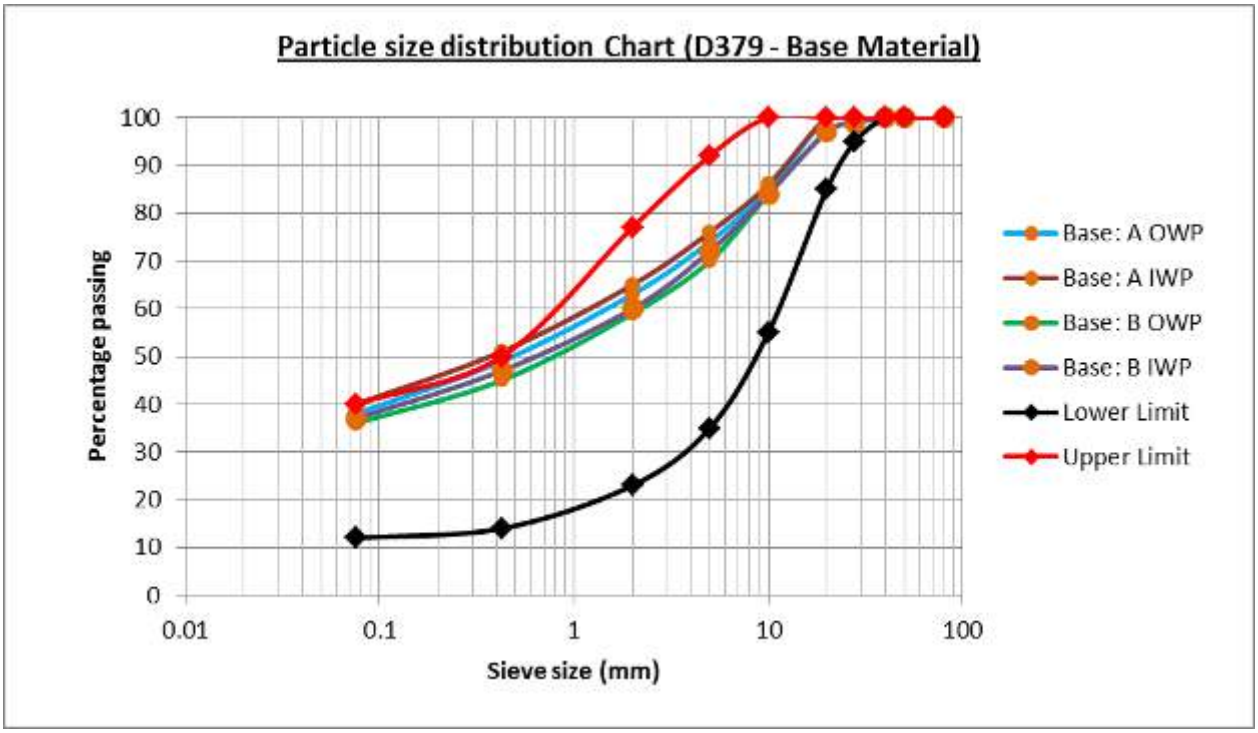


Figure 3-6: Particle size distribution of the base material (D379)

Figure 5 shows that the particle size distribution of the base material is on the finer side compare to the grading requirement for G20 material.

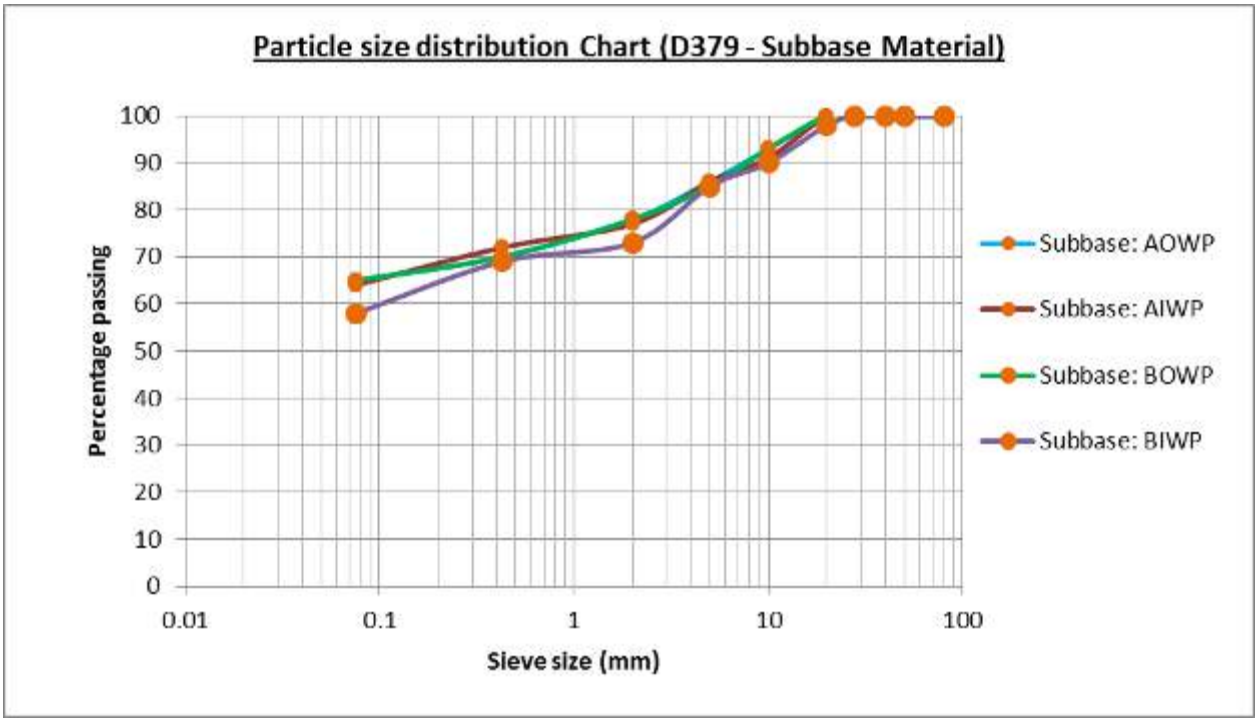


Figure 3-7: Particle size distribution of the subbase material (D379)

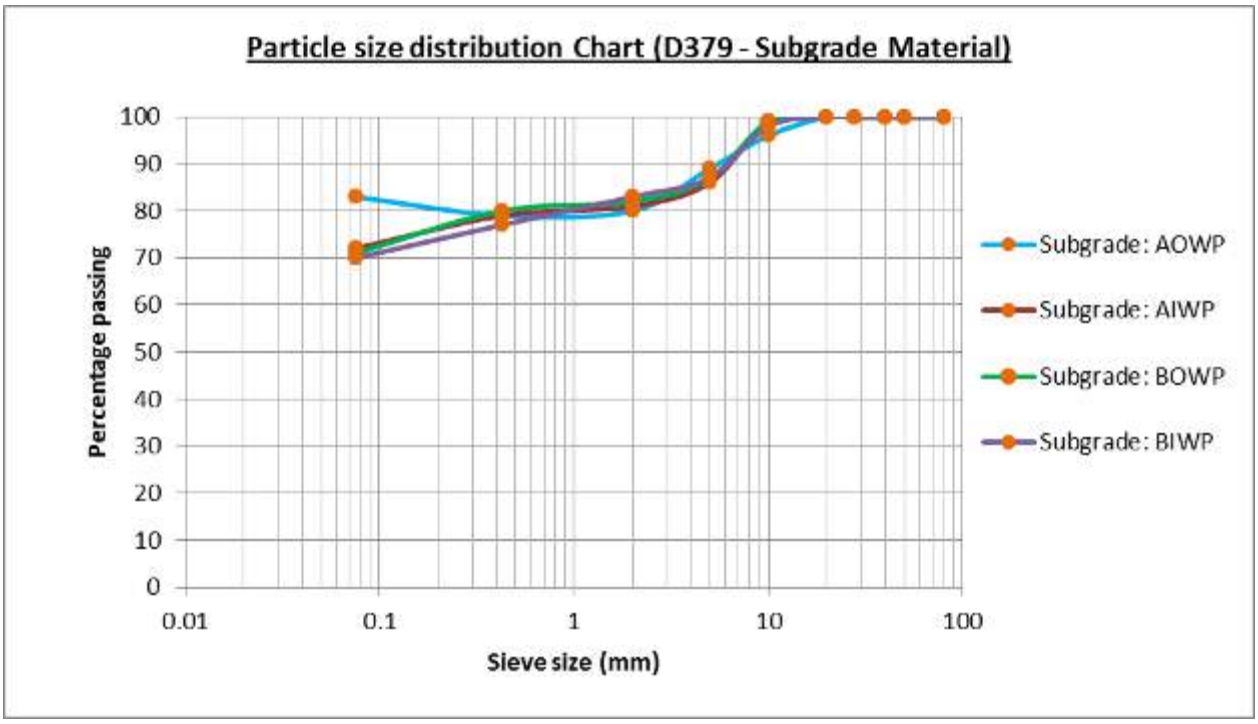


Figure 3-8: Particle size distribution of the subgrade material (D379)

3.8.5 Atterberg Limits

Table 3-10 is a summary of the index properties of each pavement layers; including the subgrade.

Table 3-10: Atterberg limits at Test Pits (D379)

Layer	Liquid Limit	Plastic Limit	Plasticity Index	Linear Shrinkage
Road D379 – Panel A – OWP				
Base	44	24	20	9
Sub-base	52	25	27	14
Subgrade	69	39	30	14
Road D379 – Panel A – IWP				
Base	42	20	22	11
Sub-base	52	32	20	10
Subgrade	51	32	20	10
Road D379 – Panel B – OWP				
Base	50	26	24	12
Sub-base	51	25	26	14
Subgrade	69	39	30	14
Road D379 – Panel B – IWP				
Base	39	21	18	9
Sub-base	67	42	25	13
Subgrade	61	32	29	14

3.8.6 Laboratory CBR

The CBR tests for the base and sub-base was conducted on 4-day soaked specimens and tested according to AASHTO T180. For the subgrade AASHTO T99 was used. The results in Table 3-11 show very low CBR values for the base and sub-base layers.

Table 3-11: Laboratory CBR values (D379)

4-day soaked CBR (%) (D379)				
Layer	**Panel A**		**Panel B**	
	OWP	**IWP**	**OWP**	**IWP**
Base	25	25	20	20
Sub-base	8	9	6	10
Subgrade	4	3	3	5

3.9 Visual Condition Assessment

3.9.1 General

Visual assessment was used to identify signs of distress and pavement defects that can affect its performance. These included:

- Describing the surface type
- Determining the extent of ravelling or stone loss of the pavement
- Describing the degree of pothole formation
- Describing the extent of edge breaks on the pavement
- Checking surface cracking and describing the extent and type of cracking

- Describing the geometry of each chainage section
- Describing the drainage condition of the pavement

For this road, light vegetation has grown on the side drains along both sides of the entire section, encroaching onto the pavement. This is foreseen to impede free drainage of water from the pavement, and thus cause the pavement to fail by action of stagnant water weakening the base.

The road has open drainage channels along the sides, averaging 700 mm from the crown of the road, with mostly 450 mm culverts across entrances to homes and the Catholic Church at the site. The road has no shoulders at any point along its length. On the carriageway, no major potholes exist. The few potholes present are relatively small.

Crack sealing was seen along a large section of the road mainly along the centre line. This must have been done after longitudinal cracking of the road.

3.9.2 Pavement Defects Assessment

Table 3-12 shows the defects assessment. No main defects were observed.

Table 3-12: Visual Condition Assessment on D379

Fig No	Location (Km)	Defect assessment and description	Photos illustrating the pavement distress & defect
Fig 1	Km 0+000 – 0+020 main carriage way	-No visible defect on the surface	

Fig 2	Km 0+000-0+030 LHS	-Light vegetation on the side drain extending towards the road edge	
Fig3	Km 0+050 main carriage way at the centerline	-Crack sealing done on the main carriage way at the centerline	
Fig 4	Km 0+060 – 0+075 main carriage way at the centerline	-Cracks sealing on the carriage way	

Fig 5	Km 0+100 – 0+130 main carriage way at the centerline	-Crack sealing on carriage way -Vegetation on the encroaching the road edge	
Fig6	Km 0+120 – 0+130 LHS	-Vegetation on side slope hindering free flow of water to the side drain	
Fig 7	Km 0+140- 0+150 main carriage way	-Longitudinal cracks sealing of shrinkage cracks that occurred soon after completion of the section. The fatty spots are emulsion repairs of minor defects and test holes.	

Fig 8	Km 0+200 – 0+250 main carriage way	-No visible defect on the main carriage way -Vegetation on the side slope extending towards the edge	
Fig 9	Km 0+260 -0+300 main carriage way	- No visible defect on the main carriage way	
Fig10	**Km 0+300 – 0+350 main carriage**	-Vegetated side slope extending towards the edge and may result into moistening pavement hence premature failure	

3.9.3 Present Serviceability Rating

Table 3-13 shows the PSR of the pavement. The value of 4.6 corresponds to a "Good" pavement.

Table 3-13: Present Serviceability Rating (D379)

Road :	Wamwangi - Karatu Road (D379)												
Section:	Km 0+000 - Km 0+ 350 main carriage way												
Pavement Structure:				**Date of Survey:**					13/11/2016				
Surfacing	Asphalt concrete mix												
Base	Neat Laterite												
Sub-base	Neat laterite												
		A	**B**	**C**	**D**	**E**	**F**	**G**	**Point summary**				
	Point score												
Sub- Section	Length (Km)	General appearance	Surface texture	Bitumen condition	Pot holes	Surface irregularity	Rutting	Cracking	Sum of (∑) Points A-G Max: 40	Average points	%	Remarks	PSR
1. Km 0+000 - 0+350	0.350	5	4.5	4.0	4.0	5.0	5.0	4.5	32	4.6	80.0	**Good**	**4.6**
Average PSR		**5**	**4.5**	**4**	**4**	**5**	**5**	**4.5**	**32**	**4.6**	**80**	**Good**	**4.6**

3.10 Rainfall Data

Precipitation over the baseline survey period is shown in Table 3-14.

Table 3-14: Precipitation at D379

Precipitation (mm) at Wamwangi - Karatu D379										
2016					**2017**					
AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE
0	17.8	4.4	218.8	32.4	xx	xx	xx	xx	xx	xx

Note: In months where no data was available, the values are labelled as XX

4 Total-Kona Mbaya Road D381

4.1 Site Description

This Trial Section starts at Total petrol station in Nyahururu town. The sealed section is 8.5 km long, ending just past Bowman Centre. The rest of the road is gravel up to Kwa Lord shopping centre. Figure 4-1 shows the location map of the road.

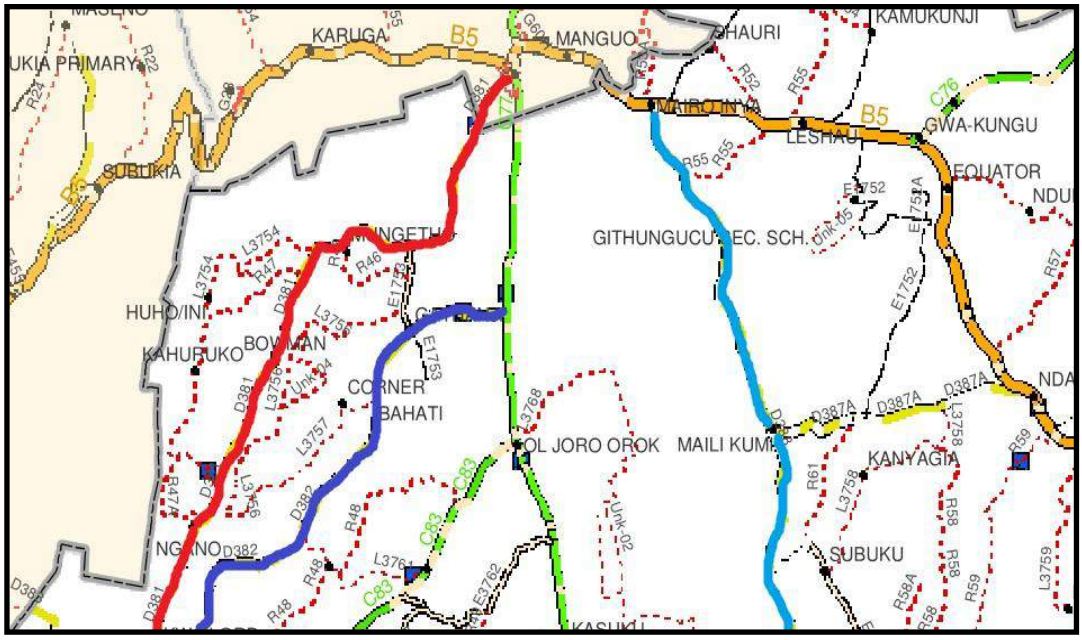


Figure 4-1: Location of Total – Kona Mbaya Road (D381) marked in red

4.2 Pavement Description

Figure 4-2 is a description of the designed pavement layers for the road and their respective thicknesses.

20 mm Cold Mix Asphalt	
100 mm Composite ETB base (cement stabilized with upper 1/3 emulsion treated)	
250 mm Granular sub-base	
Subgrade	

Figure 4-2: Designed pavement structure (D381)

4.3 Traffic Survey

4.3.1 Classified Traffic Counts

Table 4-1 shows the traffic count summary for Road D381. The counting station was about 1km from Nyahururu town.

Table 4-1: Traffic volume summary (D381)

Vehicle Type	Daily Volume (vpd)
Motorcycles	4703
Cars	617
Minibus	195
Bus	29
Light goods vehicles	134
Medium goods vehicles	103
Heavy goods vehicles	9
ADT	**5791**

The number of motorcycles using this road is quite high. This is because of the origin of the road (Nyahururu town), to and from which people travel a lot as they go about their daily businesses such as shopping, reporting to work, going to school, going to hospital, etc.

4.3.2 Axle Load Survey

Table 4-2 is a summary table of Equivalent Standard Axle (ESA) by vehicle type, and computed ESA/day.

Table 4-2: Traffic ESA (D381)

Vehicle Type	ESA/day
Bus	1.34
Medium Goods Vehicles	27.25
Heavy Goods Vehicles	2.01
Total ESA/day	**30.90**

4.4 Rutting

Table 4-3 shows the maximum rut depth left and right of each chainage point. The average value of 9 mm is acceptable for low volume roads.

Table 4-3: Maximum rut depth (D381)

Chainage	LHS Rut in mm	RHS Rut in mm
0+000	6	9
0+050	8	2
0+100	9	12
0+150	4	12
0+200	7	10
0+250	7	8
0+300	6	12
0+350	8	6
0+400	9	12
0+425	12	7
0+440	7	4

0+455	8	6
0+470	9	12
0+485	9	12
0+500	8	8
0+515	12	6
0+530	12	2
0+545	3	12
0+560	12	10
0+575	8	6
0+600	12	3
0+650	11	12
0+700	12	2
0+750	12	6
0+800	6	4
0+900	12	9
0+950	3	12
1+000	5	2
Average	**9**	**8**

4.5 Deflection/Stiffness

Table 4-4 shows the central deflection D_0 and the base, sub-base and subgrade stiffness measured at each point.

Table 4-4: Deflection and stiffness (D381)

Chainage (m)	Lane No.	Stiffness			Normalized Deflections at Geophone Locations (µm) D_0
		EBase (MPa)	ESubbase (MPa)	ESubgrade (MPa)	
0+000	1	1263	215	171	752
0+050	1	1048	180	122	780
0+150	1	438	94	147	940
0+251	1	1158	192	144	867
0+350	1	1074	192	142	760
0+560	1	1942	339	80	1128
0+562	1	297	32	145	885
0+650	1	189	72	81	1212
0+748	1	830	150	93	1306
0+752	1	2500	300	85	1733
0+850	1	578	105	171	994
0+851	1	2500	300	88	1560
0+950	1	1914	342	63	1312
0+951	1	1946	344	92	1032
1+000	1	915	165	112	996

0+000	2	1195	215	174	792
0+100	2	1104	186	200	767
0+200	2	433	77	164	1050
0+300	2	1007	171	109	1220
0+424	2	2500	300	93	1716
0+454	2	302	82	107	1151
0+485	2	1192	203	109	1032
0+514	2	546	107	165	1053
0+545	2	453	80	206	1682
0+575	2	1964	345	68	1204
0+699	2	1721	311	69	1752
0+800	2	326	79	99	1689
0+900	2	1790	317	77	1629
1+000	2	423	100	137	1014
0+100	3	207	21	145	1145
0+201	3	210	23	239	969
0+301	3	222	29	252	862
0+400	3	515	93	216	679
0+425	3	2500	300	71	1553
0+455	3	973	170	132	885
0+486	3	916	165	117	981
0+516	3	233	25	249	862
0+545	3	388	80	123	1029
0+577	3	1956	339	71	1106
0+650	3	876	156	113	1064
0+751	3	293	71	105	1529
0+851	3	1832	310	90	1209
0+952	3	1956	341	91	969
0+049	4	480	87	177	768
0+149	4	264	31	177	889
0+248	4	179	15	547	1024
0+349	4	436	52	171	650
0+408	4	2021	340	65	1039
0+440	4	1360	231	97	869
0+470	4	389	98	133	970
0+499	4	2014	336	82	1074
0+533	4	1007	170	99	1331
0+560	4	1961	343	79	1090

The rest of the deflection outputs from the FWD for all the sensors (D_0 up to D_6) for all the test locations are presented in the Appendix section of the report. Figure 4-3 shows a plot of the central deflection by chainage. The values are highly variable along the road.

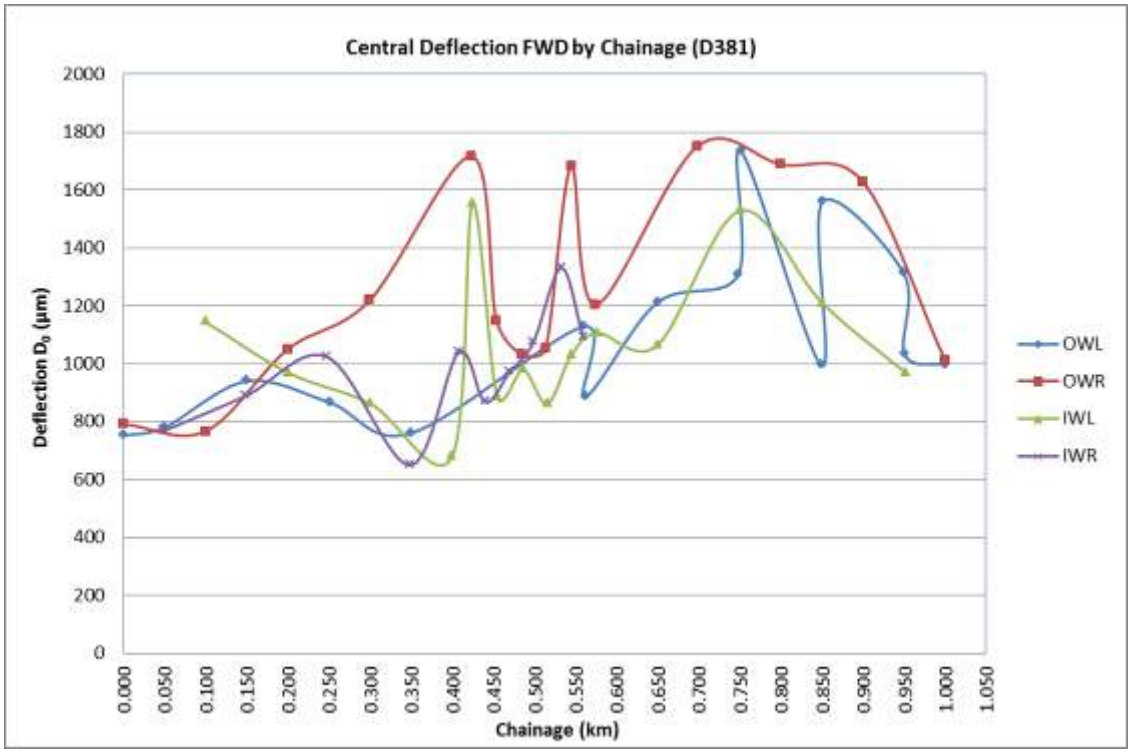


Figure 4-3: Central deflection by chainage (D381)

4.6 DCP Measurements

Table 4-5 shows the DN and DSN by layer of each test point. The values mostly lie within the specification limits.

Table 4-5: DN and DSN values (D381)

Chainage (m)	Specifications	≤3.2	≤6.0	≤12	≤19	≤25	DSN800
	Position	0-150	150-300	300-450	450-600	600-800	≥100
0+000	CL	6.2	7.8	9.5	10.6	10.0	109
0+050	CL	6.4	6.9	6.5	7.7	8.7	122
0+100	CL	4.6	5.3	3.4	11.3	6.7	177
0+150	RHS	11.3	11.1	18.7	18.7	12.4	89
0+200	CL	5.6	6.6	11.3	10.3	14.8	130
0+250	RHS	18.7	18.6	17.0	14.9	18.5	81
0+300	CL	5.0	7.0	7.3	4.0	5.2	188
0+350	RHS	5.7	9.0	15.2	9.1	11.2	103
0+400	CL	7.7	12.0	7.1	8.4	8.7	104
0+408	CL	15.9	10.1	21.1	28.8	15.1	67
0+408	IWL	8.6	14.2	11.0	5.7	9.5	110
0+408	OWL	7.7	12.7	5.7	5.4	11.8	156
0+408	IWR	6.3	14.4	19.5	18.9	17.1	68
0+408	OWR	13.4	20.7	14.0	14.1	11.3	62
0+412	RHS	8.0	17.0	13.6	17.1	13.9	69

0+578	OWR	6.2	14.5	11.1	13.5	19.6	78
0+578	IWR	4.7	11.7	14.6	11.1	13.5	92
0+578	OWL	4.4	10.2	16.4	13.6	16.6	90
0+578	IWL	5.2	5.8	7.4	14.7	10.3	125
0+578	CL	5.6	9.9	6.9	11.6	12.2	100
0+585	RHS	5.8	15.9	21.8	28.6	13.0	70
0+600	RHS	4.6	6.7	7.0	5.3	11.1	161
0+650	CL	8.8	13.1	10.9	7.1	12.9	118
0+700	RHS	7.8	16.4	13.3	6.4	8.8	97
0+750	CL	6.9	9.5	6.5	6.3	8.9	129
0+800	RHS	4.3	6.0	5.0	3.4	0.4	680
0+850	CL	9.2	12.8	9.9	7.0	10.1	99
0+900	RHS	10.0	14.4	15.3	33.5	21.6	55
0+950	CL	13.5	10.7	15.7	17.5	17.0	62

4.7 Roughness Measurements

Table 4-6 and Table 4-7 show the roughness values. These are within expected values for LVSRs. Figure 4-4 shows the roughness of each lane along the road section.

Table 4-6: Roughness values including bumps (D381)

Total – Kona Mbaya Road (D381)			
LHS		RHS	
Chainage	IRI	Chainage	IRI
0+000-0+100	2.4	0+000-0+049	2.7
0+100-0+201	2.4	0+049-0+408	3.4
0+201-0+400	2.4	0+408-0+440	3.4
0+400-0+455	2.4	0+440-0+499	1.4
0+455-0+486	2.9	0+499-0+533	1.4
0+486-0+516	2.9	0+533-0+560	4.3
0+516-0+577	2.7		
0+577-0+751	2.9		
0+751-0+952	2.4		

Table 4-7: Roughness values excluding bumps (D381)

Total – Kona Mbaya Road (D381)			
LHS		RHS	
Chainage	IRI	Chainage	IRI
0+000-0+100	2.4	0+000-0+049	2.4
0+100-0+201	2.4	0+049-0+408	2.4
0+201-0+400	2.4	0+408-0+440	2.4
0+400-0+455	2.4	0+440-0+499	2.9
0+455-0+486	2.9	0+499-0+533	2.9
0+486-0+516	2.9	0+533-0+560	2.4
0+516-0+577	2.7		

0+577-0+751	2.9	
0+751-0+952	2.4	

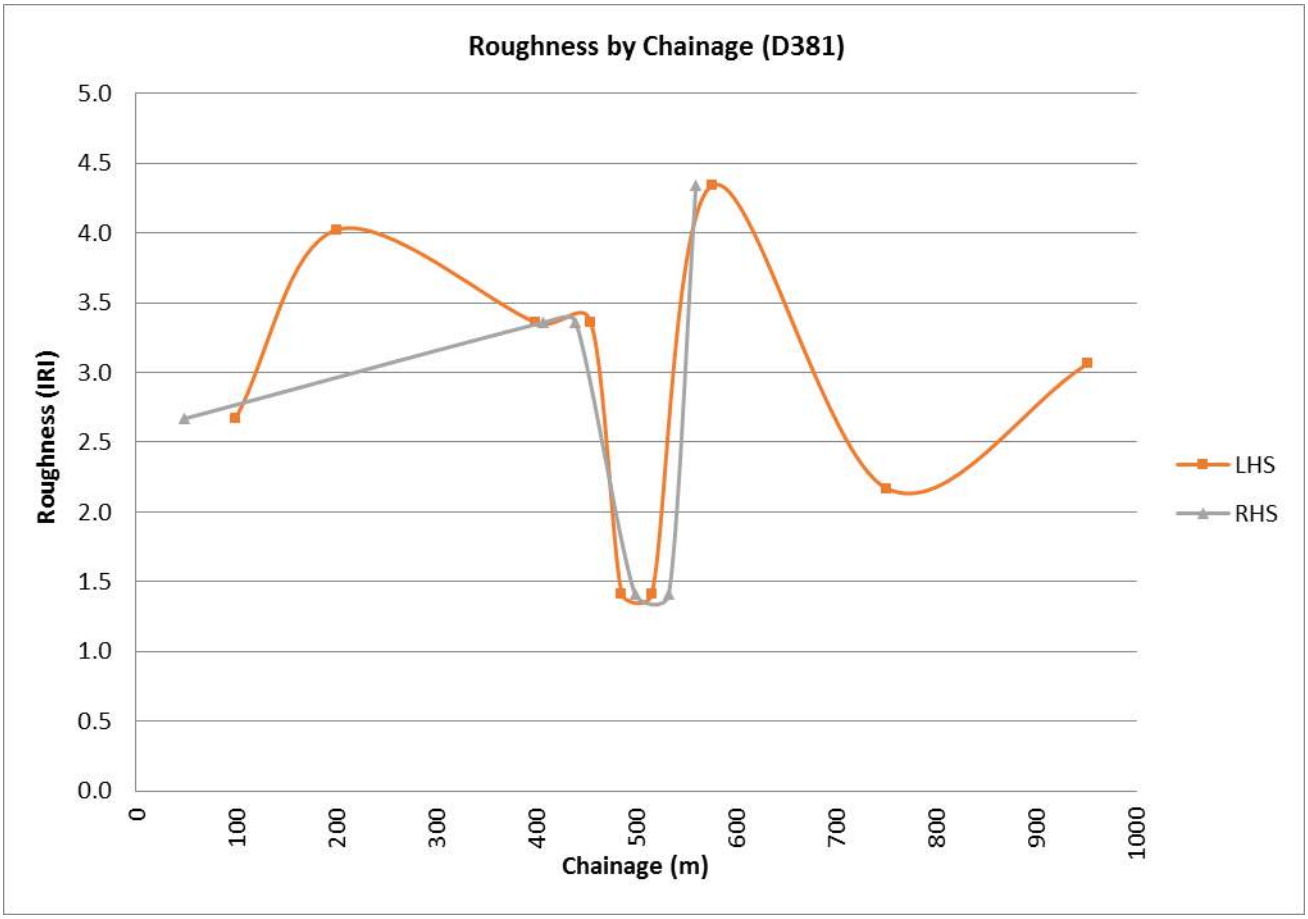


Figure 4-4: Roughness values including bumps by chainage (D381)

4.8 Test Pits

4.8.1 DN Values

Table 4-8 shows the DN of each layer in the structure measured before excavation of the test pit.

Table 4-8: DN Values at test pit (D381)

Depth (mm)	DN values (mm/blow)		
	Specifications	Pit A @ 0+412	Pit B @ 0+585
0 – 150	≤3.2	8.0	5.8
150 – 300	≤6.0	17.0	15.9
300 – 450	≤12	13.6	21.8
450 – 600	≤19	17.1	28.6
600 – 800	≤25	13.9	13.0
DSN800	≥100	69	70

The other DCP test details are presented in the Appendix section of the report.

4.8.2 Layer Thicknesses

Figure 4-5 is a description of the measured layer thickness and materials forming the pavement layers.

Test Pit A, km 0+412		Test Pit B, km 0+585
20 mm Cold Mix Asphalt		20 mm Cold Mix Asphalt
250 mm Composite emulsion treated base		250 mm Composite emulsion treated base
250 mm Granular sub-base		250 mm Granular sub-base
Subgrade		Subgrade

Figure 4-5: Layer thicknesses at test pit

4.8.3 Densities and Moisture Content

Table 4-9 below shows the dry density, the MDD, the in-situ moisture content and the OMC (AASHTO T180) for each layer for the two test pits, including the subgrade.

Table 4-9: Density and Moisture Content at Test Pits (D381)

Panel	Wheel Path	Layer	MDD (kg/m^3)	In-situ Moisture Content (%)	OMC (%)	Relative Moisture Content (FMC/OMC)
Panel A	OWP	Base	1555	23.3	16.2	1.44
		Sub-base	1500	15.6	21.0	0.74
		Subgrade	1395	22.1	25.3	0.87
	IWP	Base	1525	17.6	17.6	1.00
		Sub-base	1460	22.9	23.3	0.98
		Subgrade	1370	22.6	24.6	0.92
Panel B	OWP	Base	1565	17.3	16.1	1.07
		Sub-base	1535	19.6	21.8	0.90
		Subgrade	1455	21.9	21.6	1.01
	IWP	Base	1510	15.7	19.6	0.80
		Sub-base	1512	20.2	18.4	1.10
		Subgrade	1423	21.7	21.2	1.02

The insitu moisture contents show only a slight variation from the optimum moisture content, probably at which the layers were compacted. Thus the pavement layers are at slightly above or slightly below the optimum moisture contents.

4.8.4 Particle Size Distribution

Figure 4-6, Figure 4-7, and Figure 4-8 show the particle size distribution for each layer, base, sub-base and subgrade. The base materials largely fit within the specification envelope except on the larger sieves, where they are coarser.

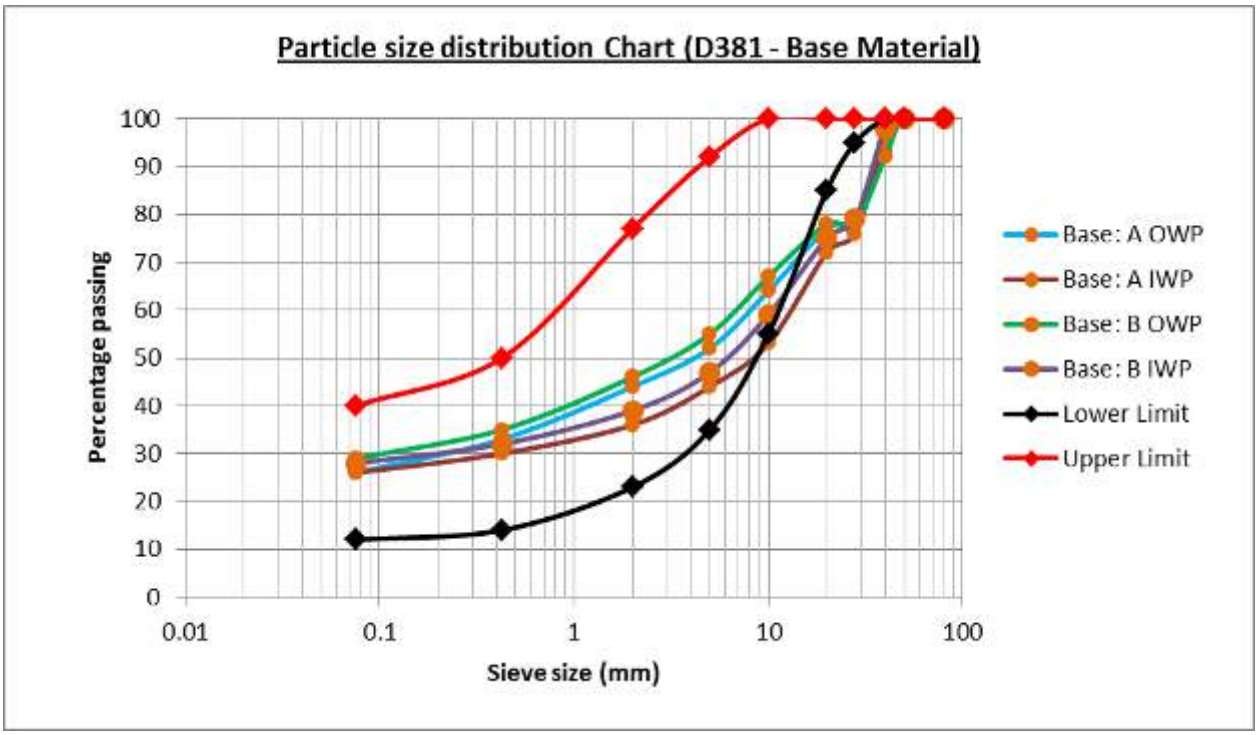


Figure 4-6: Particle size distribution for base material (D381)

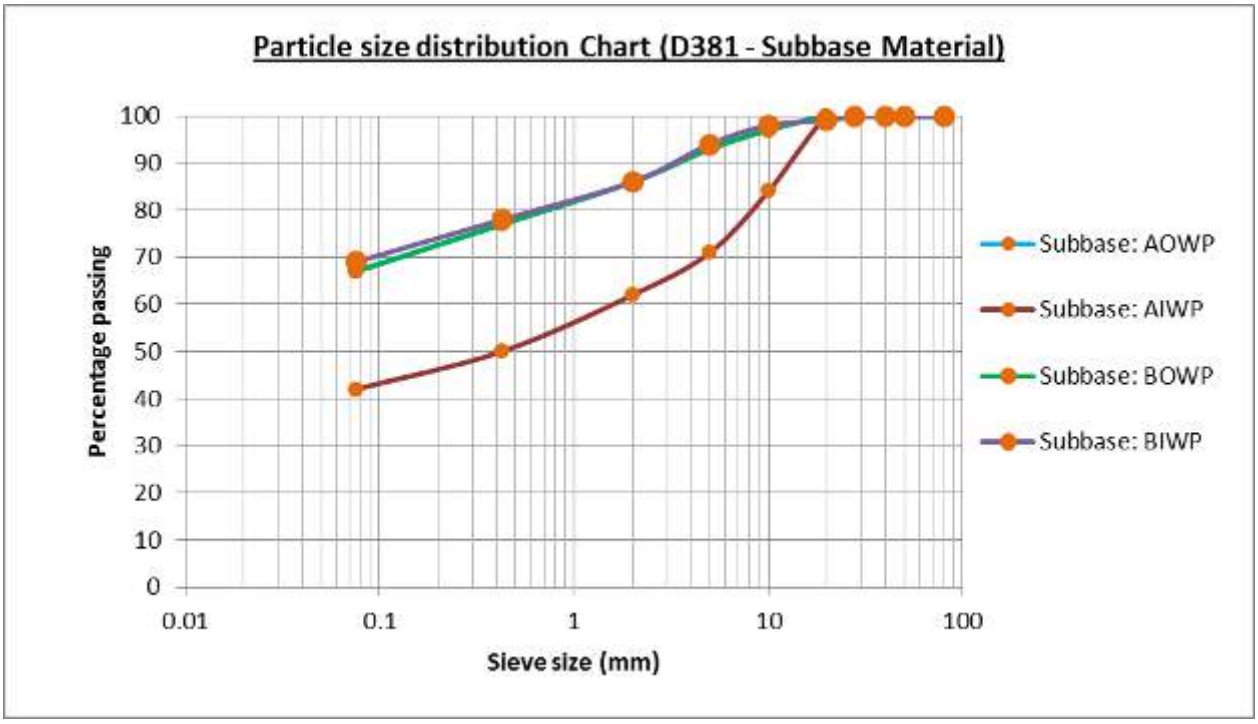


Figure 4-7: Particle Size distribution for sub-base material (D381)

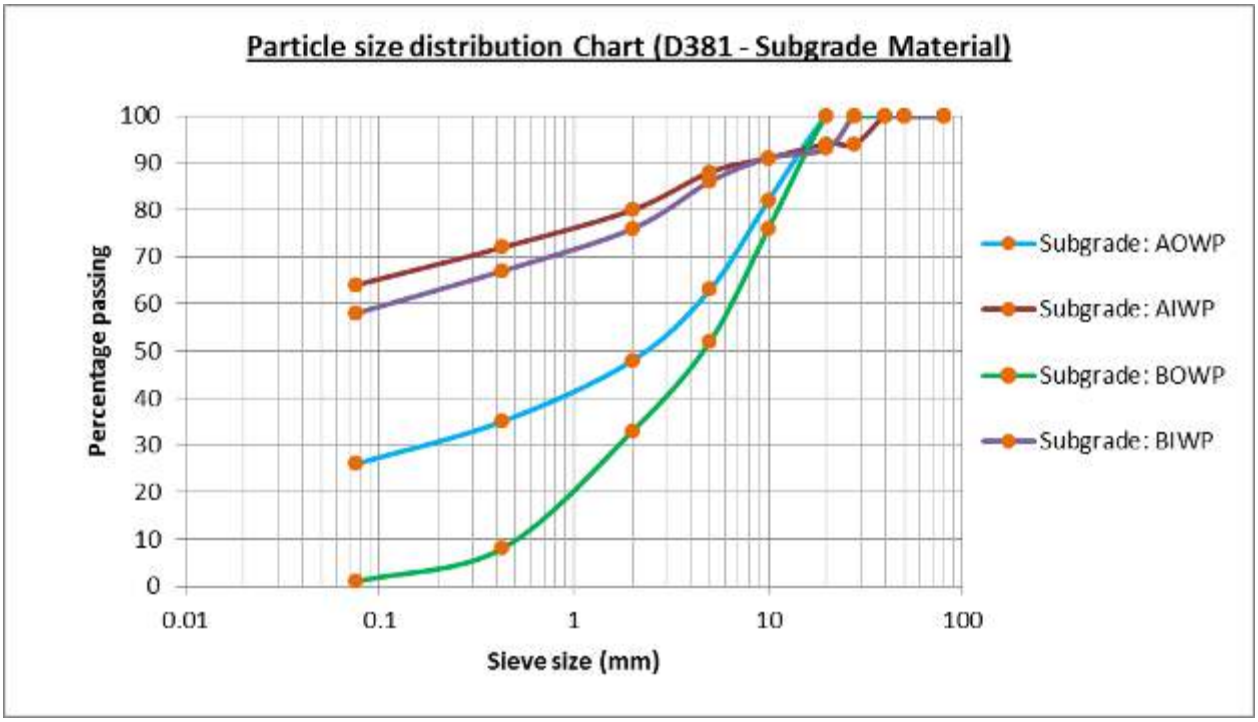


Figure 4-8: Particle size distribution for subgrade material (D381)

4.8.5 Atterberg Limits

Table 4-10 show the index properties of each pavement layer including the subgrade.

Table 4-10: Atterberg limits (D381)

Layer	Liquid Limit	Plastic Limit	Plasticity Index	Linear Shrinkage
Road D381 – Panel A – OWP				
Base	45	26	19	8
Sub-base	44	21	23	11
Subgrade	54	25	29	15
Road D381 – Panel A – IWP				
Base	46	22	24	11
Sub-base	46	19	27	13
Subgrade	44	23	21	11
Road D381 – Panel B – OWP				
Base	44	24	20	10
Sub-base	45	22	23	11
Subgrade	46	19	27	13
Road D381 – Panel B – IWP				
Base	44	23	21	10
Sub-base	46	19	27	13
Subgrade	48	24	24	12

The plasticity index of all the above samples ranges between 15 and 30 and thus all the soils are classified as medium plastic.

4.8.6 Laboratory CBR

Table 4-11 shows the 4-day soaked CBR (AASHTO T180) of each layer including the subgrade. The CBR values are excessively low for base and sub-base materials.

Table 4-11: Laboratory CBR (D381)

4-day soaked CBR (%) (D381)				
Layer	**Panel A**		**Panel B**	
	OWP	**IWP**	**OWP**	**IWP**
Base	19	18	18	20
Sub-base	6	8	6	4
Subgrade	5	5	5	5

4.9 Visual Condition Assessment

4.9.1 Pavement defects assessment

The pavement defects are shown in Table 4-12. Cracks were the main defects observed.

Table 4-12: Visual Condition Assessment (D381)

Fig No	Location (Km)	Defect assessment and description	Photos illustrating the pavement distress & defect
Fig 1	Km 0+000-0+008 LHS	-Alligator cracks on the carriage way	

Fig 2	Km 0+008–0+018 LHS carriage way	-Alligator cracks and surface irregularity on the carriage way	
Fig 3	Km 0+008–0+018 LHS carriage way	-Alligator cracks on the carriage way covering 18m long and 2m width	
Fig 4	Km 0+025 main carriageway	-Extensive alligator cracking on the carriage way	

Fig 5	Km 0+022 – 0+030 LHS	-Pothole and alligator cracks on the LHS lane approximately 40mm depth * 300mm*300mm	
Fig6	Km 0+030 – 0+042 LHS inner wheel path	-Alligator cracks on the inner wheel path	
Fig 7	Km 0+043 – 0+060 LHS main carriage way	-Alligator cracking and deforming on the inner wheel path	

Fig 8	Km 0+100 -0+120	Ponding on the potholes especially on the wheel a paths caused by road poor levels	
Fig 9	Km 0+120 -0+130 LHS	-Vegetation encroaching towards the RHS edge	
Fig10	Km 0+130 -0+160 main carriageway	-Alligator cracking all over the road carriage way and general surface irregularity -Ponding on the depressions	

Fig 11	Km 0+140 -0+160 main carriage way	-Alligator cracking all over the road carriage way and general	
Fig 11	Km 0+200 – 0+305 LHS carriage way	-Extensive alligator cracks and potholes on the carriage way especially on the LHS lane	
Fig 12	Km 0+223-0+305 LHS carriage way	-Extensive alligator cracks on the carriage way especially on the LHS lane	

Fig 13	Km 0+290 – 0+305 main carriage way on both lanes	-Extensive alligator cracks all over the carriage way especially on the LHS lane on	
Fig 14	Km 0+335 – 0+360 main carriage way	-No alligator cracks on the carriage way	
Fig 15	Km 0+356 -0+380 LHS	-Gully erosion on the side and side slope drain approx. 30m long	

Fig 17	Km 0+380 – 0+420 RHS	-Eroded side slope approximately and edge 20m long	
Fig 18	Km 0+400 – 0+420 main carriage way	-Alligator cracks all over the carriage way -Vegetation on the side slope hindering free flow of water along drain	
Fig 19	Km 0+420 -0+440 LHS	-Alligator cracks and Longitudinal depression on the outer wheel path approx. 1.3m by 22m long -Heavy vegetation on the side drain	

Fig 15	Km 0+430 -0+460 RHS main carriage way	-Alligator cracks all over the carriage way most predominant on the outer wheel path right hand side Line -Vegetation on the side slope hindering free flow of water along drain	
Fig 17	Km 0+490 – 0+500 both sides	-Alligator cracks on the carriage way -Heavy vegetation on the side drains both sides	
Fig 18	Km 0+515 – 0+560 LHS	-Heavy vegetation on the side drain especially on the LHS drain -Extensive potholes and deformation on the outer wheel path,	

Fig 19	Km 0+500 – 0+525 LHS	-Blocked with vegetation -Vegetation on the side slope extending to the Edge -Alligator cracks all over the carriage way	
Fig 15	Km 0+530 – 0+560 LHS	-Extensive potholes and deformation on the outer wheel path covering approximately 0.5m by 0.9m area, Ponding on the cracks	
Fig 17	Km 0+587 – 0+600 RHS lane	-Vegetation encroaching towards the RHS edge and shoulders -Silted & Vegetation side drain hindering free flow of water along the drain -Deformation and alligator cracks on the main carriage way	

Fig 18	Km 0+640 – 0+680 main carriage way	-Surface bumpy and irregular -Edge deformation and subsidence on the outer wheel path covering about 20mlong and 7m width with a depth 30mm	
Fig 19	Km 0+717 – 0+737 RHS lane	-Longitudinal depression and alligator on the outer wheel path approx. 1.3m by 22m long -Vegetation encroaching towards the RHS edge	
Fig 20	Km 0+750- 0+800 RHS carriage way	-Depression and ponding on the carriage way 20m long -Grass encroaching from the side drain ,side slope, shoulders and extending towards the edge - Surface bumpy and irregular	

Fig 21	Km 0+896 -0+920 LHS main carriage way both sides of the outer wheel path	-Deformation and depression leading extensive loss of surfacing material	
Fig 22	Km 0+896 -0+920 RHS main carriage way both sides of the outer wheel path	-Longitudinal depression and deformation on the RHS carriage way covering 30m long and 1.3m width caused by poor drainage system	
Fig 23	Km 0+900 – 1+000	-Alligator cracks all over the carriage way and Gully erosion on the side drain and side slope especially on the RHS	

Fig 20	Km 0+950 – 1+000	-Gully erosion on the side drain and side slope -Alligator cracks all over the carriage way	

4.9.2 Present Serviceability Rating

Table 4-13 shows the computation of the PSR. The value of 3.5 corresponds to a "Good" pavement.

Table 4-13: Present Serviceability Rating D381

Road :	TOTAL - KONAMBAYA (D381)												
Section:	Km 0+000 - Km 1+000 main carriage way												
Pavement Structure:								**Date of Survey:**	09/11/2016				
Surfacing	Cold mix asphalt												
Base	Composite emulsion treated base												
Sub-base	Granular natural gravel												
		A	B	C	D	E	F	G	Point summary				
		Point score											
Sub- Section	Length (Km)	General appearance	Surface texture	Bitumen condition	Pot holes	Surface irregularity	Rutting	Cracking	Sum of (∑) Points A-G Max: 40	Average points	%	Remarks	PSR
1. Km 0+000 - 0+500	0.5	4.5	4.5	4.5	4.0	3.0	4.5	1.0	26	3.7	65.0	**Good**	**3.7**
2. Km 0+300 - 0+600	0.5	3.5	4.5	4.5	3.0	2.0	4.0	1.0	22.5	3.2	56.3	**Fair**	**3.2**
Average PSR		**4.0**	**4.5**	**4.5**	**3.5**	**2.5**	**4.3**	**1.0**	**24.3**	**3.5**	**60.6**	**Good**	**3.5**

4.10 Rainfall Data

Table 4-14 shows the precipitation measured during the baseline period.

Table 4-14: Precipitation on D381

Precipitation (mm) on Total – Kona Mbaya Road (D381)										
2016					**2017**					
AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE
0	75.9	78.4	60.0	15.0	0	0	15.8	77.7	51.6	25.5

5 Lord-Kona Bahati Road D382

5.1 Site Description

This Road starts about 1 km from Kwa Lord Shopping centre and joins C77 road some 3 km north of Ol-Joro-Orok Township. The sealed section totals 600 m. Figure 5-1 shows the location map of the road.

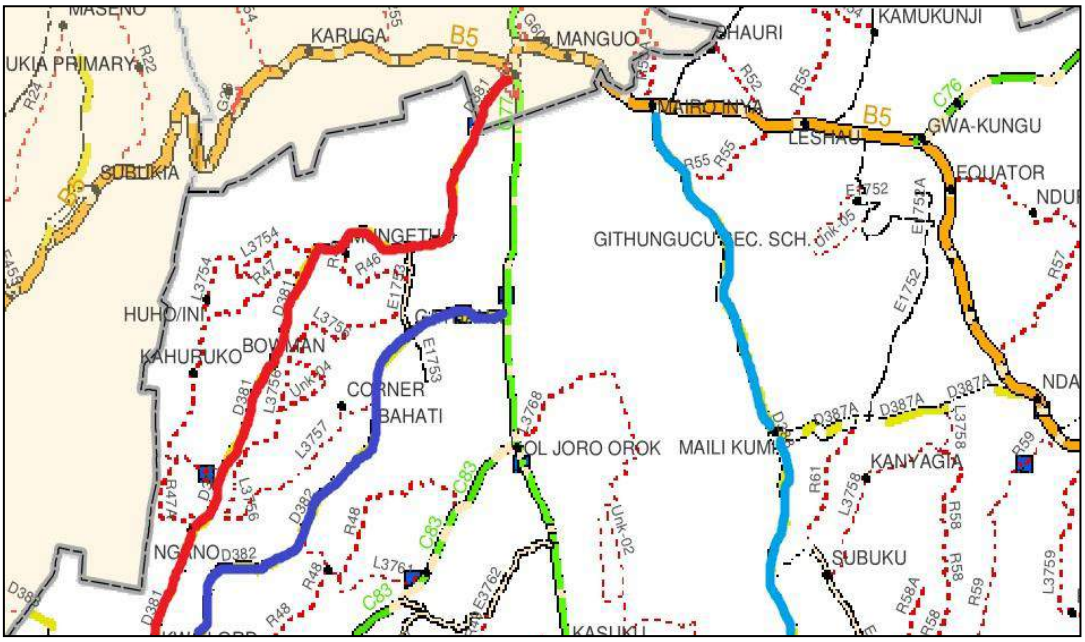


Figure 5-1: Location of Lord - Kona Bahati Road (D382), marked in red

5.2 Pavement Description

Figure 5-2 is a description of the designed pavement structure.

20 mm Cold Mix Asphalt	
140 mm Neat quarry waste base	
260 mm Granular sub-base	
Subgrade	

Figure 5-2: Designed pavement structure (D382)

5.3 Traffic Survey

5.3.1 Classified Traffic Counts

Table 5-1 shows the summary of the traffic count for the road.

Table 5-1: Traffic volume summary (D382)

Vehicle Type	Daily Volume (vpd)
Motorcycles	420
Cars	168
Minibus	177
Bus	21

Light goods vehicles	129
Medium goods vehicles	131
Heavy goods vehicles	48
ADT	**1095**

These counts were done towards the end of the potato harvesting season in the area. The numbers recorded for light, medium and heavy goods vehicles are the highest for all the eleven roads under study. These vehicles mainly transported potatoes from the farms to the market.

5.3.2 Axle Load Survey

Table 5-2 shows the Equivalent Standard Axle (ESA) by vehicle type, and the computed ESA/day.

Table 5-2: ESA/day (D382)

Vehicle Type	**ESA/day**
Bus	0.11
Medium Goods Vehicles	19.12
Heavy Goods Vehicles[1]	XXXX
Total ESA/day	**19.23**

Note 1: Although HGVs were counted during the traffic counts, they were not present during the axle load survey.

5.4 Rutting

Table 5-3 shows the maximum rut depth left and right of each chainage point for the baseline monitoring survey. The average value of 15 nears the critical limit of 20 mm for LVSRs.

Table 5-3: Maximum rut depth (D382)

Chainage	**LHS Rut in mm**	**RHS Rut in mm**
0+003	28	12
0+050	12	11
0+100	10	15
0+150	9	6
0+200	14	12
0+225	12	14
0+240	24	12
0+255	10	10
0+270	12	12
0+285	17	12
0+300	12	13
0+315	12	10
0+330	3	18
0+345	17	16
0+360	7	12
0+375	7	22
0+400	17	20
0+450	14	7

0+500	22	8
0+550	28	6
0+600	28	22
Average	**15**	**13**

5.5 Deflection/Stiffness

Table 5-4 shows the central deflection $D_{0,}$ and the base, sub-base and subgrade stiffness measured at each point.

Table 5-4: Deflection and Stiffness (D382)

Chainage (m)	Lane No.	Stiffness			Normalized Deflections at Geophone Locations (µm) D_0
		EBase (MPa)	ESubbase (MPa)	ESubgrade (MPa)	
0+000	1	1862	255	157	962
0+100	1	1953	269	134	900
0+200	1	2036	280	154	795
0+226	1	1994	270	91	1064
0+255	1	1863	252	117	1100
0+285	1	1535	232	125	910
0+315	1	2082	286	108	850
0+345	1	1927	263	111	1046
0+375	1	2032	282	120	873
0+402	1	1998	272	82	1118
0+501	1	945	151	226	657
0+600	1	1600	237	240	609
0+000	2	1404	213	151	981
0+100	2	1517	230	132	909
0+198	2	1912	260	122	977
0+240	2	1553	229	79	1118
0+270	2	1515	226	109	986
0+300	2	2036	278	136	790
0+330	2	2064	283	129	771
0+360	2	141	132	106	897
0+375	2	184	152	94	803
0+400	2	131	123	91	981
0+500	2	869	135	218	695
0+600	2	1993	270	129	842
0+050	3	1492	221	272	634
0+151	3	2005	274	94	1002
0+240	3	1575	236	94	1028
0+270	3	1588	236	120	880
0+300	3	1930	261	105	1063

0+330	3	2062	284	125	819
0+360	3	1402	212	126	1065
0+451	3	2015	276	159	783
0+551	3	355	36	375	571
0+050	4	1399	212	161	991
0+150	4	1834	250	101	1329
0+240	4	1464	218	110	1065
0+270	4	1493	218	105	1038
0+300	4	1620	245	125	852
0+330	4	1915	260	123	976
0+360	4	1605	242	129	821
0+376	4	2033	275	104	905
0+450	4	2111	291	139	726
0+550	4	915	143	226	670

The complete deflection outputs from the FWD for all the sensors (D_0 up to D_6) for all the test locations are presented in the Appendix section of the report. Figure 5-3 shows the central deflection by chainage along the road. The deflection values are highly variable.

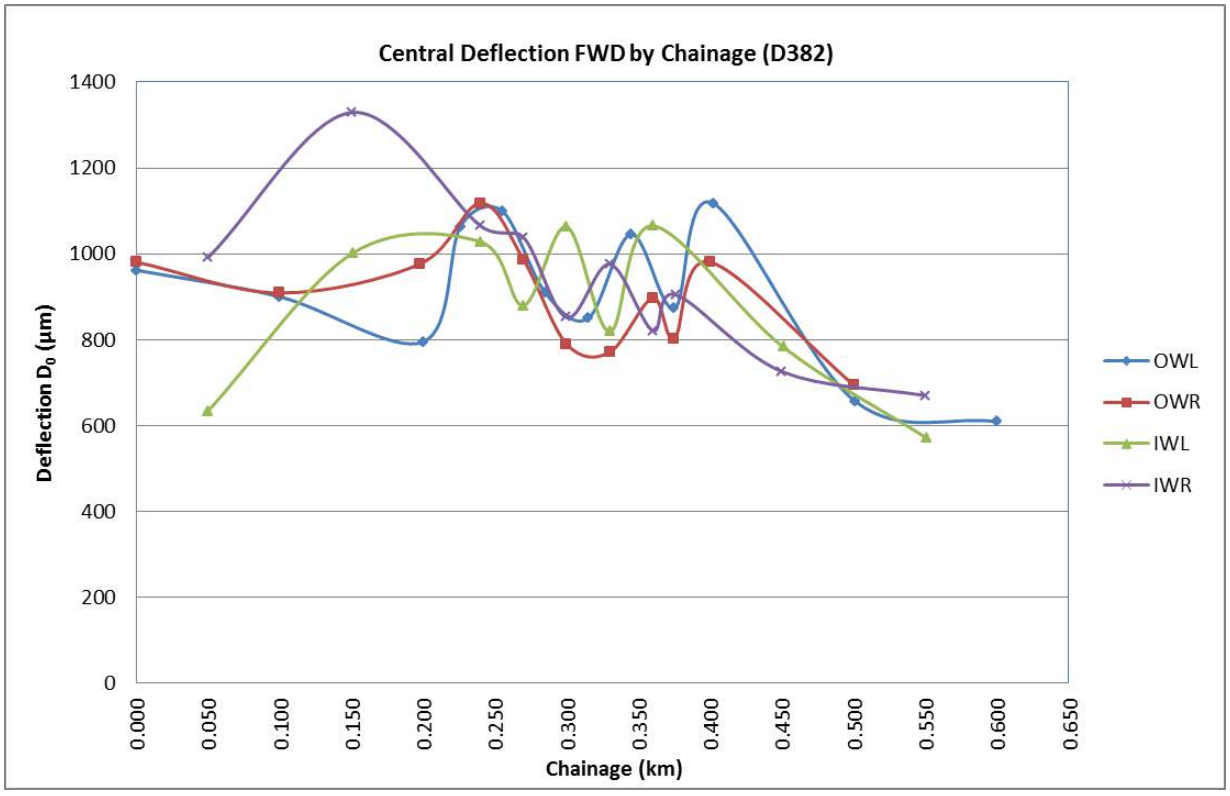


Figure 5-3: Central deflection by chainage (D382)

5.6 DCP Measurements

Table 5-5 below shows the DN and DSN values for each layer for each test point. The values are generally above the specification requirement.

Table 5-5: DN and DSN values (D382)

Chainage (m)	Specifications	≤3.2	≤6.0	≤12	≤19	≤25	DSN800
	Position	0-150	150-300	300-450	450-600	600-800	≥100
0+000	CL	18.3	10.6	10.3	13.1	17.8	65
0+050	RHS	7.8	9.1	16.7	22.5	24.6	61
0+100	CL	5.8	9.0	17.6	20.3	13.3	75
0+150	RHS	8.5	15.4	19.8	12.6	13.2	64
0+200	CL	6.3	10.5	19.8	18.6	16.5	70
0+213	CL	4.1	11.3	16.8	13.6	10.0	97
0+218	CL	7.7	15.7	18.9	17.6	13.8	63
0+218	LHS	6.0	13.8	13.9	11.5	26.2	70
0+218	LHS	8.1	13.7	21.7	17.8	16.4	57
0+218	RHS	6.7	14.0	18.2	15.1	13.8	68
0+218	RHS	9.1	12.8	13.6	18.7	25.0	66
0+225	RHS	7.6	15.7	17.2	11.5	10.0	72
0+390	RHS	8.6	8.8	12.6	15.6	16.4	75
0+390	CL	10.1	10.6	14.8	19.1	14.9	64
0+396	RHS	7.8	11.5	12.5	18.0	21.0	64
0+396	LHS	7.6	11.6	11.8	12.5	17.0	70
0+396	CL	7.1	9.7	13.6	11.6	18.7	75
0+396	CL	7.0	9.9	8.7	15.9	23.2	75
0+400	CL	8.5	11.7	16.6	18.0	11.4	67
0+450	RHS	11.9	9.3	10.8	14.1	10.2	81
0+500	CL	3.1	3.9	9.9	9.1	9.0	151
0+550	RHS	7.0	9.6	18.1	16.7	9.6	80
0+000	CL	3.9	5.3	11.8	14.4	11.3	116

5.7 Roughness Measurements

Roughness values along the road are shown in Table 5-6 and Table 5-7. The values are within acceptable ranges for LVSRs. Figure 5-4 shows the roughness of each lane along the road section.

Table 5-6: Roughness values including bumps (D382)

Lord - Kona Bahati Road (D382)			
LHS		RHS	
Chainage	IRI	Chainage	IRI
0+000-0+100	2.5	0+000-0+050	2.5
0+100-0+200	2.5	0+050-0+150	2.5
0+200-0+226	2.5	0+150-0+240	2.5
0+226-0+285	2.5	0+240-0+270	2.5
0+285-0+315	2.5	0+270-0+300	2.5
0+315-0+345	2.5	0+300-0+330	2.5
0+345-0+402	3.8	0+330-0+360	3.8
0+402-0+501	2.9	0+360-0+376	3.8

0+501-0+600	1.8	0+376-0+450	3.8
		0+450-0+550	2.9

Table 5-7: Roughness values excluding bumps (D382)

Lord - Kona Bahati Road (D382)			
LHS		RHS	
Chainage	IRI	Chainage	IRI
0+000-0+100	2.2	0+000-0+050	2.2
0+100-0+200	2.2	0+050-0+150	2.2
0+200-0+226	2.2	0+150-0+240	2.2
0+226-0+285	2.2	0+240-0+270	2.2
0+285-0+315	2.2	0+270-0+300	2.2
0+315-0+345	2.2	0+300-0+330	2.2
0+345-0+402	2.2	0+330-0+360	2.2
0+402-0+501	2.2	0+360-0+376	2.2
0+501-0+600	2.8	0+376-0+450	2.2
		0+450-0+550	2.2

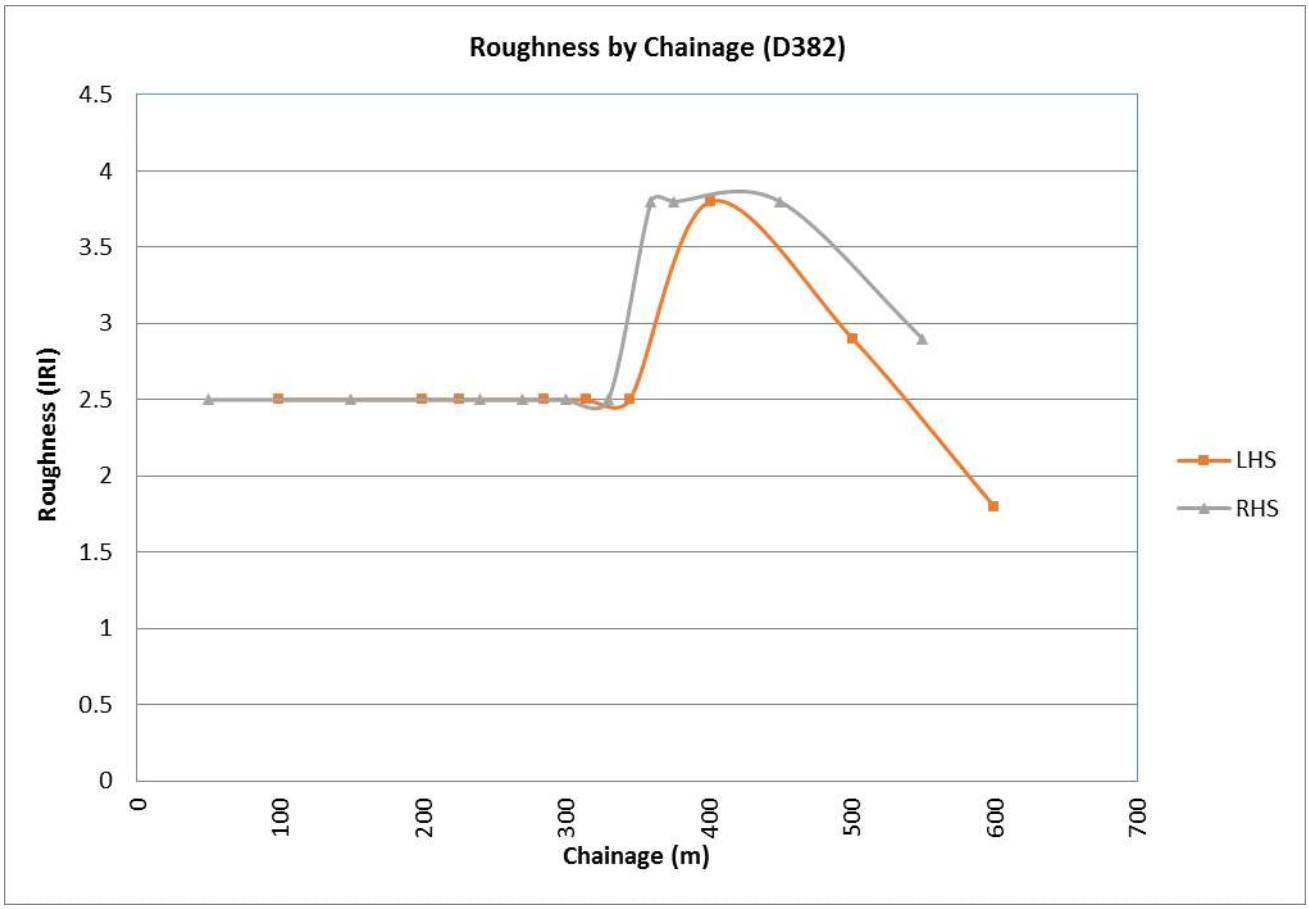


Figure 5-4: Roughness values including bumps by chainage (D382)

5.8 Test Pits

5.8.1 DN Values

Table 5-8 shows the DN of each layer in the structure measured before excavation of the test pit. The values are generally above specification limits, except for the sub-base.

Table 5-8: DN values at test pit (D382)

Depth (mm)	DN values (mm/blow)		
	Specifications	Pit A @ 0+225	Pit B @ 0+390
0 – 150	≤3.2	7.6	8.6
150 – 300	≤6.0	15.7	8.8
300 – 450	≤12	17.2	12.6
450 – 600	≤19	11.5	15.6
600 – 800	≤25	10.0	16.4
DSN800	≥100	72	75

The rest of the DCP details are presented in the Appendix section of the report.

5.8.2 Layer Thicknesses

Figure 5-5 is a representation of the measured layer thicknesses and materials descriptions for the two test pits.

Test Pit A, km 0+225		Test Pit B, km 0+390
20 mm Cold Mix Asphalt		20 mm Cold Mix Asphalt
140 mm Neat quarry waste base		140 mm Neat quarry waste base
260 mm Granular natural gravel sub-base		270 mm Granular natural gravel subbase
Subgrade		Subgrade

Figure 5-5: Layer thicknesses at test pits (D382)

5.8.3 Densities and Moisture Content

Table 5-9 shows the dry density, the MDD, the in-situ moisture content and the OMC (AASHTO T180) for each layer for the two test pits, including the subgrade.

Table 5-9: Density and moisture content at test pits (D382)

Panel	Wheel Path	Layer	MDD (kg/m^3)	In-situ Moisture Content (%)	OMC (%)	Relative Moisture Content (FMC/OMC)
Panel A	OWP	Base	1600	13.0	18.9	0.69
		Sub-base	1500	26.3	20.3	1.30
		Subgrade	1390	29.5	21.6	1.37
	IWP	Base	1635	20.6	17.5	1.18
		Sub-base	1520	27.5	19.7	1.40
		Subgrade	1490	28.1	25.0	1.12
Panel B	OWP	Base	1620	19.6	18.0	1.09
		Sub-base	1570	25.0	18.2	1.37
		Subgrade	1400	27.1	22.3	1.22
	IWP	Base	1610	20.6	18.3	1.13
		Sub-base	1550	25.3	19.0	1.33
		Subgrade	1418	27.8	21.1	1.32

The subbase and subgrade layers of this road recorded higher moisture content than the optimum moisture content, probably due to underground seepage from higher ground.

5.8.4 Particle Size Distribution

The plots in Figure 5-6, Figure 5-7, and Figure 5-8 below illustrate the particle size distribution for each layer. The base material generally lies within the envelope.

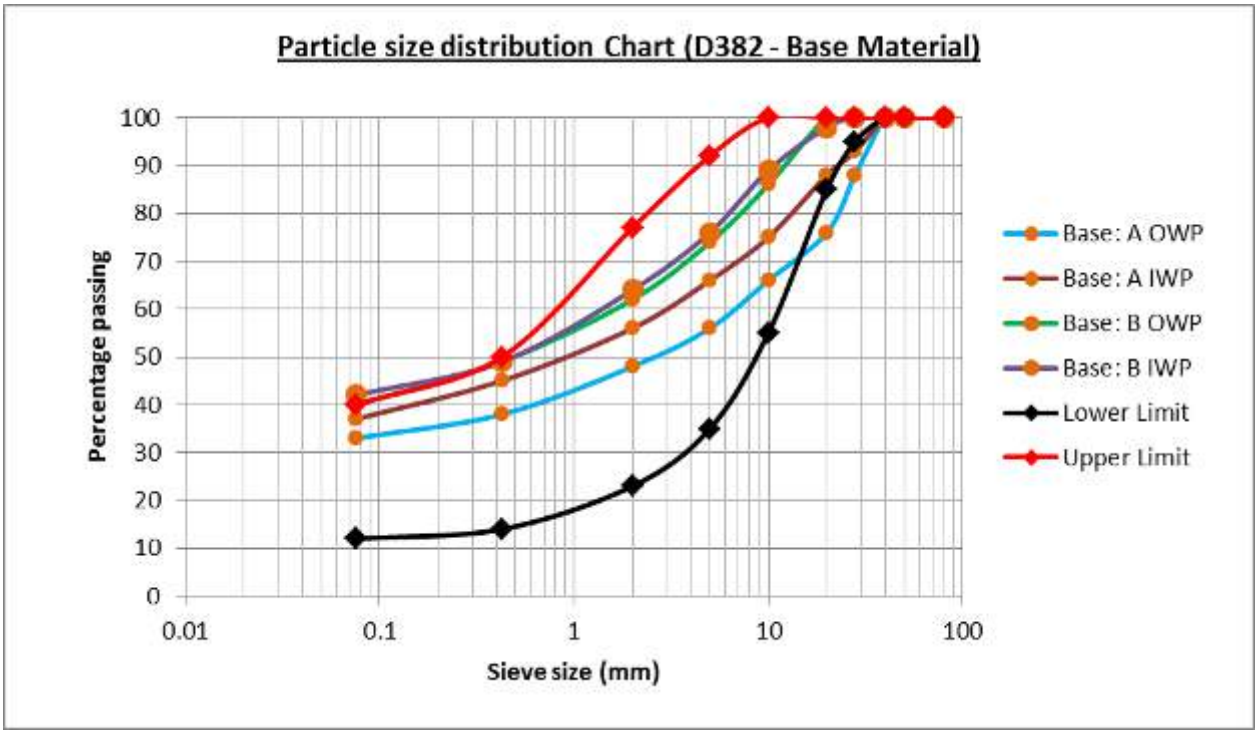


Figure 5-6: Particle size distribution for base material (D382)

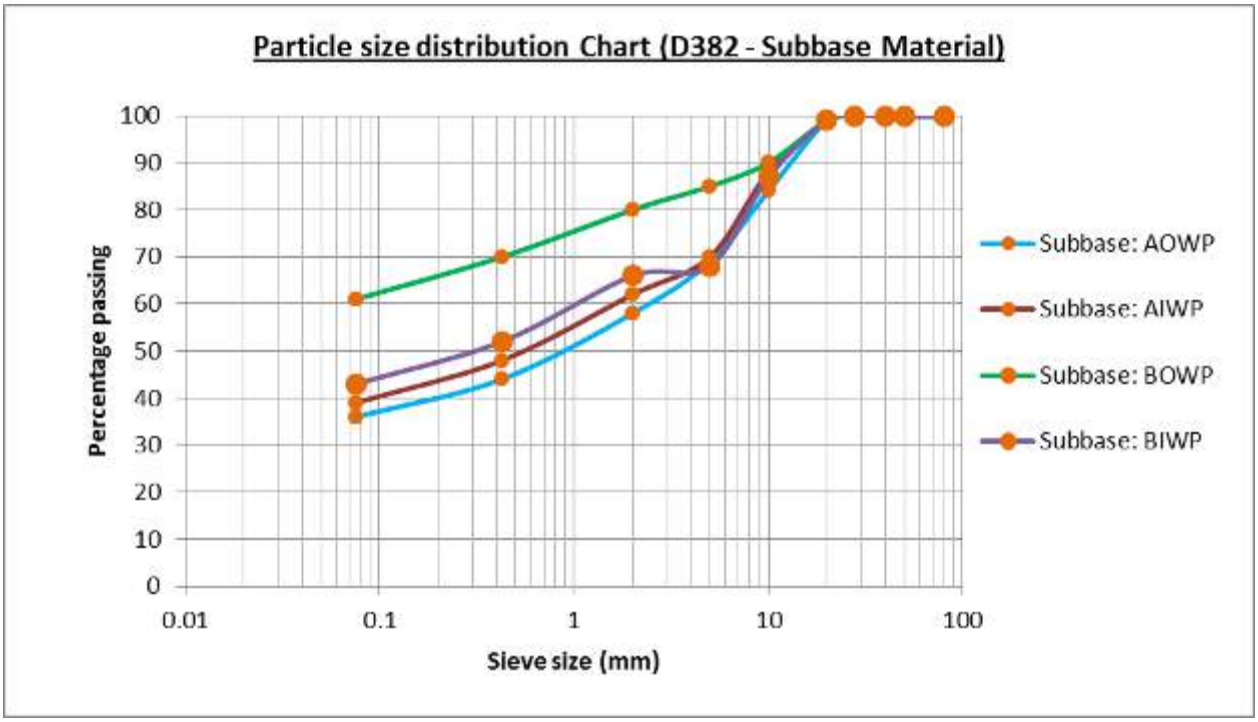


Figure 5-7: Particle size distribution for sub-base material (D382)

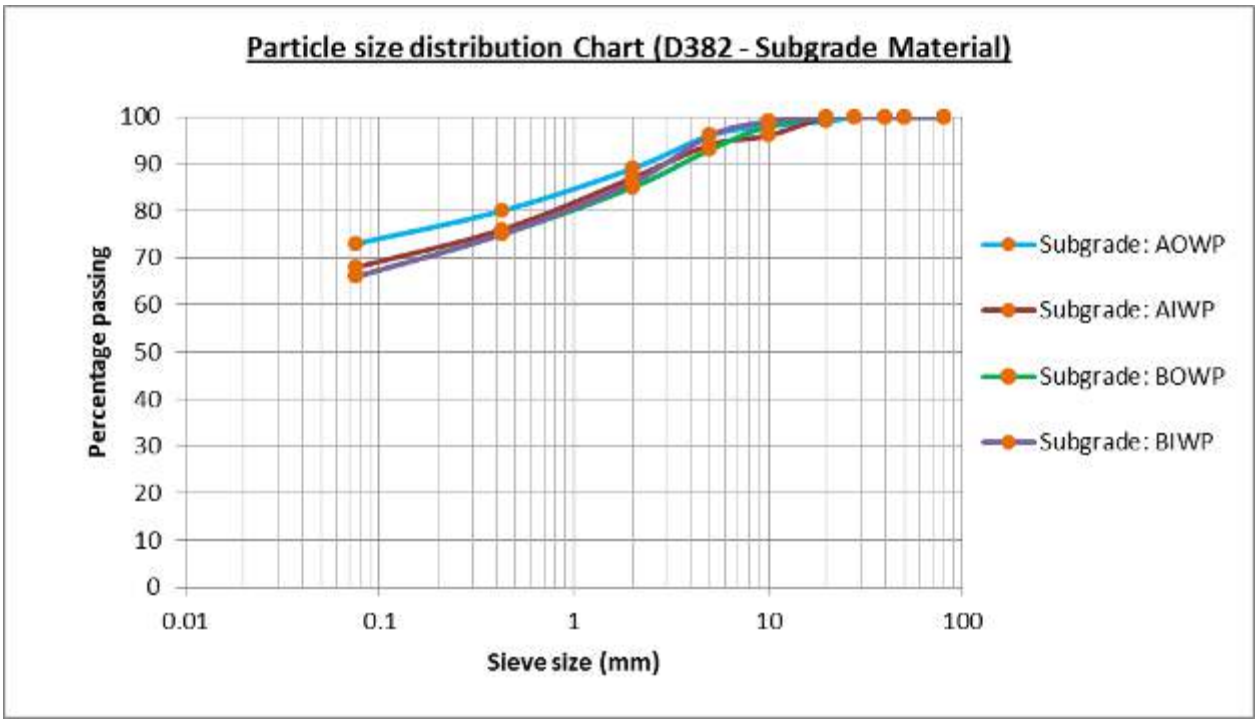


Figure 5-8: Particle size distribution chart for subgrade material (D382)

5.8.5 Atterberg Limits

Table 5-10 below shows the index properties of each pavement layer including the subgrade. From the plasticity indices, all the soils above can be classified as medium plastic.

Table 5-10: Atterberg limits (D382)

Layer	Liquid Limit	Plastic Limit	Plasticity Index	Linear Shrinkage
Road D382 – Panel A - OWP				
Base	46	29	17	9
Sub-base	43	29	14	6
Subgrade	46	19	27	13
Road D382 – Panel A - IWP				
Base	44	21	23	11
Sub-base	45	28	17	9
Subgrade	50	23	27	14
Road D382 – Panel B – OWP				
Base	43	23	20	10
Sub-base	41	23	18	9
Subgrade	47	22	25	13
Road D382 – Panel B - IWP				
Base	45	30	15	8
Sub-base	45	28	17	9
Subgrade	45	29	16	9

5.8.6 Laboratory DN / CBR

Table 5-11 below shows the 4-day soaked CBR (AASHTO T180) of each layer including the subgrade. The CBRs for the base and sub-base are just at the minimum recommended value of 30% for LVSRs (T5-4).

Table 5-11: Laboratory CBR (D382)

4-day soaked CBR (%) (D382)				
Layer	**Panel A**		**Panel B**	
	OWP	**IWP**	**OWP**	**IWP**
Base	30	30	25	35
Sub-base	22	21	20	24
Subgrade	8	8	7	9

5.9 Visual Condition Assessment

5.9.1 Pavement Defects Assessment

Table 5-12 shows the main pavement defects – alligator cracking in this case.

Table 5-12: Visual condition assessment on D382

Fig No	Location (Km)	Defect assessment and description	Photos illustrating the pavement distress & defect
Fig 1	Km 0+000 – 0+011 main carriage way	Alligator cracks and localized loose of pavement materials covering an area 1m by 5m long(A-5m^2) at the centerline	
Fig 2	Km 0+021 main carriage way centerline	Alligator cracks on the outer wheel path covering an area (3m and 0.5m)m2	
Fig 3	K 0+120 LHS	-Erosion gullies on the side drain	

Fig 4	Km 0+030 – 0+045	-Silted and vegetated stone pitching on the side drain and scour checks	
Fig 5	Km 0+085-0+130 RHS	-Moistening of the edge due to grass growing on the side slope and extending to towards the edge	
Fig6	Km 0+145 – 0+190 RHS	-Grass encroaching the road edge moistening and softening the pavement that would eventually lead to premature pavement deformation and failure	

Fig 7	Km 0+140 LHS	-Blocked side drain and silted access culvert	
Fig 8	Km 0+200 – 0+210 main carriage way LHS lane	-Alligator cracks on the outer wheel path accompanied with surfacing failure covering an area of about (1.02m*9m long) 9.05m^2	
Fig 9	Km 0+255 – 0+260 main carriage way at centerline	- Alligator cracks ,pothole and loss of pavement material due insufficient lift thickness at centerline -3.4m*4.4m long	

Fig10	Km 0+250-0+270LHS	-Vegetation on the side drain on the LHS lane	
Fig 11	Km 0+277 main carriage way	-Slight bleeding visible on the surface indicating too much bitumen in the mix approximately 6m long and 2.0 m width (Approx. area 12m $^{2)}$	
Fig 11	Km 0+296-0+310 LHS outer wheel path	- Extensive alligator cracks on the surface, pothole and localized loss of asphalt concrete layer of about 11m long *1.5 m width at especially at the LHS lane	

Fig 12	Km 0+296-0+310 LHS outer wheel path	A close view of Alligator cracks on the surface, pothole and localized loss of asphalt concrete layer of about 11m long *1.5 m width at especially at the LHS lane	
Fig 13	Km 0+330 RHS main carriage at the inner wheel path	Alligator cracks on the road centerline surface and potholes	
Fig 14	Km 0+340 -0+350 Centerline	-Extensive alligator cracks on the surface, pothole and localized loss of asphalt layer of about 11m long *2 m width at especially at the centerline	

Fig 15	Km 0+335 main carriage way at the centerline	-Alligator cracks on the surface	
Fig 17	Km 0+550 -0+600 RHS	-Grass encroaching the road edge moistening and softening the pavement that would eventually lead to premature pavement deformation and failure	

5.9.2 Present Serviceability Rating

Table 5-13 shows the PSR for the road section. This ranges from fair to good.

Table 5-13: Present Serviceability Rating (D382)

Road :	LORD - CORNER BAHATI ROAD (D382)												
Section:	Km 0+000 - Km 0+600 main carriage way												
Pavement Structure:		**Date of Survey:**							9/11/2016				
Surfacing	Cold mix asphalt												
Base	Neat quarry waste												
Sub-base	Natural gravel												
		A	B	C	D	E	F	G	Point summary				
		Point score											
Sub- Section	Length (Km)	General appearance	Surface texture	Bitumen condition	Pot holes	Surface irregularity	Rutting	Cracking	Sum of (∑) Points A-G Max: 40	Average points	%	Remarks	PSR
1. Km 0+000 - 0+300	0.3	4.0	3.5	4.0	2.0	3.0	4.5	2.0	23	3.3	57.5	**Fair**	**3.3**
2. Km 0+300 - 0+600	0.3	4.0	3.5	4.0	3.0	3.0	4.5	3.0	25	3.6	62.5	**Good**	**3.6**
Average PSR		**4.0**	**3.5**	**4.0**	**2.5**	**3.0**	**4.5**	**2.5**	**24.0**	**3.4**	**60.0**	**Good**	**3.4**

5.10 Rainfall Data

The rainfall data collected during the baseline survey is shown in Table 5-14.

Table 5-14: Precipitation on D382

Precipitation (mm) on Lord – Kona Bahati Road (D382)										
2016					**2017**					
AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE
15.6	6.0	5.3	6.1	1.5	0	0	20.4	58.9	152.6	17.0

6 Mairo Inya-Kaheho Road D388

6.1 Site Description

This road starts at Mairo-Inya shopping centre and extends 8.5 km southwards towards Kaka Shopping Centre. Figure 6-1 shows the location of the road.

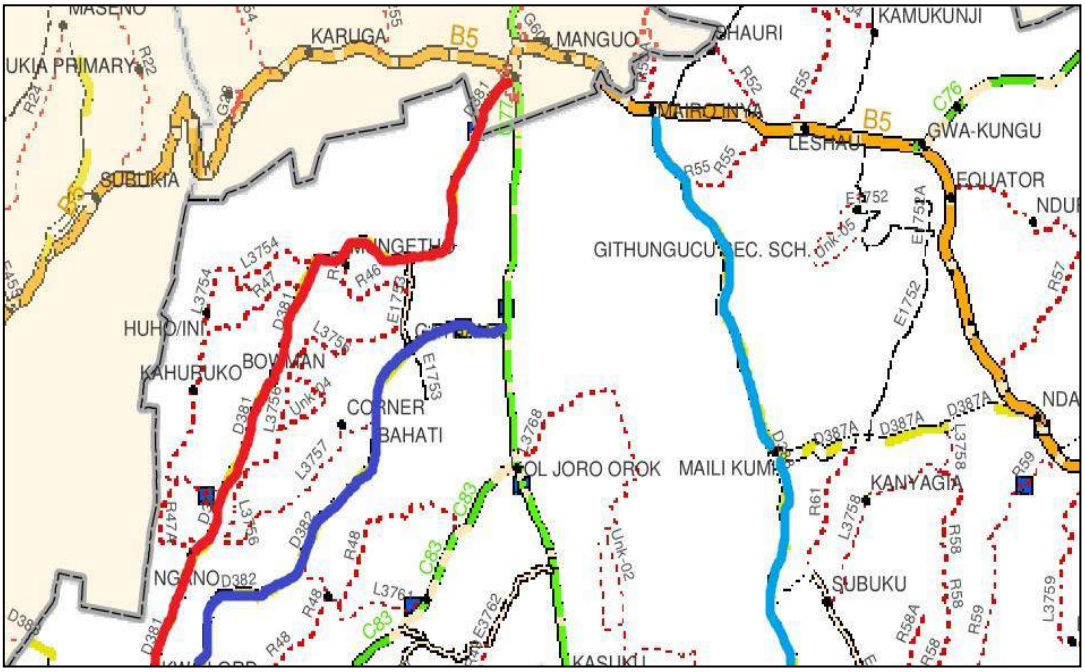


Figure 6-1: Location of Mairo Inya - Kaheho Road (D388), marked in light blue

6.2 Pavement Description

Figure 6-2 is a description of the designed pavement structure.

Figure 6-2: Designed pavement structure (D388)

6.3 Traffic Survey

6.3.1 Classified Traffic Counts

Table 6-1 shows the summary of the traffic count for this road. The road carries a very large number of motorcycles.

Table 6-1: Traffic Volume Summary

Vehicle Type	Daily Volume (vpd)
Motorcycles	1,114
Cars	306
Minibus	96

Bus	10
Light goods vehicles	57
Medium goods vehicles	33
Heavy goods vehicles	1
ADT	**1617**

6.3.2 Axle Load Survey

Table 6-2 below is a table of ESA by vehicle type, and computed ESA/day.

Table 6-2: Equivalent standard axle (D388)

Vehicle Type	**ESA/day**
Bus	3.5
Medium Goods Vehicles	16.71
Heavy Goods Vehicles[1]	XXX
Total ESA/day	**20.21**

Note 1: Although HGVs were counted during the traffic counts, they were not present during the axle load survey.

6.4 Rutting

Table 6-3 below shows the maximum rut depth left and right of each chainage point. The average value of 14 mm is nearing critical for LVSRs.

Table 6-3: Maximum Rut Depth

Chainage	**LHS Rut in mm**	**RHS Rut in mm**
0+000	11	8
0+025	3	16
0+040	16	15
0+055	12	6
0+070	32	5
0+085	8	12
0+100	14	6
0+115	26	4
0+130	9	9
0+140	10	9
0+160	7	5
0+175	12	25
0+200	3	18
0+250	22	28
0+300	5	12
0+350	34	26
0+400	21	24
0+450	5	3
0+500	12	5
0+550	4	19
0+600	9	19
0+650	9	21

0+700	8	16
0+750	4	20
0+800	4	25
0+850	2	16
0+900	3	1
0+950	5	4
1+000	4	6
Average	**11**	**14**

6.5 Deflection/Stiffness

Table 6-4 shows the D_0 and the base, sub-base and subgrade stiffness measured at each point.

Table 6-4: Deflection and stiffness (D388)

Chainage (m)	Lane No.	Stiffness			Normalized Deflections at Geophone Locations (µm) D_0
		EBase (Mpa)	ESubbase (Mpa)	ESubgrade (Mpa)	
0+000	1	300	200	46	919
0+025	1	139	147	60	1103
0+056	1	90	90	170	1030
0+087	1	197	66	178	817
0+115	1	225	48	224	770
0+145	1	195	71	158	796
0+175	1	877	337	66	1487
0+200	1	97	94	159	1247
0+300	1	134	112	208	1116
0+400	1	234	63	186	732
0+500	1	121	124	133	1000
0+600	1	126	132	166	859
0+700	1	1292	350	107	1048
0+800	1	310	84	607	465
0+900	1	3731	716	107	219
1+000	1	2998	472	82	309
0+040	2	188	67	112	927
0+070	2	175	45	185	926
0+100	2	317	50	272	598
0+130	2	246	53	183	711
0+160	2	193	57	159	842
0+250	2	213	68	193	749
0+350	2	216	78	141	782
0+450	2	203	61	137	838
0+550	2	171	61	127	944
0+650	2	104	121	99	932

0+750	2	214	178	125	681
0+850	2	100	94	143	1295
0+950	2	2522	29922	169	119
0+040	3	203	37	129	926
0+071	3	218	36	255	776
0+100	3	276	40	321	653
0+130	3	173	58	120	946
0+160	3	205	67	143	832
0+251	3	333	72	170	629
0+350	3	183	44	151	887
0+452	3	172	49	143	916
0+551	3	183	57	127	892
0+650	3	1026	403	93	954
0+750	3	1146	379	114	815
0+850	3	1097	431	59	1983
0+950	3	2455	19194	191	122
0+000	4	155	150	89	844
0+025	4	202	30	157	928
0+054	4	246	56	175	754
0+085	4	265	37	316	690
0+115	4	233	39	195	774
0+145	4	161	40	150	959
0+175	4	136	40	106	1166
0+199	4	165	33	252	922
0+300	4	195	31	318	874
0+398	4	309	52	237	642
0+500	4	286	53	197	670
0+600	4	235	59	186	735
0+700	4	170	166	88	934
0+800	4	264	186	152	534
0+900	4	1320	2078	136	258
1+000	4	5299	13988	124	132

The complete deflection outputs from the FWD for all the sensors (D_0 up to D_6) for all the test locations are presented in the Appendix section of the report. Figure 6-3 shows the central deflection along each wheel path. The values vary significantly.

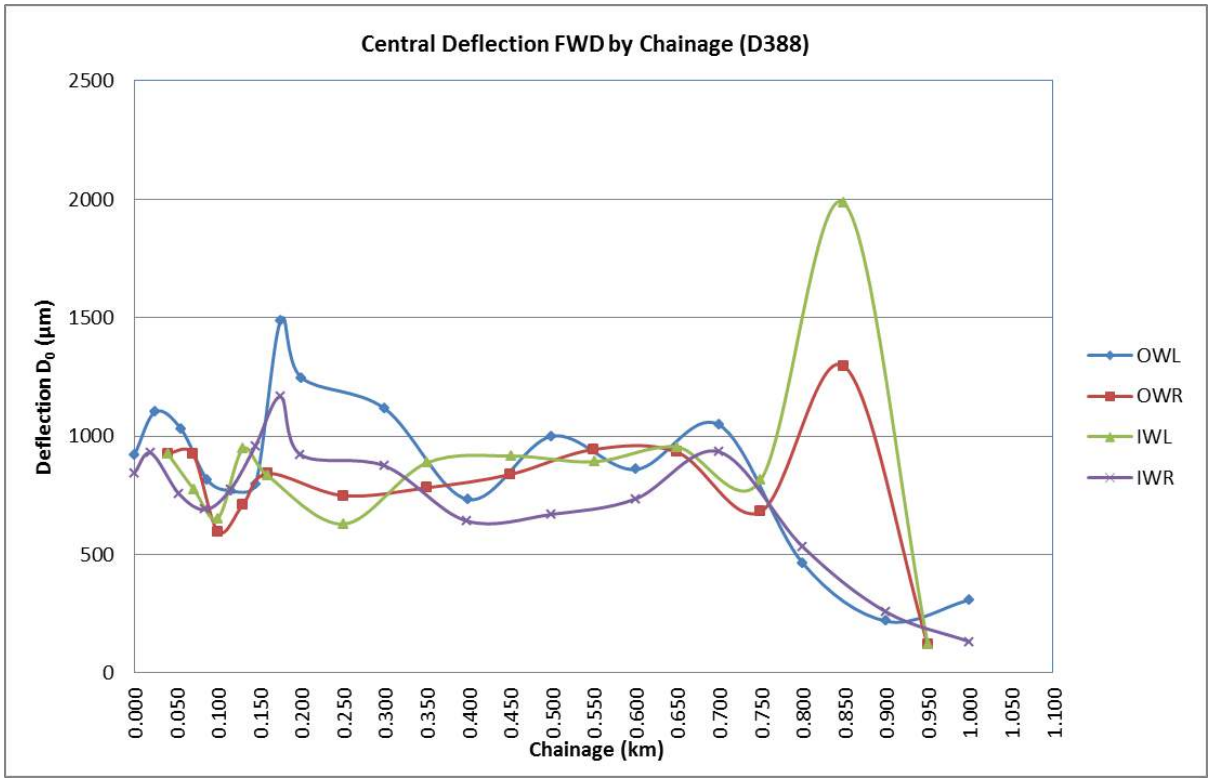


Figure 6-3: Central deflection by chainage (D388)

6.6 DCP Measurements

Table 6-5 shows the DN and DSN values by layer for each test point. The values lie on either side of the specifications.

Table 6-5: DN and DSN values (D388)

Chainage (m)	Specifications	≤3.2	≤6.0	≤12	≤19	≤25	DSN800
	Position	0-150	150-300	300-450	450-600	600-800	≥100
0+065	LHS	9.6	8.7	10.0	13.6	13.5	78
0+070	OWR	5.2	9.7	13.4	13.6	10.3	102
0+070	IWR	5.6	6.6	12.4	12.2	23.3	90
0+070	CL	3.3	4.7	16.2	4.8	7.0	168
0+070	IWL	3.9	6.6	8.2	15.6	18.2	114
0+070	OWL	6.8	13.6	11.3	15.1	10.2	87
0+190	LHS	10.0	10.5	18.2	33.8	24.0	53
0+194	OWL	10.0	10.5	18.2	33.8	24.0	53
0+194	IWL	5.3	4.8	5.9	9.7	17.3	124
0+194	CL	6.7	6.0	5.1	5.9	6.9	141
0+194	IWR	5.7	5.3	5.6	8.2	9.2	138
0+194	OWR	8.2	8.1	7.7	8.1	9.2	99
0+200	LHS	8.7	15.3	15.2	18.2	18.7	58
0+250	RHS	3.8	4.0	7.1	6.2	7.1	164
0+300	LHS	10.2	14.3	11.1	12.7	19.7	65
0+350	RHS	4.3	6.7	7.2	8.0	7.7	141

0+400	LHS	8.2	11.4	11.4	11.2	11.8	80
0+450	RHS	4.7	5.6	5.5	7.0	7.5	149
0+500	LHS	7.2	10.1	11.9	4.9	9.9	116
0+550	RHS	11.2	8.0	11.7	18.1	17.0	88
0+600	LHS	6.8	10.4	12.4	21.5	15.1	86
0+650	RHS	4.4	6.0	6.6	7.5	7.2	150
0+700	LHS	5.1	11.7	13.3	34.6	26.9	73
0+750	RHS	8.1	18.4	15.8	19.3	15.5	67
0+800	LHS	5.3	8.5	12.6	13.2	6.2	126
0+850	RHS	9.2	17.4	7.0	3.7	3.7	155

6.7 Roughness Measurements

Roughness values shown in Table 6-6 and Table 6-7 are acceptable for LVSRs. Figure 6-4 shows the roughness of each lane along the road section.

Table 6-6: Roughness values including humps (D388)

Mairo Inya - Kaheho Road (D388)			
LHS		RHS	
Chainage	IRI	Chainage	IRI
0+000-0+040	5.3	0+000-0+025	5.3
0+040-0+071	5.3	0+025-0+054	5.3
0+071-0+100	2.3	0+054-0+085	2.3
0+100-0+130	2.3	0+085-0+115	2.3
0+130-0+160	2.3	0+115-0+145	2.3
0+160-0+251	4.5	0+145-0+175	2.3
0+251-0+350	4.0	0+175-0+199	4.2
0+350-0+452	3.3	0+199-0+398	4.0
0+452-0+551	2.7	0+398-0+500	1.0
0+551-0+650	5.2	0+500-0+600	2.7
0+650-0+750	6.0	0+600-0+700	6.0
0+750-0+850	4.3	0+700-0+800	3.8
0+850-0+950	5.0	0+800-0+900	5.0
		0+900-1+000	4.2

Table 6-7: Roughness values excluding humps (D388)

Mairo Inya - Kaheho Road (D388)			
LHS		RHS	
Chainage	IRI	Chainage	IRI
0+000-0+040	3.1	0+000-0+025	3.1
0+040-0+071	3.1	0+025-0+054	3.1
0+071-0+100	3.9	0+054-0+085	3.9
0+100-0+130	3.9	0+085-0+115	3.9
0+130-0+160	3.9	0+115-0+145	3.9
0+160-0+251	3.1	0+145-0+175	3.9

0+251-0+350	3.1	0+175-0+199	3.1
0+350-0+452	3.9	0+199-0+398	3.1
0+452-0+551	3.1	0+398-0+500	3.9
0+551-0+650	3.1	0+500-0+600	3.9
0+650-0+750	3.1	0+600-0+700	3.1
0+750-0+850	3.1	0+700-0+800	3.1
0+850-0+950	3.1	0+800-0+900	3.1
		0+900-1+000	3.1

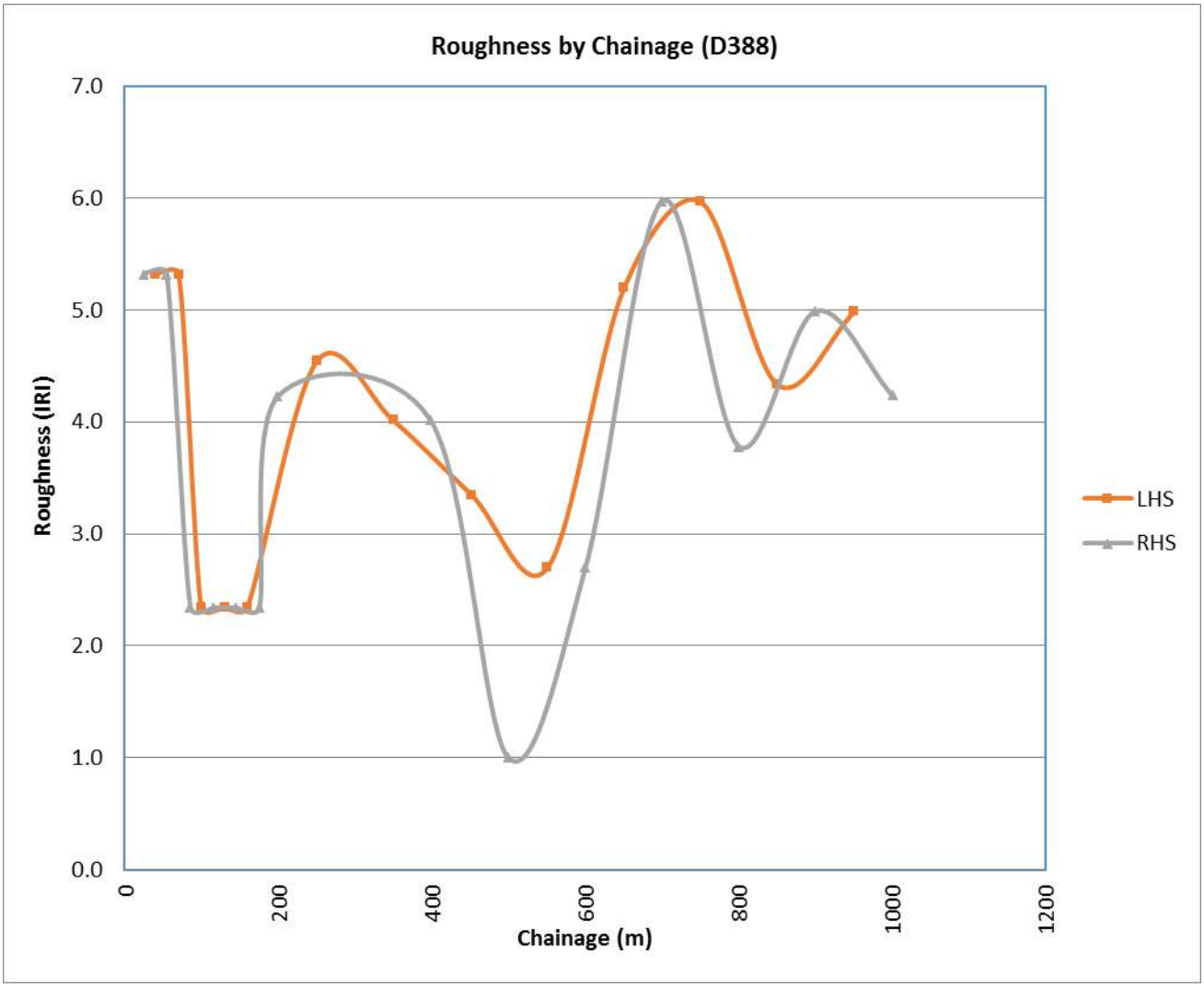


Figure 6-4: Roughness values including humps by chainage (D388)

6.8 Test Pits

6.8.1 DN Values

Table 6-8 shows the DN of each layer in the structure measured before excavation. The values do not meet the specifications for the base layer but generally meet the sub-base requirements.

Table 6-8: DN values at test pit (D388)

Depth (mm)	DN values (mm/blow)		
	Specifications	Pit A @ 0+065	Pit B @ 0+190
0 – 150	≤3.2	9.6	10.0
150 – 300	≤6.0	8.7	10.5
300 – 450	≤12	10.0	18.2
450 – 600	≤19	13.6	33.8
600 – 800	≤25	13.6	24.0
DSN800	≥100	78	53

The rest of the DCP details are presented in the Appendix section of the report.

6.8.2 Layer Thicknesses

Figure 6-5 is an illustration of the measured layer thickness and descriptions as obtained from the test pit.

Test Pit A, km 0+065		Test Pit B, km 0+190
20 mm Cold Mix Asphalt		20 mm Cold Mix Asphalt
150 mm improved natural gravel base		150 mm improved natural gravel base
250 mm Granular sub-base		250 mm Granular sub-base
Subgrade		Subgrade

Figure 6-5: Pavement structure (D388)

6.8.3 Densities and Moisture Content

Table 6-9 shows the dry density, the MDD, the in-situ moisture content and the OMC (AASHTO T180) for each layer for the two test pits, including the subgrade. No IMC results are available for this road.

Table 6-9: Density and moisture contents at Test Pits (D388)

Panel	Wheel Path	Layer	MDD (kg/m^3)	In-situ Moisture Content (%)	OMC (%)	Relative Moisture Content (FMC/OMC)
Panel A	OWP	Base	1500		21.5	
		Sub-base	1565		21.3	
		Subgrade	1320		30.3	
	IWP	Base	1520		20.8	
		Sub-base	1550		21.8	
		Subgrade	1380		29.2	
Panel B	OWP	Base	1365		27.2	

		Sub-base	1505		22.3	
		Subgrade	1385		28.2	
	IWP	**Base**	1485		22.6	
		Sub-base	1525		21.9	
		Subgrade	1370		25.8	

6.8.4 Particle Size Distribution

The plots in Figure 6-6, Figure 6-7, and Figure 6-8 below show the particle size distribution for each layer. The base material generally fits into the specification envelope, except on the larger sieves, where the material is generally coarser.

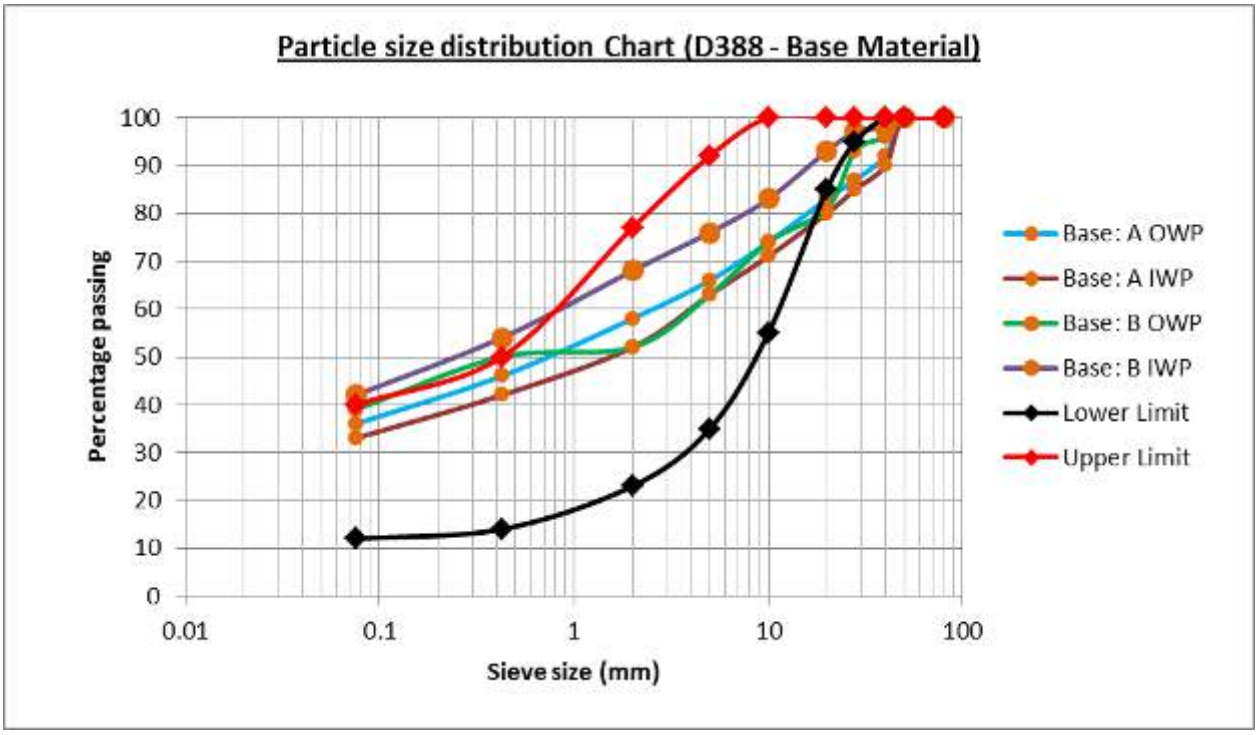


Figure 6-6: Particle size distribution for base material (D388)

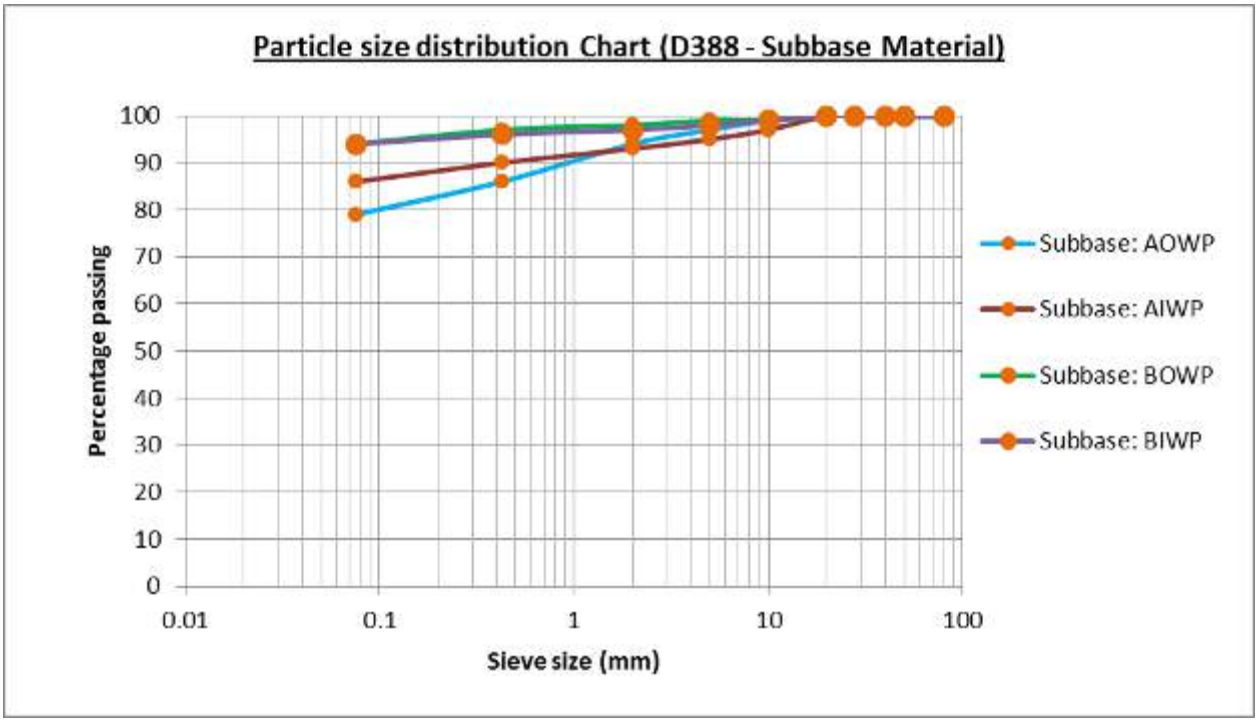


Figure 6-7: Particle size distribution for subbase material: (D388)

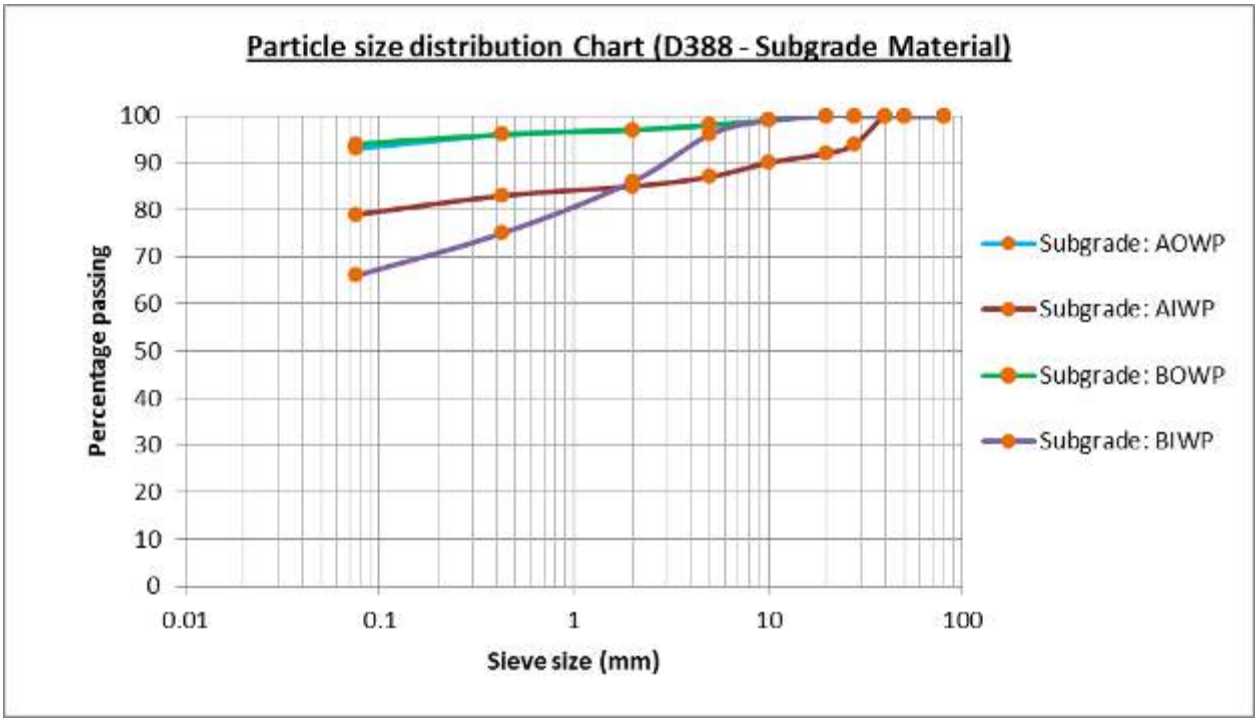


Figure 6-8: Particle size distribution chart for subgrade material (D388)

6.8.5 Atterberg Limits

Table 6-10 shows the index properties of each pavement layer including the subgrade. From the plasticity index, all the above soils are classified as medium plastic.

Table 6-10: Atterberg limits at test pits (D388)

Layer	Liquid Limit	Plastic Limit	Plasticity Index	Linear Shrinkage
Road D388 – Panel A - OWP				
Base	40	23	17	9
Sub-base	49	27	22	12
Subgrade	48	24	24	12
Road D388 – Panel A - IWP				
Base	52	34	18	9
Sub-base	56	40	16	8
Subgrade	56	29	27	14
Road D388 – Panel B - OWP				
Base	48	33	15	7
Sub-base	47	26	21	12
Subgrade	47	23	24	13
Road D388 – Panel B - IWP				
Base	38	18	20	10
Sub-base	49	27	22	12
Subgrade	52	30	22	11

6.8.6 Laboratory CBR

Table 6-11 shows the 4-day soaked CBR of each layer including the subgrade. The base and sub-base were measured as per AASHTO –T180 and the subgrade as per AASHTO T-99. The CBR values for the base and subbase are considerably low compared to the required values for Low volume sealed roads.

Table 6-11: Laboratory CBR (D388)

4-day soaked CBR (%) (D388)				
Layer	**Panel A**		**Panel B**	
	OWP	**IWP**	**OWP**	**IWP**
Base	18	20	16	19
Sub-base	5	9	7	8
Subgrade	4	2	3	5

6.9 Visual Condition Assessment

6.9.1 Pavement Defects Assessment

The main surface defect on this road is alligator cracking as shown in Table 6-12.

Table 6-12: Visual condition assessment of D388

Fig No	Location (Km)	Defect assessment and description	Photos illustrating the pavement distress & defect
Fig 1	Km 0+000 – 0+010 RHS	Eroded and breaking edge at Km 0+007RHS	
Fig 2	Km 0+025 – 0+050 main carriage way	-Alligator cracks on both side of the carriage way on isolated areas approx. 30m long	
Fig3	Km 0+055- 0+095 main carriage way both sides	-Alligator cracks all over the carriage way covering approx area of about (6m*10m)60m^2 long	

Fig 4	Km 0+095-0+115 LHS	-Slightly eroded, caused by stopping matatus picking and dropping passengers -Slight vegetation causing ponding on the side drain	
Fig 5	Km 0+116 – 0+140 main carriageway	-Alligator cracks scattered in isolated areas within carriage way	
Fig6	Km 0+100-0+145RHS	- Slightly eroded ,caused stopping matatus picking and dropping passengers approx. 40m long	

Fig 7	Km 0+145 -0+180 RHS and main carriage way	-Alligator cracks scattered all over the carriage way -Eroded side slope -Spot bleeding on the main carriageway	
Fig 8	Km 0+234– 0+250 LHS	-Alligator cracks scattered all over the carriage way covering 16m long	
Fig 9	Km 0+300 – 0+350 main carriage way	-Alligator cracks scattered all over the carriage way covering 100m long and 3m width -Bleeding on the LHS main carriage way	

Fig10	Km 0+310- 0+350 main carriage way and RHS	-Edge erosion and edge breaking of about 40m long and average width of 70mm -Alligator cracks scattered all over the carriage way covering 100m long and 3m width and bleeding on the surface	
Fig 11	Km 0+400 -0+473	-Vegetation on the side slope hindering free flow of water to the drain	
Fig 12	Km 0+473-0+500	-Alligator cracks all over the carriage way covering 30m long and 3m width	

Fig 13	Km 0+500 -0+600	-Alligator cracks all over the carriage way covering 100m long and 4m width especially on the centerline	
Fig 14	Km 0+600 – 0+642 at the centerline	-Pothole developing at the centerline -Visible alligator cracks on the LHS carriage way	
Fig 15	Km 0+683 – 0+816 main carriage way	-No visible defect on the main carriage way	

Fig 16	Km 0+816-0+821 LHS	Alligator cracks on the LHS carriage way , area -(7m*2m) 14m^2	
Fig 17	Km 0+843 – 0+854 LHS	Alligator cracks ,depression and deformation on the main carriage way on the outer wheel path 10m long and 3m width	
Fig 18	Km 0+937 RHS	-No visible defect on the main carriage way -Loss of surface texture and aggregates (3.0*5)15m^2 long	

Fig 19	Km 0+963-0+990 LHS	-Transverse cracks on the concrete slab on LHS	

6.9.2 Present Serviceability Rating

Table 6-13 shows the PSR for the road section. The value of 4.2 is considered "Good".

Table 6-13: Present Serviceability Rating (D388)

Road :	Mairo inya - Kahero Road (D388)													
Section:	Km 0+000 - Km 1+ 000 main carriage way													
Pavement Structure:					**Date of Survey:**				10/11/2016					
Surfacing	Asphalt concrete mix and Concrete pavement													
Base	Improved natural gravel													
Sub-base	Neat natural gravel													
		A	**B**	**C**	**D**	**E**	**F**	**G**	**Point summary**					
	Point score													
Sub- Section	Length (Km)	General appearance	Surface texture	Bitumen condition	Pot holes	Surface irregularity	Rutting	Cracking	Sum of (∑) Points A-G Max: 40	Average points	%	Remarks	PSR	**Remarks**
1. Km 0+000 - 0+854	0.854	4.5	4.5	5.0	4.0	4.0	5.0	1.0	28	4.0	70.0	**Good**	**4.0**	A/c mix
2. Km 0+854 - 1+000	0.146	4.5	4.3	4.0	5.0	4.5	5.0	3.0	30.3	4.3	75.8	**Good**	**4.3**	Concrete mix
Average PSR		**4.5**	**4.4**	**4.5**	**4.5**	**4.25**	**5**	**2**	**29.15**	**4.16**	**72.9**	**Good**	**4.2**	

6.10 Rainfall Data

The rainfall measured during the baseline period is shown in Table 6-14.

Table 6-14: Precipitation at D388

Precipitation (mm) at Mairo Inya – Kaheho Road (D388)										
2016					**2017**					
AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE
12.5	5.0	4.3	4.8	0	0	0	12.1	54.6	52.0	14.0

7 Muruka-Kandara Road D415

7.1 Site Description

This is a 7.5 km trial section starting at Makenzi shopping centre, passes through Muruka, and goes up to Kandara. Makenzi is just 5 km off A2 road. The road is in Murang'a County. Figure 7-1 shows the location map.

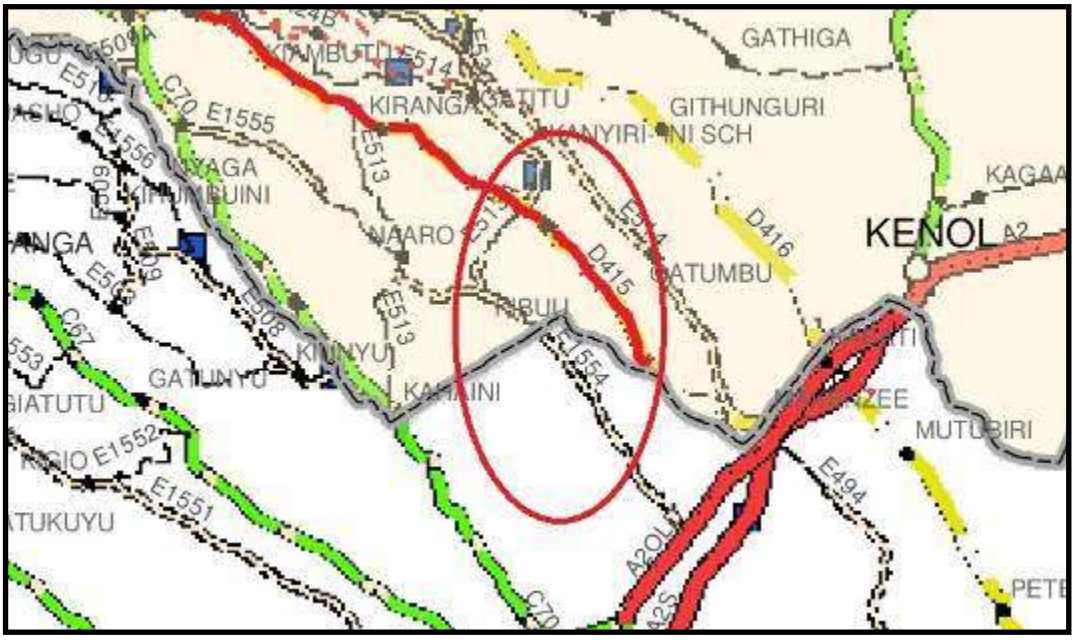


Figure 7-1: Location of Makenzi - Kandara road (D415), marked in red

7.2 Pavement Description

Figure 7-2 is a representation of the designed pavement structure thickness.

20 mm Cold Mix Asphalt	
200 mm Emulsion treated lateritic gravel base	
200 mm Neat lateritic gravel sub-base	
Subgrade	

Figure 7-2: Designed pavement structure (D415)

7.3 Traffic Survey

7.3.1 Classified Traffic Counts

Table 7-1 shows the summary of the traffic count conducted on this road. Motorcycles dominate this road for the better part of the day, connecting people between Makenzi and Kandara and the numerous settlements along the road.

Table 7-1: Traffic volume summary (D415)

Vehicle Type	Daily Volume (vpd)
Motorcycles	2381
Cars	355
Minibus	156
Bus	4
Light Goods Vehicle	120
Medium Goods Vehicle	71
Heavy Goods Vehicle	23
ADT	**3110**

7.3.2 Axle Load Survey

Table 7-2 is a summary table of ESA by vehicle type, and the computed ESA/day

Table 7-2: Traffic ESA (D415)

Vehicle Type	ESA/day
Bus	0.79
Medium Goods Vehicles	66.99
Heavy Goods Vehicles	29.38
Total ESA/day	**97.16**

7.4 Rutting

Table 7-3 shows the maximum rut depth left and right of each chainage point. The rut depths for this road are the lowest compared to the other roads.

Table 7-3: Maximum rut depth (D415)

Chainage	LHS Rut in mm	RHS Rut in mm
0+000	6	5
0+050	2	2
0+100	7	3
0+150	3	3
0+200	10	7
0+250	6	12
0+300	2	3
0+350	7	12
0+400	5	9
0+425	10	2
0+440	1	12
0+445	1	8

0+470	9	7
0+485	12	3
0+500	3	7
0+515	1	12
0+530	5	1
0+545	9	2
0+560	12	6
0+575	12	2
0+600	0	12
0+650	4	6
0+700	12	2
0+750	4	6
0+800	4	2
0+850	10	4
0+900	9	10
0+950	1	7
0+000	8	3
Average	**6**	**6**

7.5 Deflection/Stiffness

Table 7-4 shows the central deflection D_0 and the base, sub-base and subgrade stiffness measured at each point.

Table 7-4: Deflection and stiffness (D415)

Chainage (m)	Lane No.	Stiffness			Normalized Deflections at Geophone Locations (µm) D_0
		EBase (MPa)	ESubbase (MPa)	ESubgrade (MPa)	
0+000	1	176	47	111	958
0+050	1	362	102	160	611
0+100	1	234	51	152	793
0+151	1	273	78	141	734
0+200	1	422	56	272	521
0+250	1	377	50	241	573
0+300	1	386	79	157	603
0+350	1	279	33	229	720
0+400	1	306	73	130	692
0+425	1	1867	291	140	650
0+440	1	1035	290	109	688
0+455	1	380	96	160	596
0+471	1	373	65	171	596
0+485	1	386	83	168	585
0+500	1	1832	289	145	676
0+515	1	323	72	155	655

0+530	1	1146	271	106	733
0+545	1	1175	285	118	670
0+561	1	1134	280	114	734
0+574	1	379	88	136	613
0+600	1	261	61	115	778
0+650	1	1188	289	111	707
0+699	1	388	57	165	610
0+751	1	412	89	139	596
0+799	1	300	200	142	474
0+851	1	1364	285	127	772
0+900	1	289	54	179	695
0+950	1	310	87	137	660
1+000	1	267	44	169	754
0+000	3	266	40	195	720
0+100	3	298	61	214	655
0+200	3	1877	322	150	640
0+300	3	393	49	215	571
0+400	3	279	53	171	717
0+425	3	1129	308	110	701
0+455	3	1498	304	134	627
0+485	3	384	45	214	588
0+515	3	76	50	201	660
0+545	3	1358	264	118	769
0+575	3	263	64	128	759
0+600	3	309	41	193	668
0+701	3	1413	288	128	705
0+800	3	333	51	198	641
0+900	3	377	84	154	607
1+001	3	1139	282	110	745
0+050	4	192	158	84	784
0+150	4	219	58	113	848
0+240	4	633	85	202	427
0+350	4	331	83	135	660
0+440	4	401	60	175	585
0+470	4	292	93	170	626
0+500	4	289	58	152	698
0+530	4	363	111	162	567
0+560	4	357	74	143	649
0+649	4	1457	278	121	681
0+750	4	313	67	138	673
0+847	4	1737	278	144	863
0+950	4	278	63	151	703

The complete deflection outputs from the FWD for all the sensors (D_0 up to D_6) for all the test locations are presented in the Appendix section of the report. Figure 7-3 shows a plot of the central deflection by chainage for each wheel path. The values are highly variable.

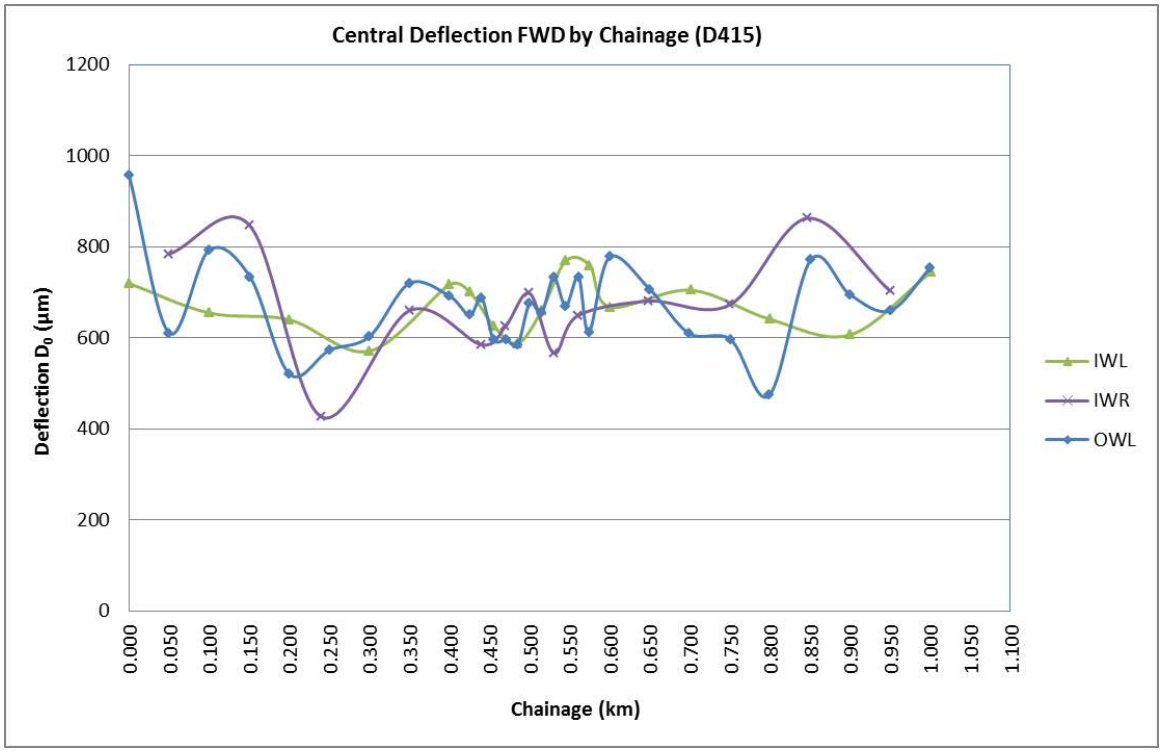


Figure 7-3: Central deflection by chainage (D415)

7.6 DCP Measurements

Table 7-5 shows the DN and DSN values by layer for each test point. The values all lie within the specifications.

Table 7-5: DN and DSN values (D415)

Chainage (m)	Specifications	≤3.2	≤6.0	≤12	≤19	≤25	DSN800
	Position	0-150	150-300	300-450	450-600	600-800	≥100
0+000	CL	2.160	4.1	2.0	3.9	4.0	292
0+050	RHS	4.400	3.9	4.9	6.8	5.6	174
0+010	CL	5.190	5.1	6.4	5.7	7.0	153
0+150	RHS	2.140	3.3	3.2	6.2	5.9	241
0+200	CL	1.810	3.6	4.5	13.9	7.3	261
0+250	RHS	3.130	3.3	4.7	7.0	3.1	257
0+300	CL	2.080	3.0	2.6	3.5	1.5	433
0+350	RHS	2.800	5.5	6.4	9.9	8.1	159
0+400	CL	4.260	5.4	5.2	5.1	6.1	183
0+405	OWL	3.870	4.7	10.2	14.7	12.1	123
0+405	IWL	3.010	4.0	3.5	2.8	2.7	283
0+405	CL	2.620	2.8	3.5	2.9	5.6	267

0+405	IWR	3.360	3.7	4.5	3.2	3.6	243
0+405	OWR	2.990	3.1	4.4	7.4	9.2	186
0+416	CL	3.520	12.1	11.4	29.4	16.5	98
0+584	CL	1.290	3.2	5.3	9.2	16.2	274
0+584	CL	0.940	1.7	4.4	1.2	1.4	773
0+584	LHS	0.990	1.0	6.0	2.1	1.5	702
0+584	RHS	1.440	2.1	3.3	1.7	1.3	617
0+584	RHS	2.130	2.0	2.3	1.8	1.9	459
0+594	RHS	4.510	4.0	4.2	6.0	4.7	204
0+600	RHS	4.330	5.4	4.3	3.6	6.7	179
0+650	CL	1.100	1.4	0.8	0.7	0.7	1090
0+700	RHS	0.970	0.5	0.5	0.5	0.5	1821
0+750	CL	3.960	6.9	4.1	2.6	2.1	316
0+800	RHS	2.920	3.7	5.0	2.9	2.5	276
0+850	CL	2.390	2.1	1.6	1.8	1.9	478
0+900	RHS	4.120	8.7	8.5	11.2	9.6	113
0+950	CL	3.260	4.1	3.4	4.8	3.3	231
1+000	RHS	5.140	3.3	7.1	7.6	10.5	144

7.7 Roughness Measurements

The roughness values in Table 7-6 and Table 7-7 are within the acceptable range for LVSRs. Figure 7-4 shows the roughness of each lane along the road section.

Table 7-6: Roughness values including bumps (D415)

Makenzi - Kandara road (D415)			
LHS		RHS	
Chainage	IRI	Chainage	IRI
0+000-0+100	1.4	0+000-0+050	1.4
0+100-0+200	2.2	0+050-0+150	2.9
0+200-0+400	2.5	0+150-0+240	2.2
0+400-0+545	2.6	0+240-0+560	2.6
0+545-0+575	2.6	0+560-0+649	4.7
0+575-0+600	2.6	0+649-0+750	4.9
0+600-0+701	4.7	0+750-0+847	4.3
0+701-0+800	4.9	0+847-0+950	4.3
0+800-0+900	4.3		

Table 7-7: Roughness values excluding bumps (D415)

Makenzi - Kandara road (D415)			
LHS		RHS	
Chainage	IRI	Chainage	IRI
0+000-0+100	3.3	0+000-0+050	3.3
0+100-0+200	3.3	0+050-0+150	2.6
0+200-0+400	3.3	0+150-0+240	3.3

0+400-0+545	3.3	0+240-0+560	3.3
0+545-0+575	3.3	0+560-0+649	2.6
0+575-0+600	3.3	0+649-0+750	2.6
0+600-0+701	2.6	0+750-0+847	2.6
0+701-0+800	2.6	0+847-0+950	2.6
0+800-0+900	2.6		

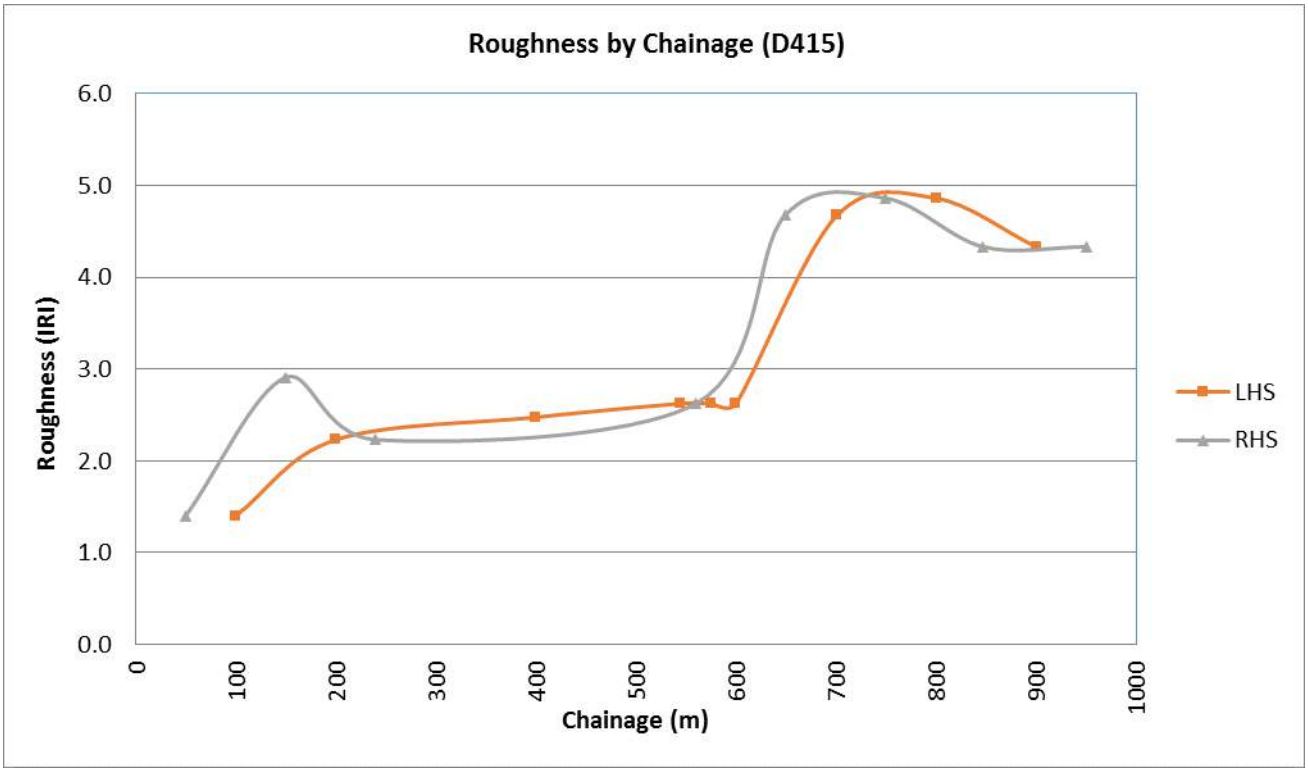


Figure 7-4: Roughness values including bumps by chainage (D415)

7.8 Test Pits

7.8.1 DN Values

Table 7-8 shows the DN of each layer in the structure measured before excavation. Pit B values are within the specifications but Pit A is outside the specifications.

Table 7-8: DN values at test pit (D415)

Depth (mm)	DN values (mm/blow)		
	Specifications	Pit A @ 0+416	Pit B @ 0+594
0 – 150	≤3.2	3.5	4.5
150 – 300	≤6.0	12.1	3.9
300 – 450	≤12	11.4	4.2
450 – 600	≤19	29.4	5.9
600 – 800	≤25	16.5	4.7
DSN800	≥100	98	204

7.8.2 Layer Thicknesses

Figure 7-5 is representation of the pavement materials and the measured layer thicknesses.

Test Pit A, km 0+416		Test Pit B, km 0+594
20 mm Cold Mix Asphalt		20 mm Cold Mix Asphalt
200 mm Emulsion treated lateritic gravel base		160 mm Emulsion treated lateritic gravel base
200 mm Neat lateritic gravel sub-base		150 mm Neat lateritic gravel sub-base
Subgrade		Subgrade

Figure 7-5: Layer thicknesses at test pit (D415)

7.8.3 Densities and Moisture Content

Table 7-9 shows the dry density, the MDD, the in-situ moisture content and the OMC (AASHTO T180 for base and sub-base) for each of the two test pits, including the subgrade (AASHTO T99).

Table 7-9: Density and moisture contents (D415)

Panel	Wheel Path	Layer	MDD (kg/m^3)	In-situ Moisture Content (%)	OMC (%)	Relative Moisture Content (FMC/OMC)
Panel A	OWP	Base	1855	16.0	15.2	1.05
		Sub-base	1600	23.8	18.6	1.28
		Subgrade	1395	21.1	22.3	0.95
	IWP	Base	1830	13.5	17.6	0.77
		Sub-base	1595	21.3	20.1	1.06
		Subgrade	1410	26.5	24.5	1.08
Panel B	OWP	Base	1845	16.0	15.6	1.03
		Sub-base	1630	19.7	19.6	1.01
		Subgrade	1430	10.7	23.6	0.45
	IWP	Base	1775	12.4	17.5	0.71
		Sub-base	1585	19.9	21.6	0.92
		Subgrade	1400	24.5	24.3	1.01

7.8.4 Particle Size Distribution

The plots in Figure 7-6, Figure 7-7, and Figure 7-8 below show the particle size distribution for each layer. Except for one point, all the base materials lie within the specification envelope.

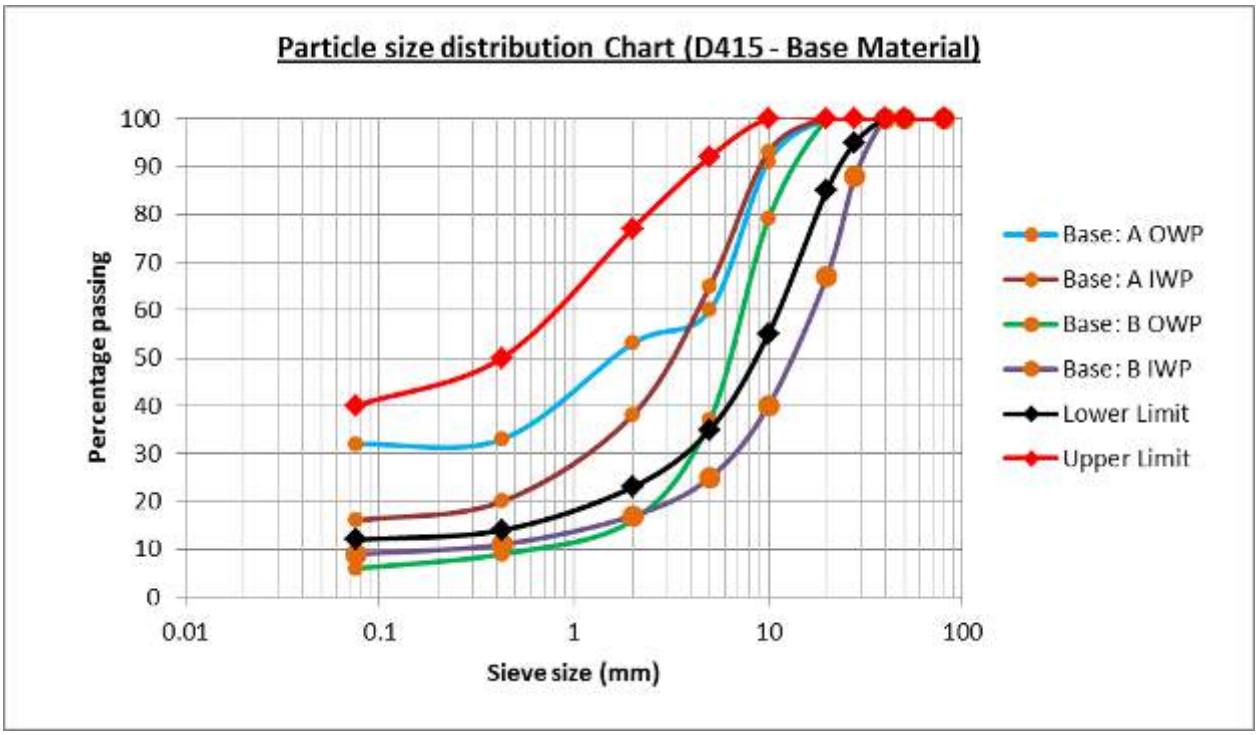


Figure 7-6: Particle size distribution for base material (D415)

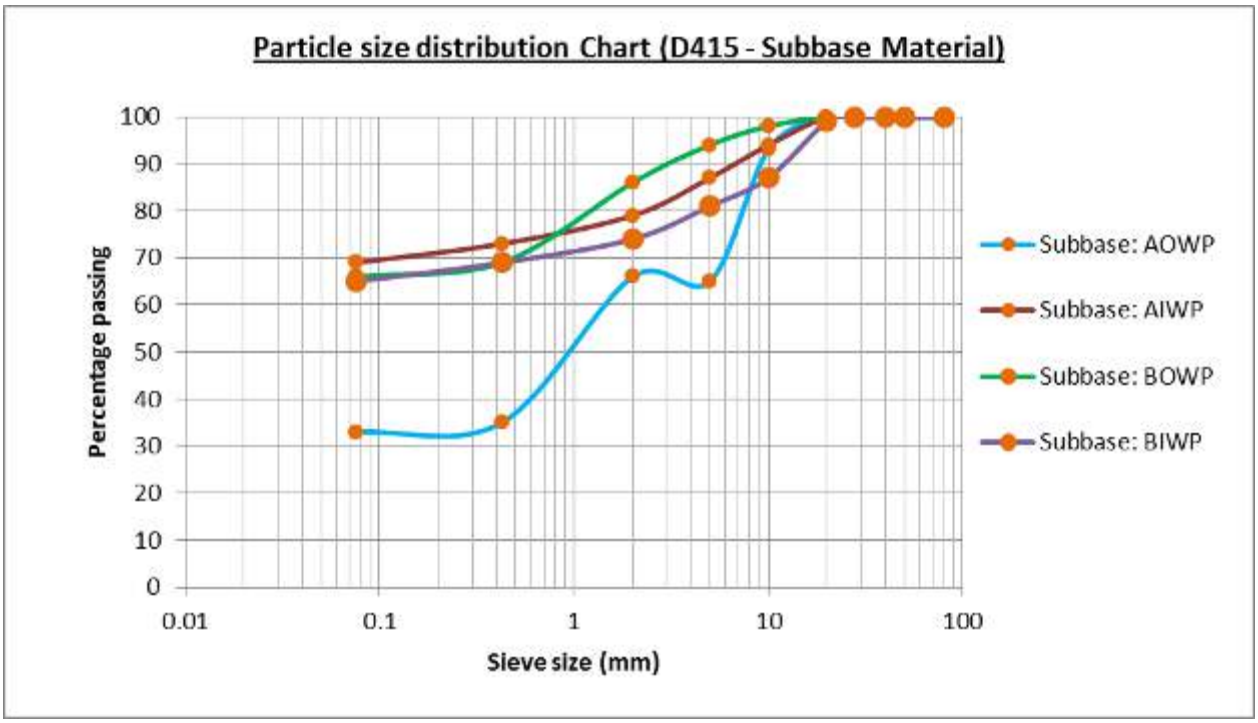


Figure 7-7: Particle size distribution for sub-base material (D415)

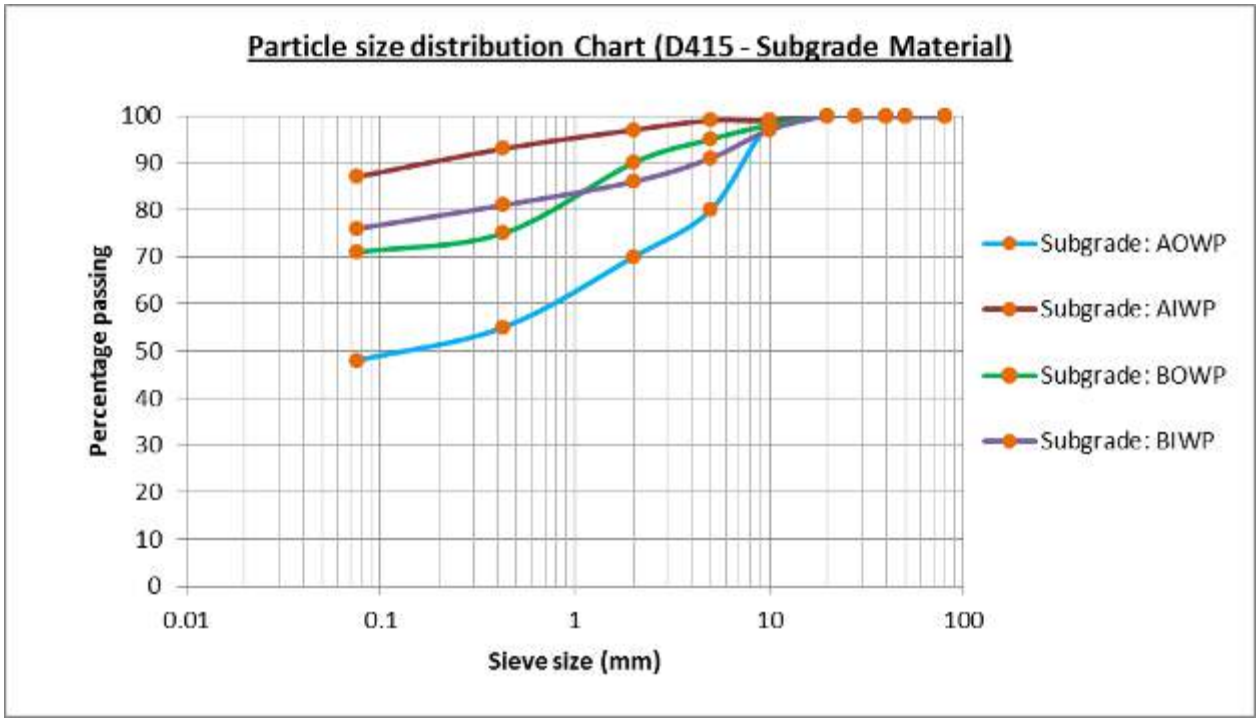


Figure 7-8: Particle size distribution for subgrade material (D415)

7.8.5 Atterberg Limits

Table 7-10 shows the index properties of each pavement layer, including the subgrade. All the soils above can be classified as medium plastic, as shown by the plasticity index values.

Table 7-10: Atterberg limits at test pit (D415)

Layer	Liquid Limit	Plastic Limit	Plasticity Index	Linear Shrinkage
Road D415 – Panel A - OWP				
Base	45	33	12	6
Sub-base	42	23	19	9
Subgrade	56	34	22	11
Road D415 – Panel A – IWP				
Base	52	28	24	12
Sub-base	54	23	31	16
Subgrade	56	29	27	14
Road D415 – Panel B - OWP				
Base	58	35	23	11
Sub-base	53	24	29	14
Subgrade	60	27	33	16
Road D415 – Panel B - IWP				
Base	42	23	19	9
Sub-base	56	34	22	11
Subgrade	54	24	30	14

7.8.6 Laboratory CBR

Table 7-11 is a summary of the 4-day soaked CBR (AASHTO T180 for base and AASHTO T99 for subgrade) for each layer from the test pit. The base CBR is generally just within the minimum threshold of 30%.

Table 7-11: Laboratory CBR (D415)

4-day soaked CBR (%) (D415)				
Layer	**Panel A**		**Panel B**	
	OWP	**IWP**	**OWP**	**IWP**
Base	30	35	30	26
Sub-base	15	13	14	14
Subgrade	7	6	6	7

7.9 Visual Condition Assessment

7.9.1 Pavement Defects Assessment

The main defects on this road section are edge breaks and cracking as shown in Table 7-12.

Table 7-12: Visual condition assessment of D415

Fig No	Location (Km)	Defect assessment and description	Photos illustrating the pavement distress & defect
Fig 1	Km 0+000-0+040 LHS	Eroded side slope and edge of approximately 50 m long	
Fig 2	Km 0+100LHS	-Eroded edge and shoulders of about 15cm by 500cm	

Fig 3	Km 0+120 RHS	-Alligator cracks ,bleeding and sticky -Patchwork and alligator cracks on the inner and outer wheel path	
Fig 4	Km 0+140LHS	-Damaged shoulders towards LHS carriage covering an area of 0.3m*0.4m)M^2	
Fig 5	Km 0+150 – 0+175 main carriage way	-Extensive alligator cracks and crack sealing on the centerline of the carriage way	

Fig 6	Km 0+190-0+203 LHS	-Eroded shoulders and side slope approximately 13m long caused by motorists turn at the junction	
Fig 7	Km 0+226 main carriage way	-Alligator cracks and potholes at the centerline approximate area of 3cm*4cm(12cm$^{2)}$ -Area of section affected 12m long and 2.5m width	
Fig 8	**Km 0+300LHS**	-Eroded side slope and road edge 10m long -No proper drainage system	

Fig 9	**Km 0+425 LHS**	-Gulley erosion on the side slope	
Fig 10	**Km 0+455 main carriage at the centerline**	-Extensive alligator cracks o the carriage way especially at the centreline	
Fig 11	**Km 0+467 Centerline**	-Extensive alligator cracks leading to the development potholes at the centreline	

Fig 12	**Km 0+540 RHS on inner wheel path**	-Alligator cracks and pothole on the inner wheel path	
Fig 13	**Km 0+550 – 0+570**	-Extensive alligator cracks and crack sealing done on the surface 10m long and 2.5m width	
Fig 14	**Km 0+820 – 0+850 main carriage and RHS**	-Alligator cracks on the LHS carriage way -Erosion on the side slope and shoulders	

Fig 15			
Fig 16	Km 0+860 - 0+900 main carriage way	-Extensive alligator cracks all over the surface leading to penetration of water into underlying layers	
Fig 17	Km 0+950 - 0+980 main carriage way	-Alligator cracks all over the surface	

Fig 18	Km 0+980 – 1+000	-Alligator cracks and slight bleeding on the surface	

7.9.2 Present Serviceability Rating

The PSR for this road section is about 3.9 which is regarded as "Good".

Table 7-13: Present Serviceability Rating (D415)

Road :	Muruka - Kandara Road (D415)												
Section:	Km 0+000 - Km 1+ 000 main carriage way												
Pavement Structure:				**Date of Survey:**					13/11/2016				
Surfacing	Asphalt concrete mix and Concrete pavement												
Base	Emulsion treated lateritic gravel												
Sub-base	Neat lateritic gravel												
		A	**B**	**C**	**D**	**E**	**F**	**G**	**Point summary**				
	Point score												
Sub- Section	Length (Km)	General appearance	Surface texture	Bitumen condition	Pot holes	Surface irregularity	Rutting	Cracking	Sum of (Σ) Points A-G Max: 40	Average points	%	Remarks	PSR
1. Km 0+000 - 0+500	0.500	4.5	4.5	5.0	2.0	4.5	5.0	2.0	27.5	3.9	69	**Good**	**3.9**
2. Km 0+500- 1+000	0.500	4.0	4.2	5.0	4.0	4.5	5.0	0.0	26.7	3.8	67	**Good**	**3.8**
Average PSR		**4.25**	**4.35**	**5**	**3**	**4.5**	**5**	**1**	**27.1**	**3.87**	**67.8**	**Good**	**3.87**

7.10 Rainfall Data

No data is available for this station and there is no Kenya Metrological Department gauging station in the area.

8 Maragua Town-Gakoigo Jn Road D419

8.1 Site Description

This Trial section is found in Murang'a County. It starts right from Maragua Town, goes through Gakoigo Junction, Ng'inda, Irembu, Gikomoro and ends at Ngaburi. The sealed section ends at Nginda, while the rest is still earth road. Figure 8-1 shows the location map of the road.

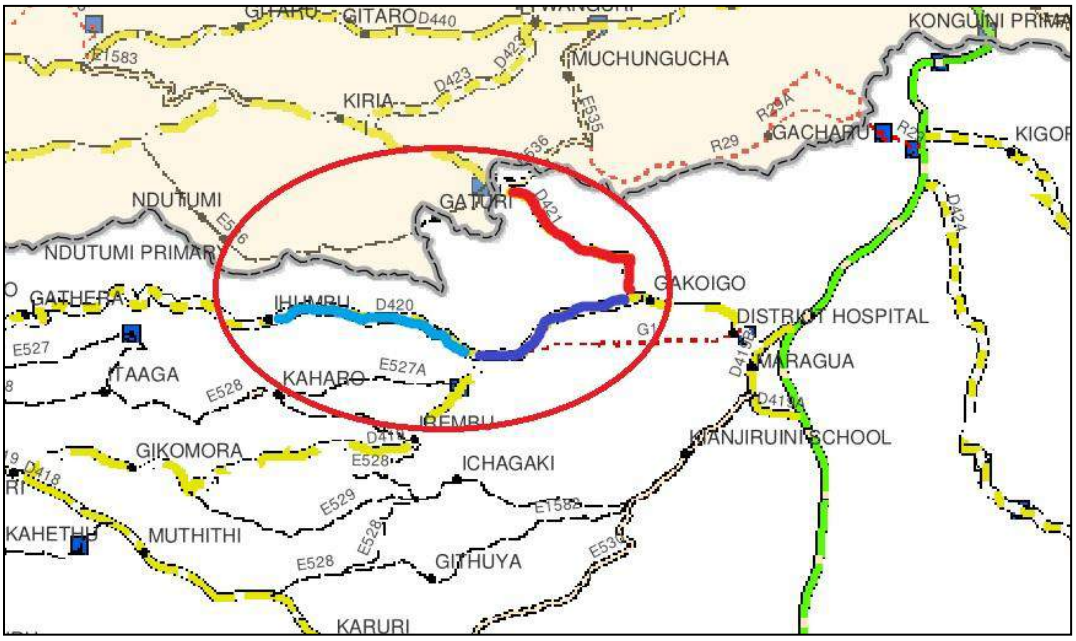


Figure 8-1: Location of Maragua – Gakoigo Road (D419), marked in Purple

8.2 Pavement Description

Figure 8-2 shows a representation of the designed pavement structure.

20 mm Asphalt concrete mix	
150 mm Emulsion treated base	
230 mm Neat gravel subbase	
Subgrade	

Figure 8-2: Designed pavement structure (D419)

8.3 Traffic Survey

8.3.1 Classified Traffic Counts

Table 8-1 shows the summary of the traffic count summary. The high count of heavy goods vehicles can be attributed to an ongoing road construction project around Gathera shopping centre, as narrated by the drivers. Most of these vehicles were carrying gravel, and a few of them sand. The source of the gravel is the outskirts of Maragua town.

Table 8-1: Traffic count summary (D419)

Vehicle Type	Daily Volume (vpd)
Motorcycles	1174
Cars	259
Minibus	132
Bus	17
Light Goods Vehicle	74
Medium Goods Vehicle	97
Heavy Goods Vehicle	58
ADT	**1811**

8.3.2 Axle Load Survey

Table 8-2 is a summary of ESA by vehicle type, and the computed ESA/day. Amongst the 11 roads surveyed, this road has the highest ESA/day.

Table 8-2: Traffic ESA (D419)

Vehicle Type	ESA/day
Bus[1]	XXX
Medium Goods Vehicles	50.23
Heavy Goods Vehicles	111.01
Design ESA/day	**161.24**

Note 1: Although Buses were counted during the traffic counts, they were not present during the axle load survey.

8.4 Rutting

Table 8-3 shows the maximum rut depth left and right of each chainage point. The average value of 9 mm is acceptable for LVSRs.

Table 8-3: Maximum rut depth (D419)

Chainage	LHS Rut in mm	RHS Rut in mm
0+000	9	4
0+050	7	8
0+100	6	1
0+150	5	8
0+200	7	8
0+250	5	10
0+300	5	9
0+350	12	5
0+400	12	12
0+425	10	4
0+440	12	9
0+455	12	12
0+470	12	6
0+485	9	5
0+500	10	7
0+515	12	5
0+530	12	5
0+545	12	6

0+560	12	8
0+575	12	10
0+600	12	10
0+650	12	9
0+700	5	7
0+750	2	2
0+800	5	8
0+850	9	8
0+900	10	5
0+950	12	12
1+000	1	12
Average	**9**	**8**

8.5 Deflection/Stiffness

Table 8-4 shows the central deflection D_0, and the base, sub-base and subgrade stiffness measured at each point.

Table 8-4: Deflection and stiffness (D419)

Chainage (m)	Lane No.	Stiffness			Normalized Deflections at Geophone Locations (µm) D_0
		EBase (MPa)	ESubbase (MPa)	ESubgrade (MPa)	
0+000	1	457	104	155	756
0+100	1	347	84	125	798
0+200	1	372	93	136	824
0+300	1	990	170	118	929
0+400	1	1506	259	85	1058
0+425	1	141	117	74	1047
0+455	1	1028	178	120	893
0+485	1	1051	179	131	816
0+515	1	417	88	143	705
0+545	1	321	35	194	781
0+575	1	1076	192	129	767
0+600	1	276	36	214	757
0+700	1	387	57	118	771
0+800	1	378	48	162	729
0+900	1	1089	195	127	841
1+000	1	1048	181	121	813
0+050	2	1569	265	86	945
0+150	2	336	37	186	777
0+250	2	993	176	132	868
0+350	2	409	98	151	738
0+440	2	188	147	82	827
0+470	2	457	54	170	646

0+500	2	454	82	147	636
0+530	2	220	169	89	817
0+560	2	1073	186	131	786
0+650	2	545	103	179	893
0+750	2	263	32	185	806
0+851	2	987	175	126	745
0+950	2	349	71	119	918
0+050	3	444	98	149	775
0+150	3	409	93	143	810
0+251	3	183	141	110	781
0+350	3	1181	214	132	757
0+441	3	979	171	99	1006
0+470	3	406	89	145	838
0+500	3	466	92	149	890
0+530	3	383	96	134	860
0+560	3	297	30	154	858
0+650	3	872	155	123	945
0+751	3	1307	219	100	912
0+850	3	1195	199	155	832
0+949	3	1007	173	134	777
0+000	4	236	175	116	662
0+100	4	406	83	132	909
0+200	4	464	84	209	887
0+300	4	379	78	132	734
0+400	4	1024	186	102	919
0+425	4	279	73	104	1073
0+455	4	272	61	99	962
0+484	4	1019	174	95	968
0+515	4	357	55	114	826
0+544	4	241	172	102	700
0+575	4	276	191	110	673
0+600	4	1177	208	123	575
0+700	4	462	83	222	855
0+800	4	401	101	147	824
0+900	4	388	94	142	751
1+000	4	1014	176	111	744

The complete deflection outputs from the FWD for all the sensors (D_0 up to D_6) for all the test locations are presented in the Appendix section of the report. Figure 8-3 shows the central deflection by chainage along each wheel path. The values are highly variable.

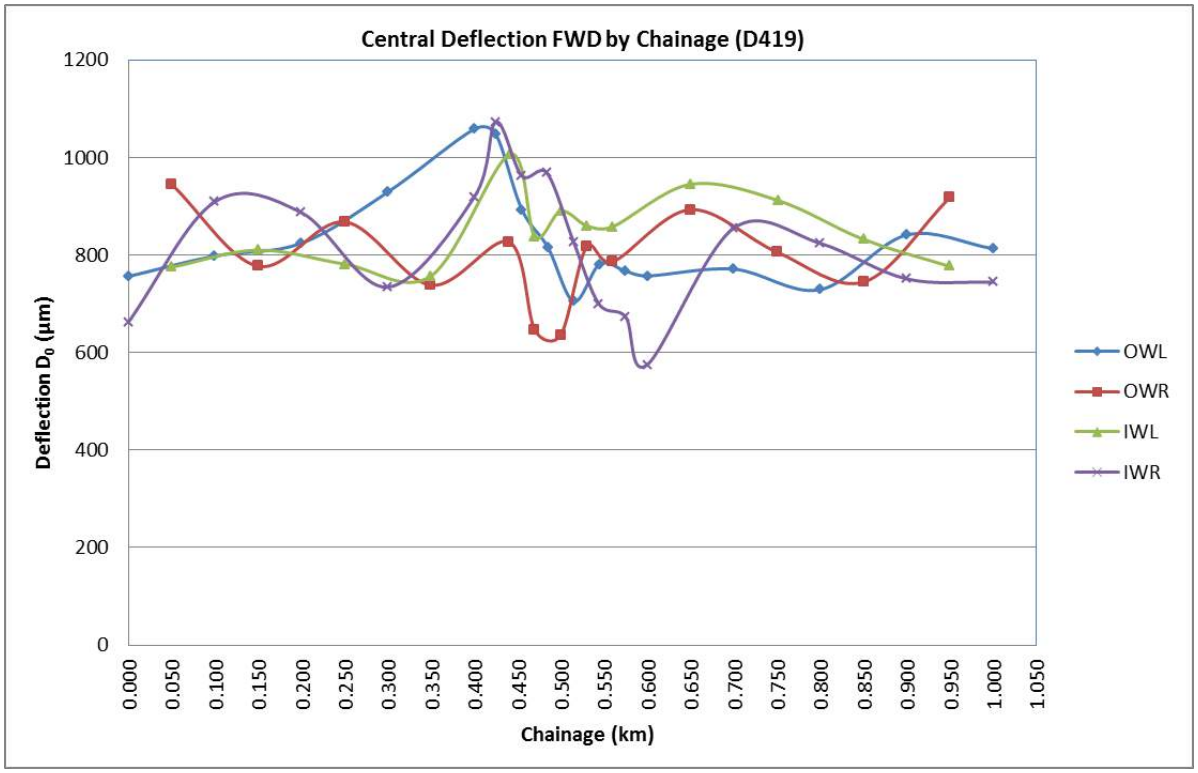


Figure 8-3: Central deflection by chainage (D419)

8.6 DCP Measurements

Table 8-5 below shows the DN and DSN values by layer for each test point. Except for a few points, the values are generally within the acceptable specifications.

Table 8-5: DN values for the rest of the section (D419)

Chainage (m)	Specifications	≤3.2	≤6.0	≤12	≤19	≤25	DSN800
	Position	0-150	150-300	300-450	450-600	600-800	≥100
0+000	LHS	7.9	23.0	11.7	12.8	16.0	67
0+050	RHS	46.8	5.9	5.6	6.4	7.5	124
0+100	LHS	7.1	4.5	4.6	10.7	9.4	144
0+150	RHS	9.0	12.2	10.9	9.4	9.3	95
0+150	RHS	7.7	8.8	8.7	8.2	25.1	93
0+250	RHS	8.0	6.4	28.3	5.9	6.1	128
0+300	LHS	8.9	10.2	9.7	12.8	13.6	84
0+350	RHS	10.2	6.2	6.4	10.6	10.3	110
0+400	LHS	10.1	11.8	5.8	7.8	9.6	101
0+403	OWL	10.0	8.6	7.0	11.1	14.1	90
0+403	IWL	8.5	9.2	10.1	16.3	11.7	87
0+403	CL	9.0	11.2	5.8	7.2	8.2	122
0+403	IWR	6.2	6.7	6.6	7.8	5.0	142
0+403	OWR	6.9	10.1	30.2	32.3	36.9	58
0+409	RHS	8.7	7.5	13.6	20.3	10.3	82

0+593	LHS	7.8	6.3	8.1	9.8	9.4	102
0+597	OWL	5.9	6.4	6.4	8.0	9.4	119
0+597	IWL	5.3	3.8	5.2	7.9	9.7	149
0+597	CL	7.4	3.8	4.5	6.0	11.5	148
0+597	IWR	9.2	5.7	6.1	5.8	9.9	130
0+597	OWR	7.5	4.5	4.7	6.1	6.0	177
0+650	RHS	3.8	4.5	4.3	3.3	3.3	228
0+700	LHS	2.3	2.1	3.2	6.7	5.6	272
0+750	RHS	5.0	6.4	7.5	8.1	9.6	116
0+800	LHS	6.5	12.2	16.6	18.1	16.0	70
0+850	RHS	7.2	3.8	0.3	0.3	0.3	150
0+900	LHS	7.7	7.2	9.4	10.2	9.2	98
0+950	RHS	4.6	6.7	6.3	7.3	6.3	142
1+000	LHS	9.2	6.9	5.1	0.2	0.1	150

8.7 Roughness Measurements

The roughness values in Table 8-6 and

Table 8-7 are within the expected values for LVSRs. Figure 8-4 shows the roughness of each lane along the road section.

Table 8-6: Roughness values including humps (D419)

Maragua – Gakoigo Road (D419)			
LHS		RHS	
Chainage	IRI	Chainage	IRI
0+000-0+050	3.0	0+000-0+100	2.9
0+050-0+251	3.7	0+100-0+200	3.7
0+251-0+350	1.8	0+200-0+300	1.8
0+350-0+441	2.3	0+300-0+400	2.3
0+441-0+500	3.7	0+400-0+425	2.3
0+500-0+530	3.7	0+425-0+455	2.3
0+530-0+560	3.7	0+455-0+484	3.7
0+560-0+650	2.7	0+484-0+515	3.7
0+650-0+751	4.5	0+515-0+544	3.7
0+751-0+850	4.2	0+544-0+600	2.7
0+850+0+949	4.1	0+600-0+700	4.5
		0+700-0+800	4.2
		0+800-1+000	4.1

Table 8-7: Roughness values excluding humps (D419)

Maragua – Gakoigo Road (D419)			
LHS		RHS	
Chainage	IRI	Chainage	IRI
0+000-0+050	2.3	0+000-0+100	2.3
0+050-0+251	2.3	0+100-0+200	2.3
0+251-0+350	2.9	0+200-0+300	2.9
0+350-0+441	2.9	0+300-0+400	2.9
0+441-0+500	2.3	0+400-0+425	2.9
0+500-0+530	2.3	0+425-0+455	2.9
0+530-0+560	2.3	0+455-0+484	2.3
0+560-0+650	2.3	0+484-0+515	2.3
0+650-0+751	2.3	0+515-0+544	2.3
0+751-0+850	2.3	0+544-0+600	2.3
0+850+0+949	2.3	0+600-0+700	2.3
		0+700-0+800	2.3
		0+800-1+000	2.3

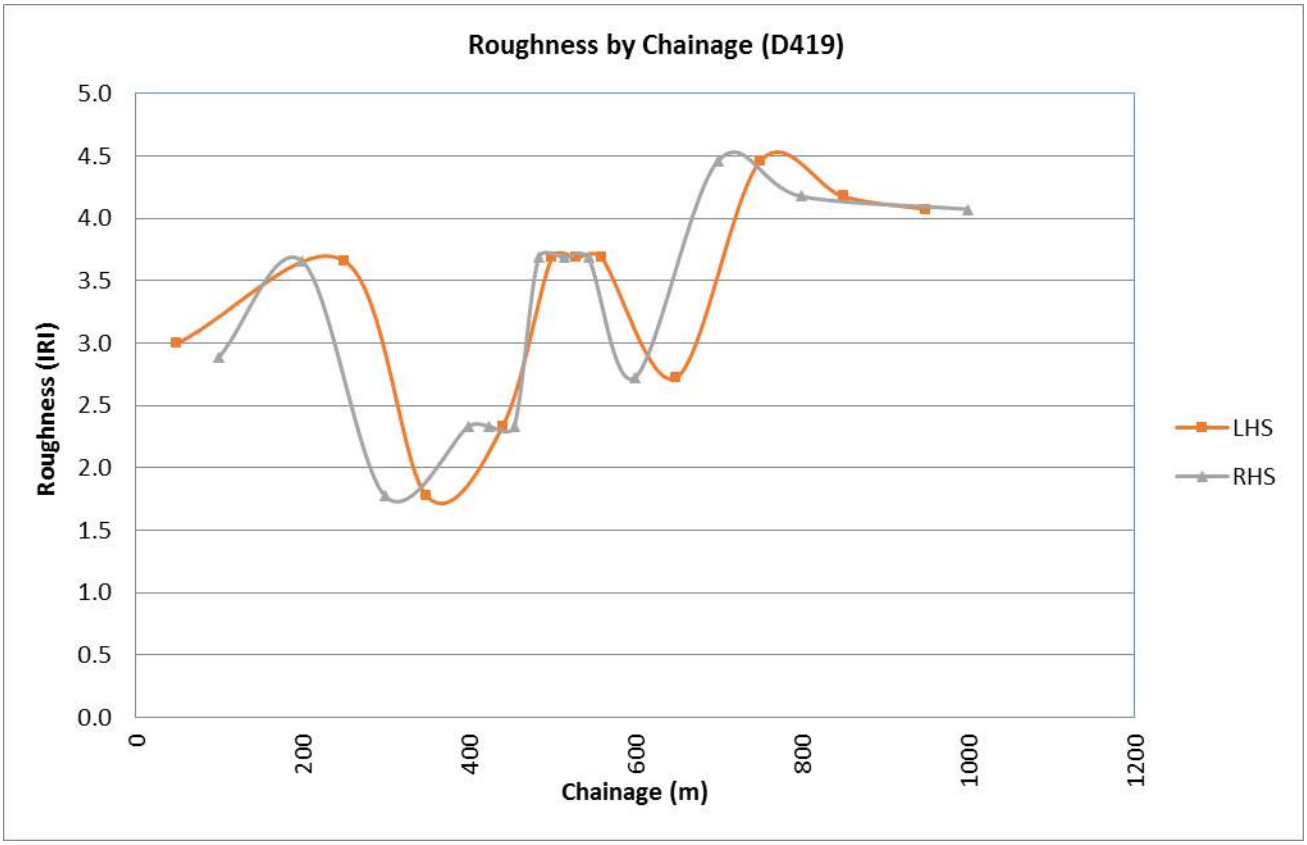


Figure 8-4: Roughness values including humps by chainage (D421)

8.8 Test Pits

8.8.1 DN Values

Table 8-8 shows the DN values of each layer in the structure measured before excavation of the test pit. The values representing the base layer do not meet the specifications. The sub-base values are well within the specifications.

Table 8-8: DN values at test pit (D419)

Depth (mm)	Specifications	DN values (mm/blow)	
		Pit A @ 0+409	Pit B @ 0+593
0 – 150	≤3.2	8.7	7.8
150 – 300	≤6.0	7.5	6.3
300 – 450	≤12	13.6	8.1
450 – 600	≤19	20.3	9.8
600 – 800	≤25	10.3	9.4
DSN800	≥100	82	102

The rest of the DCP details are presented in the Appendix section of the report.

8.8.2 Layer Thicknesses

Figure 8-5 illustrates the measured layer thickness and material descriptions as observed in the test pits.

Test Pit A, km 0+409		Test Pit B, km 0+593
20 mm Asphalt concrete mix		20 mm Asphalt concrete mix
150 mm Emulsion treated base		150 mm Emulsion treated base
230 mm Neat Granular subbase		250 mm Neat Granular subbase
Subgrade		Subgrade

Figure 8-5: Layer thicknesses at test pits (D419)

8.8.3 Densities and Moisture Content

Table 8-9 shows the dry density, the MDD, the in-situ moisture content and the OMC (AASHTO T180 for base and sub-base and AASHTO T99 for subgrade) for each layer.

Table 8-9: Density and moisture content at test pit (D419)

Panel	Wheel Path	Layer	MDD (kg/m^3)	In-situ Moisture Content (%)	OMC (%)	Relative Moisture Content (FMC/OMC)
Panel A	OWP	Base	1630	24.6	21.3	1.15
		Sub-base	1575	25.1	22.1	1.14
		Subgrade	1345	35.1	26.3	1.33
	IWP	Base	1600	23.6	20.9	1.13
		Sub-base	1580	25.8	21.6	1.19
		Subgrade	1285	31.8	32.0	0.99
Panel B	OWP	Base	1635	18.8	21.8	0.86
		Sub-base	1600	18.2	22.2	0.82
		Subgrade	1310	25.2	29.6	0.85
	IWP	Base	1540	21.6	21.8	0.99
		Sub-base	1540	23.0	23.4	0.98
		Subgrade	1400	24.3	31.2	0.78

8.8.4 Particle Size Distribution

The plots in Figure 8-6, Figure 8-7, and Figure 8-8 below show the particle size distribution for each layer. The base materials are generally finer than the specification envelope.

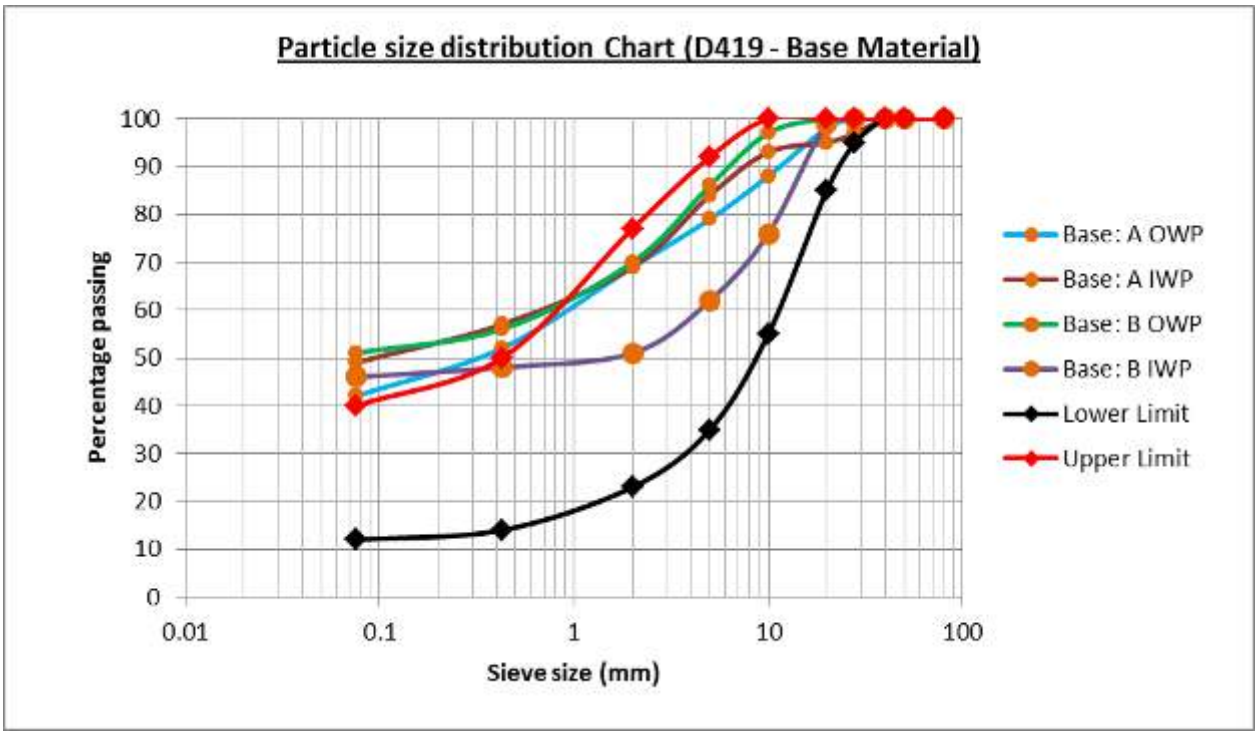


Figure 8-6: Particle size distribution for base material (D419)

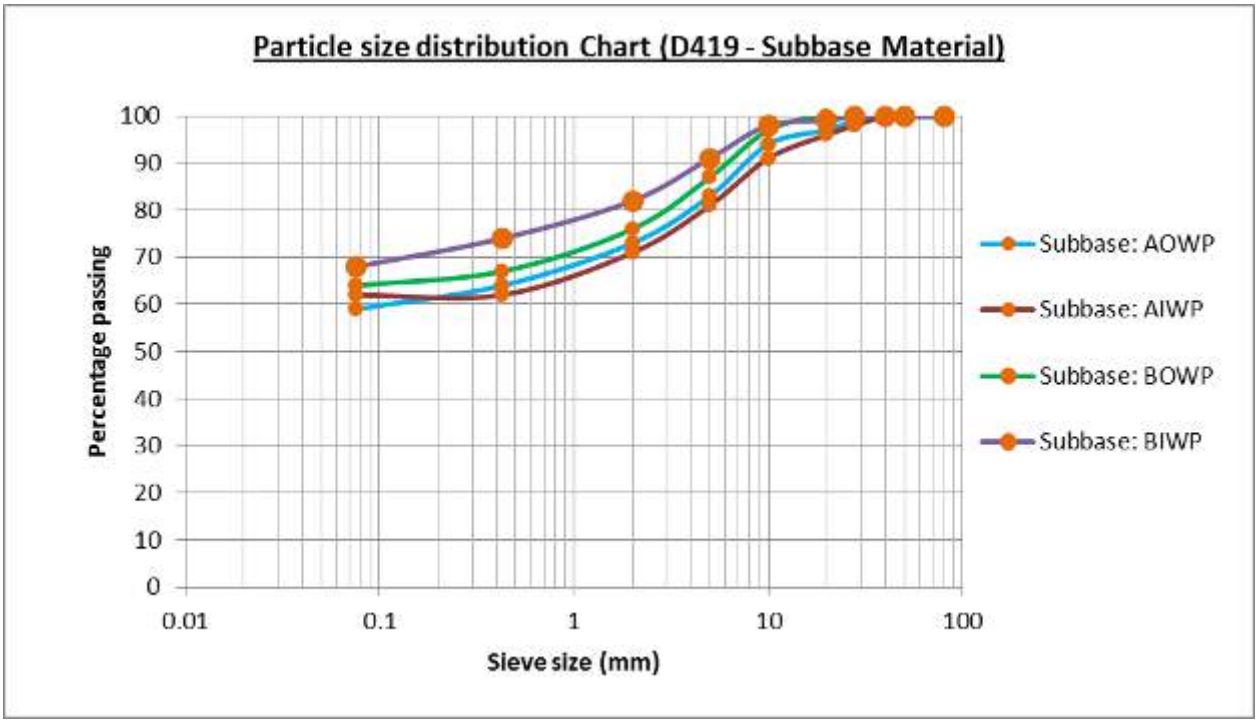


Figure 8-7: Particle size distribution for subbase material (D419)

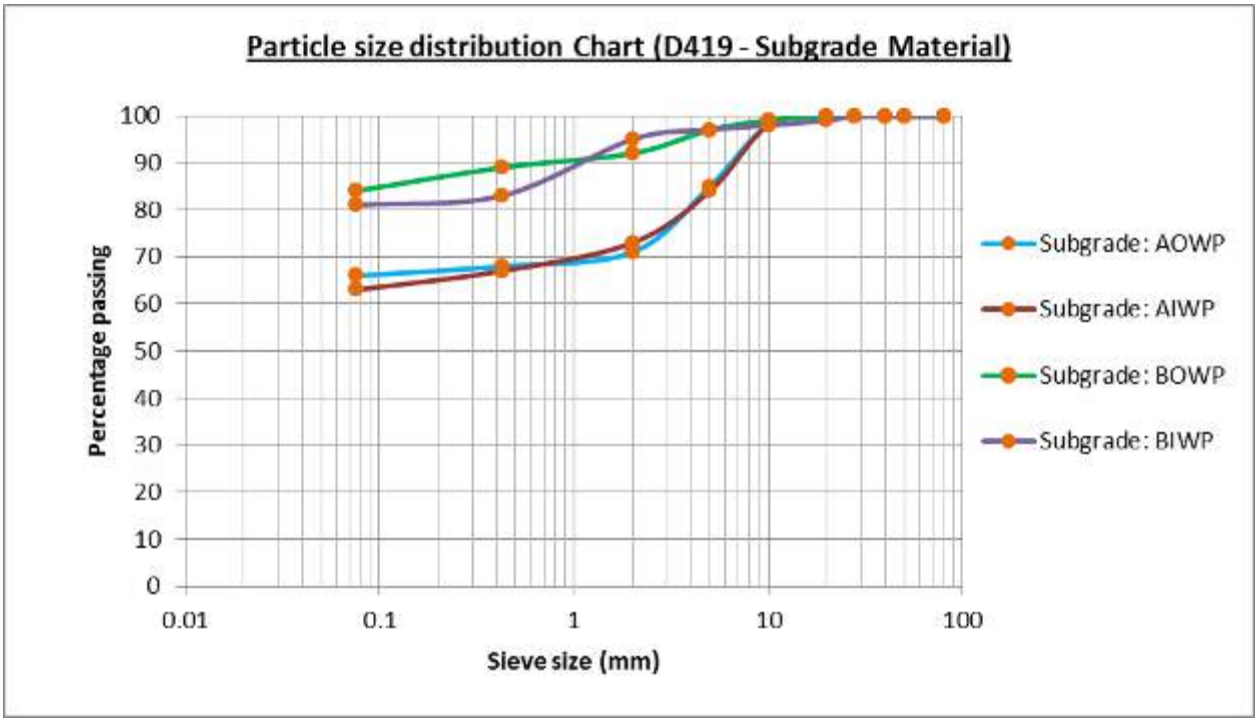


Figure 8-8: Particle size distribution chart for subgrade material (D419)

8.8.5 Atterberg Limits

Table 8-10 shows the index properties of each pavement layer including the subgrade. The soils above can all be classified as medium plastic, as indicated by the plasticity index.

Table 8-10: Atterberg limits at test pits (D419)

Layer	Liquid Limit	Plastic Limit	Plasticity Index	Linear Shrinkage
Road D419 – Panel A - OWP				
Base	44	25	19	9
Sub-base	41	23	18	9
Subgrade	56	26	30	15
Road D419 – Panel A – IWP				
Base	51	30	21	10
Sub-base	60	40	20	10
Subgrade	49	24	25	13
Road D419 – Panel B - OWP				
Base	49	26	23	11
Sub-base	59	40	19	9
Subgrade	48	20	28	14
Road D419 – Panel B - IWP				
Base	58	40	18	9
Sub-base	49	28	21	11
Subgrade	55	21	26	14

8.8.6 Laboratory DN / CBR

Table 8-11 shows the 4-day soaked CBR (AASHTO T180 for base and sub-base and AASHTO T99 for subgrade) of each layer, including the subgrade.

Table 8-11: Laboratory CBR (D419)

4-day soaked CBR (%) (D419)				
Layer	**Panel A**		**Panel B**	
	OWP	**IWP**	**OWP**	**IWP**
Base	14	15	13	16
Sub-base	9	8	7	6
Subgrade	6	5	4	4

8.9 Visual Condition Assessment

8.9.1 Pavement Defects Assessment

The pavement shows a few raveled and pot-holed areas as shown in Table 8-12.

Table 8-12: Visual condition assessment of D419

Fig No	Location (Km)	Defect assessment and description	Photos illustrating the pavement distress & defect
Fig 1	Km 0+000 - 0+060LHS	-Slightly silted side drain -No visible defects on the surface	

Fig 2	Km 0+080 LHS	-Partial clogged culvert and silted side drain	
Fig 3	Km 0+240 - 0+270LHS	-Silted side drain - No visible defects on the surface	
Fig 4	**Km 0+340 – 0+356LHS** **carriage way**	-Stripping on the LHS lane covering 12m long and 3m width – Could have been contributed to a coarser mix -Noticeable inconsistency in the mix	

Fig 5	**Km 0+360-0+380 main carriage way**	-Noticeable inconsistency in the mix	
Fig 6	**Km 0+400 -0+420 RHS lane**	-2No Potholes on the RHS carriage way approximate area of -0.5m*0.5m (Area -0.25m^2)and 0.3m*0.5m(Area 0.15m^2) respectively on both outer and inner wheel path -The mix used appears too coarse	
Fig 7	Km 0+479 RHS	1No Pothole at the inner wheel path covering 0.6m by 0.5m with adepth of 65mm	

Fig 8	Km 0+560 LHS	-Pothole developing on the LHS carriage way at inner wheel path	
Fig 9	Km 0+693RHS	-Pothole developing on the RHS carriage way at inner wheel path	
Fig 10	**Km 0+600 main carriage way**	-No road marking starting from 0+600 main carriage way	

Fig 11	**Km 0+675 -0+690 RHS**	-Silted and blocked with vegetation	
Fig 12	Km0+778-0+800 both sides	-Erosion on side slope and shoulders and edge braking caused by traffic dodging the bump	
Fig 13	**Km 0+885 at the Centerline**	-Pothole developing at centerline	

Fig 14	**Km 0+889 RHS**	-Silted side drain and access culvert	
Fig 15	**Km 0+950 at the centerline**	-Alligator cracks developing on the centerline of the main carriage way	
Fig 16	**Km 0+970 main carriage way**	Extensive alligator cracks at the centerline covering 10m long by 2m width	

Fig 17	**Km 0+970 – 1+000 main carriage way**	-Swallow side drain - Vegetation on shoulders hindering free flow of water to side drain	

8.9.2 Present Serviceability Rating

The computed PSR, in Table 8-13, for this road section is 4.2. This is regarded as "Good".

Table 8-13: Present Serviceability Rating D419

Road:	Gakiogo - Nginda School								
Section:	Km 0+000 - Km 1+ 000 main carriage way								
Pavement Structure:	**Date of Survey:**							13/11/2016	
Surfacing	Asphalt concrete mix								
Base	Emulsion Treated Base								
Sub-base	Neat gravel								
		A	**B**	**C**	**D**	**E**	**F**	**G**	**Point summary**
	Point score								

Sub- Section	Length (Km)	General appearance	Surface texture	Bitumen condition	Pot holes	Surface irregularity	Rutting	Cracking	Sum of (∑) Points A-G Max: 40	Average points	%	Remarks	PSR
1. Km 0+000 - 1+000	1.000	4.5	4.5	5.0	2.0	4.5	5.0	4.0	29.5	4.2	73.8	**Good**	**4.2**
Average PSR		**4.5**	**4.5**	**5**	**2**	**4.5**	**5**	**4**	**29.5**	**4.2**	**73.8**	**Good**	**4.2**

8.10 Rainfall Data

The rainfall measured during the baseline period is shown in Table 8-14.

Table 8-14: Precipitation at D419

Precipitation (mm) at Maragua Town – Gakoigo Jn Road (D419)										
2016					**2017**					
AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE
1.6	216.0	14.8	5.2	24.4	0	26.7	44.0	79.2	87.0	7.0

9 Karega – Gathara – Ithumbi Road 420

9.1 Site Description

This road starts at Nginda, goes through Ihumbu shopping centre, Gathera and ends at Karega. This is a total of 13.7 km. It is located in Murang'a County. Figure 9-1 shows the location map for this road.

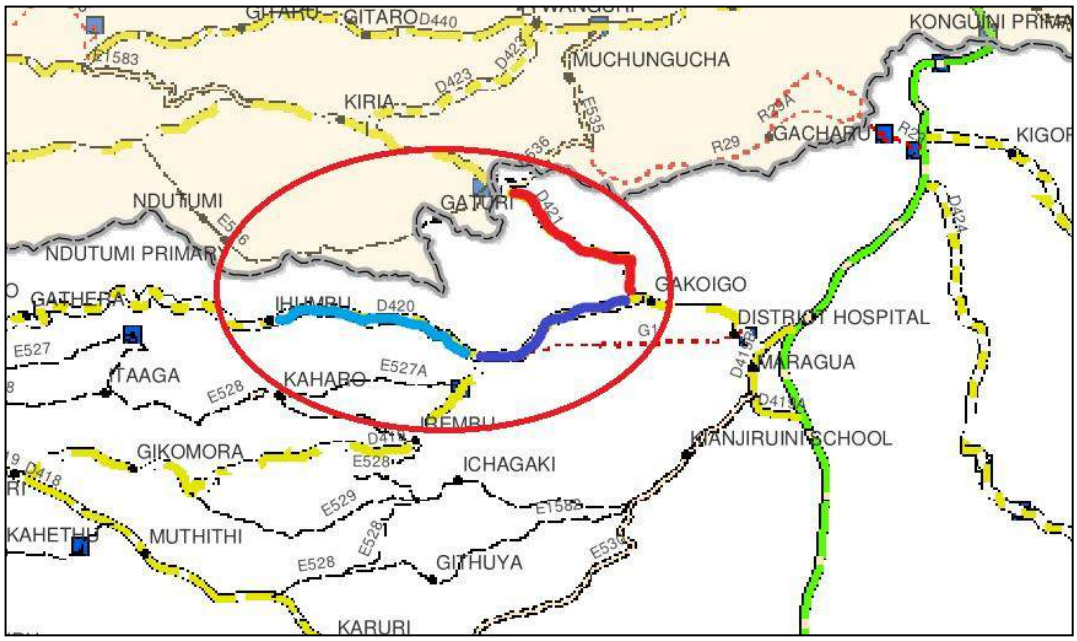


Figure 9-1: Location of Karega-Gathara-Ithumbi Road (D420), marked in light blue

9.2 Pavement Description

Figure 9-2 is a representation of the designed pavement structure.

20 mm Asphalt concrete mix	
150 mm Emulsion stabilized base	
250 mm Lateritic sub-base	
Subgrade	

Figure 9-2: Designed pavement Structure (D420)

9.3 Traffic Survey

9.3.1 Classified Traffic Counts

Table 9-1 shows a summary of traffic count. The high count of heavy goods vehicles can be attributed to an ongoing road construction project around Gathera shopping centre, as narrated by the drivers. This is also reflected on Road D419 since Road D420 is a continuation of Road D419. Most of these vehicles were carrying murram, and a few of them sand. The source of the murram is the outskirts of Maragua town. The trucks also came back empty after offloading the construction material.

Table 9-1: Traffic volume summary (D420)

Vehicle Type	Daily Volume (vpd)
Motorcycles	1,599
Cars	252
Minibus	61
Bus	8
Light Goods Vehicle	114
Medium Goods Vehicle	64
Heavy Goods Vehicle	70
ADT	**2,168**

9.3.2 Axle Load Survey

Table 9-2 shows the ESA by vehicle type, and the computed ESA/day.

Table 9-2: Traffic ESA (D420)

Vehicle Type	ESA/day
Bus[1]	XXX
Medium Goods Vehicles	35.79
Heavy Goods Vehicles	149.53
Design ESA/day	**185.32**

Note 1: Although Buses were counted during the traffic counts, they were not present during the axle load survey.

9.4 Rutting

Table 9-3 shows the maximum rut depth left and right of each chainage point. The average of 8 mm is acceptable for LVSRs.

Table 9-3: Maximum Rut Depth

Chainage	LHS Rut in mm	RHS Rut in mm
0+000	9	8
0+050	10	12
0+100	2	12
0+150	10	12
0+200	12	5
0+250	8	9
0+300	12	6
0+350	12	9
0+400	2	6
0+425	12	12
0+440	4	12
0+455	12	10
0+470	6	5
0+485	4	6
0+500	12	6
0+515	8	3

0+530	12	12
0+545	12	9
0+560	8	9
0+575		
0+600	8	9
0+650	5	12
0+700	3	5
0+750	6	6
0+800	9	7
0+850	3	1
0+900	5	4
0+950	4	3
1+000	1	9
Average	**8**	**8**

9.5 Deflection/Stiffness

Table 9-4 shows the central deflection D_0 and the base, sub-base and subgrade stiffness measured at each point.

Table 9-4: Deflection and stiffness (D420)

Chainage (m)	Lane No.	Stiffness			Normalized Deflections at Geophone Locations (µm) D_0
		EBase (MPa)	ESubbase (MPa)	ESubgrade (MPa)	
0+000	1	278	77	103	1047
0+100	1	334	34	164	839
0+200	1	1525	277	84	1097
0+300	1	311	35	148	867
0+400	1	554	56	211	550
0+425	1	331	79	121	981
0+455	1	321	38	127	881
0+486	1	394	71	117	1102
0+515	1	492	90	151	976
0+545	1	409	76	139	856
0+581	1	304	32	234	777
0+600	1	389	55	120	777
0+700	1	377	25	147	907
0+800	1	1957	342	84	1043
0+901	1	164	17	172	1196
1+003	1	349	86	129	1083
0+050	2	300	34	151	844
0+150	2	407	46	145	744
0+249	2	405	64	134	746
0+350	2	375	50	137	790

0+440	2	898	160	135	922
0+470	2	1107	185	145	947
0+500	2	367	85	124	919
0+530	2	205	24	235	929
0+560	2	314	32	179	811
0+651	2	368	38	401	584
0+751	2	307	64	108	976
0+847	2	1033	186	138	824
0+950	2	2500	300	89	1517
0+050	3	189	19	131	1174
0+150	3	925	164	151	825
0+250	3	341	72	119	863
0+350	3	313	61	99	1090
0+441	3	290	32	136	892
0+470	3	968	173	107	975
0+500	3	305	59	104	1038
0+530	3	342	35	260	680
0+560	3	353	41	180	742
0+652	3	466	47	208	576
0+754	3	219	22	183	959
0+850	3	334	77	109	1145
0+954	3	111	8	163	1967
0+000	4	350	80	123	838
0+100	4	407	87	133	934
0+200	4	293	68	106	1173
0+300	4	293	57	98	1132
0+400	4	400	84	134	946
0+424	4	350	76	125	976
0+485	4	425	78	124	1148
0+514	4	955	167	105	940
0+544	4	403	76	125	964
0+573	4	254	30	169	910
0+600	4	352	47	212	681
0+700	4	459	89	148	911
0+800	4	331	53	111	867
0+900	4	2500	300	74	1521
0+988	4	187	10	6230	1059

All the deflection outputs from the FWD for all the sensors (D_0 up to D_6) for all the test locations are presented in the Appendix section of the report. Figure 9-3 shows a lot of the central deflection of each wheel path along the road. There is high variability in the central deflection.

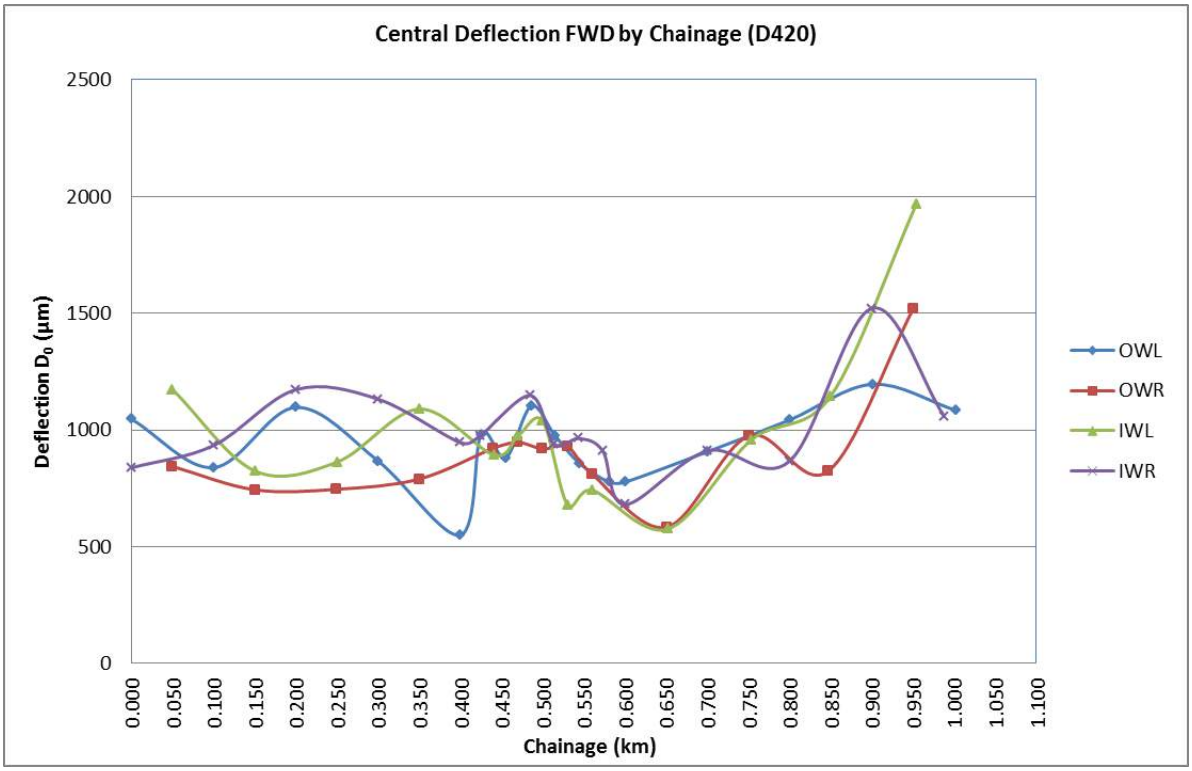


Figure 9-3: Central deflection by chainage (D420)

9.6 DCP Measurements

Table 9-5 shows the DN and DSN values by layer for each test point. The values mostly lie outside the specification limits.

Table 9-5: DN and DSN values (D420)

Chainage (m)	Specifications	≤3.2	≤6.0	≤12	≤19	≤25	DSN800
	Position	0-150	150-300	300-450	450-600	600-800	≥100
0+000	LHS	3.8	6.3	4.2	9.9	11.1	146
0+100	RHS	2.7	0.2	0.2	0.2	0.2	150
0+100	LHS	5.0	4.4	5.4	9.4	27.7	120
0+150	RHS	4.3	4.6	5.7	9.4	14.3	135
0+200	LHS	7.5	12.3	21.0	27.9	37.0	54
0+250	RHS	10.5	10.9	23.3	25.2	31.2	53
0+300	LHS	9.4	11.3	34.0	29.4	32.8	51
0+350	RHS	2.9	3.1	2.3	9.4	11.6	220
0+400	LHS	7.8	10.6	20.4	42.2	39.6	55
0+403	RHS	5.7	6.3	11.0	20.4	25.8	99
0+409	OWL	6.4	9.0	9.3	14.5	19.5	83
0+409	IWL	8.0	6.2	16.8	27.0	39.4	69
0+409	CL	6.8	3.6	7.4	18.4	26.4	120
0+409	IWR	4.7	3.5	5.0	9.8	40.0	143
0+409	OWR	5.5	8.3	11.6	18.7	25.5	77

0+578	OWR	2.7	1.1	0.5	0.5	0.5	150
0+578	IWR	3.6	2.1	1.9	3.0	5.5	318
0+578	CL	4.0	2.0	2.1	4.6	2.6	350
0+578	IWL	4.2	7.4	3.4	6.7	18.3	226
0+578	OWL	6.0	6.2	9.4	13.2	34.3	93
0+582	LHS	2.8	3.1	2.3	3.3	3.7	309
0+650	LHS	4.1	2.4	2.6	5.0	11.2	247
0+700	RHS	3.7	2.9	2.5	3.9	9.4	238
0+750	LHS	4.5	3.7	3.7	4.7	23.9	209
0+800	LHS	3.5	3.6	2.2	3.4	8.9	246
0+850	LHS	4.8	5.0	5.2	10.4	9.8	160
0+900	RHS	6.1	9.2	3.3	5.6	8.5	156
0+950	LHS	6.1	3.8	6.8	7.0	20.3	136
1+000	RHS	5.8	3.8	6.1	7.6	19.1	140

9.7 Roughness Measurements

Roughness measured within the section is within the acceptable range for LVSRs, as shown in Table 9-6 and Table 9-7. Figure 9-4 shows the roughness of each lane along the road section.

Table 9-6: Roughness values including humps (D420)

Karega-Gathara-Ithumbi Road (D420)			
LHS		RHS	
Chainage	IRI	Chainage	IRI
0+000-0+150	5.4	0+000-0+300	5.4
0+150-0+250	5.4	0+300-0+400	4.2
0+250-0+350	6.1	0+400-0+424	4.2
0+350-0+441	4.2	0+424-0+485	5.6
0+441-0+470	5.6	0+485-0+514	5.6
0+470-0+500	5.6	0+514-0+544	5.6
0+500-0+560	5.6	0+544-0+600	2.6
0+560-0+652	2.6	0+600-0+700	4.2
0+652-0+754	1.6	0+700-0+900	7.3
0+754-0+850	1.6	0+900-0+988	3.9
0+850-0+954	7.3		

Table 9-7: Roughness values excluding humps (D420)

Karega-Gathara-Ithumbi Road (D420)			
LHS		RHS	
Chainage	IRI	Chainage	IRI
0+000-0+150	3.0	0+000-0+300	3.0
0+150-0+250	3.0	0+300-0+400	3.0
0+250-0+350	3.0	0+400-0+424	3.0
0+350-0+441	3.0	0+424-0+485	3.0

0+441-0+470	3.0	0+485-0+514	3.0
0+470-0+500	3.0	0+514-0+544	3.0
0+500-0+560	3.0	0+544-0+600	3.7
0+560-0+652	3.7	0+600-0+700	3.0
0+652-0+754	3.7	0+700-0+900	3.0
0+754-0+850	3.7	0+900-0+988	3.0
0+850-0+954	3.0		

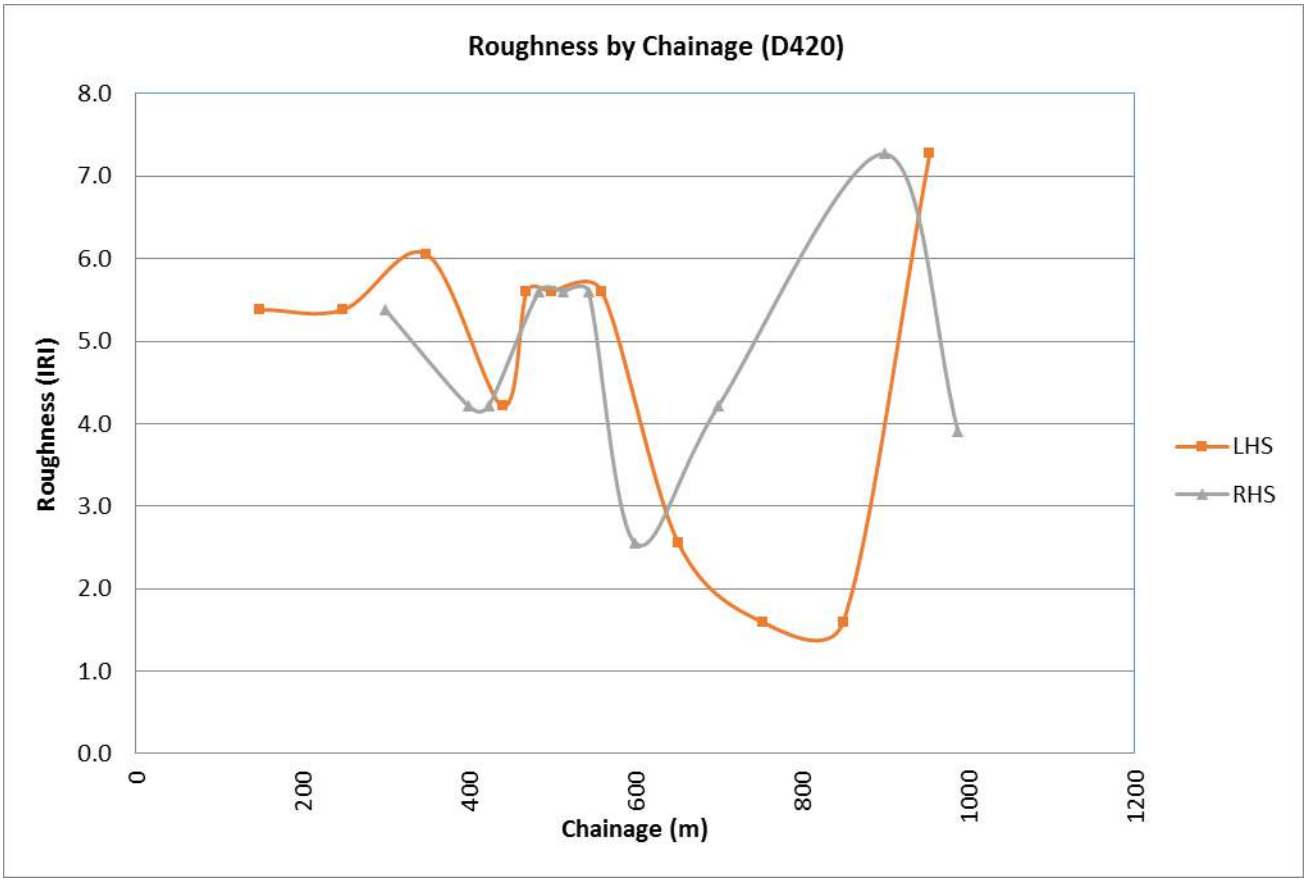


Figure 9-4: Roughness values including humps by chainage (D420)

9.8 Test Pits

9.8.1 DN Values

Table 9-8 shows the DN of each layer in the structure measured before excavation the test pit. Pit A values lie outside the specification and Pit B values lie within the specification.

Table 9-8: DN values at test pit (D420)

Depth (mm)	Specifications	DN values (mm/blow)	
		Pit A @ 0+403	Pit B @ 0+582
0 – 150	≤3.2	5.7	2.8
150 – 300	≤6.0	6.3	3.1
300 – 450	≤12	11.0	2.3
450 – 600	≤19	20.4	3.3

600 – 800	≤25	25.8	3.7
DSN800	≥100	99	309

The rest of the DCP test details are presented in the Appendix section of the report.

9.8.2 Layer Thicknesses

Figure 9-5 shows the measured layer thickness and descriptions of the pavement materials.

Test Pit A, km 0+403		**Test Pit B, km 0+582**
20 mm Asphalt concrete mix		20 mm Asphalt concrete mix
150 mm Emulsion stabilized base		150 mm Emulsion stabilized base
250 mm Lateritic gravel sub-base		250 mm Lateritic gravel sub-base
Subgrade		Subgrade

Figure 9-5: Layer thicknesses at test pit

9.8.3 Densities and Moisture Content

Table 9-9 shows the dry density, the MDD, the in-situ moisture content and the OMC (AASHTO T180 for base and sub-base, and AASHTO T99 for subgrade) for each pavement layer, including the subgrade. The IMC values lie close to the OMC.

Table 9-9: Density and moisture content at test pit (D420)

Panel	Wheel Path	Layer	MDD (kg/m^3)	In-situ Moisture Content (%)	OMC (%)	Relative Moisture Content (FMC/OMC)
Panel A	OWP	Base	1580	20.2	21.2	0.95
		Sub-base	1540	18.7	26.7	0.70
		Subgrade	1370	30.2	28.6	1.06
	IWP	Base	1510	16.7	20.9	0.80
		Sub-base	1530	25.8	25.2	1.02
		Subgrade	1365	-	27.4	-
Panel B	OWP	Base	1650	17.0	21.0	0.81
		Sub-base	1620	19.2	21.0	0.91
		Subgrade	1400	-	29.2	-
	IWP	Base	1600	33.6	20.9	1.61
		Sub-base	1565	19.1	23.8	0.80
		Subgrade	1400	-	30.0	-

9.8.4 Particle Size Distribution

The plots in Figure 9-6, Figure 9-7, and Figure 9-8 show the particle size distribution for each layer. The base materials are generally finer than the specification envelope.

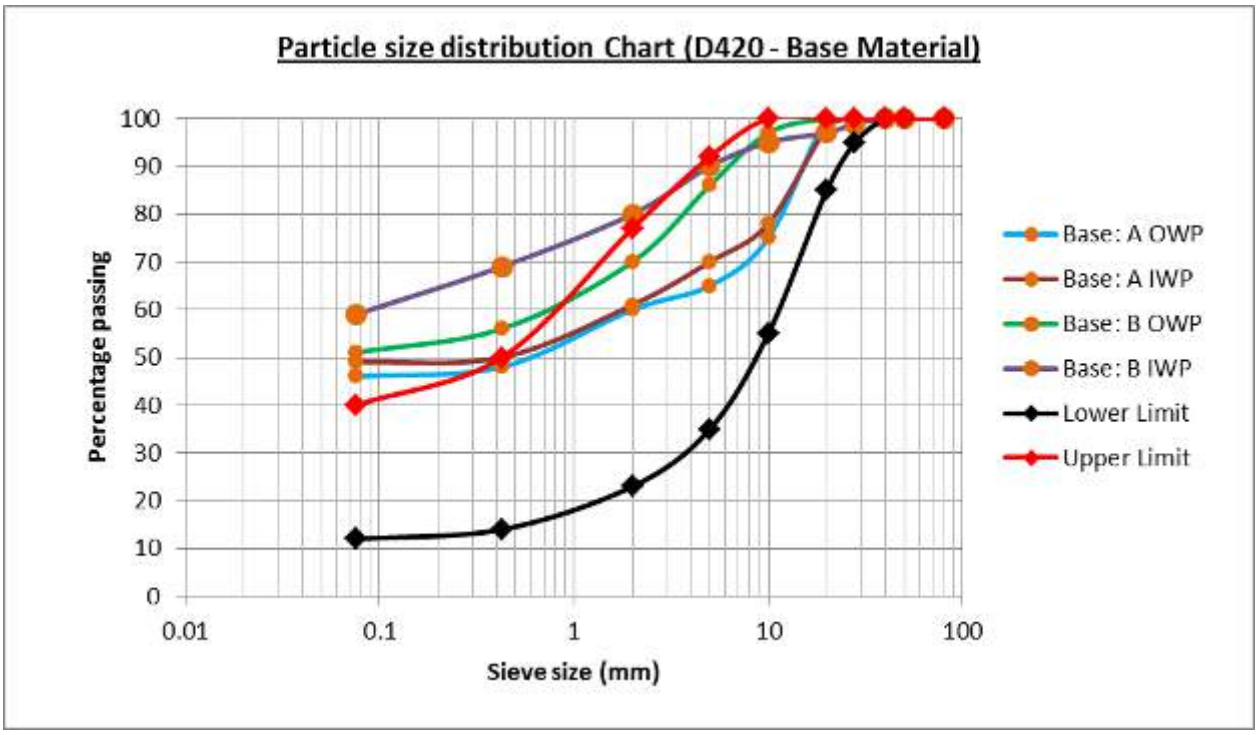


Figure 9-6: Particle size distribution for base material (D420)

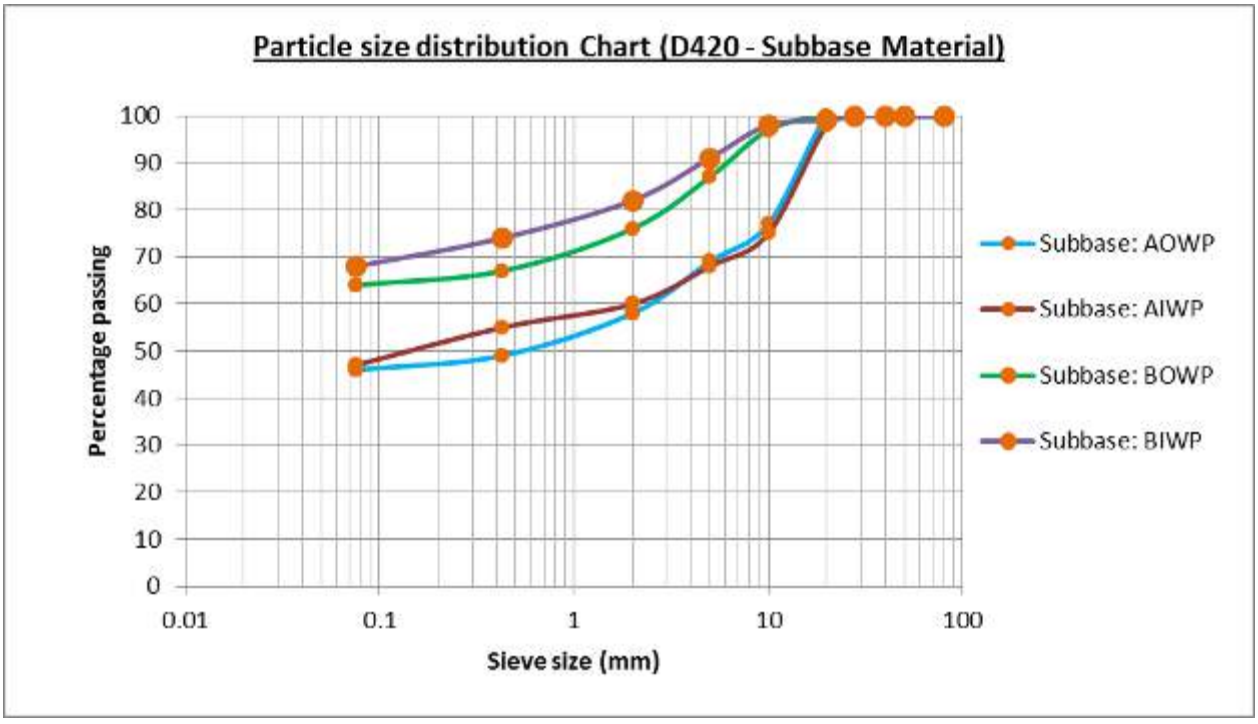


Figure 9-7: Particle distribution for subbase material (D420)

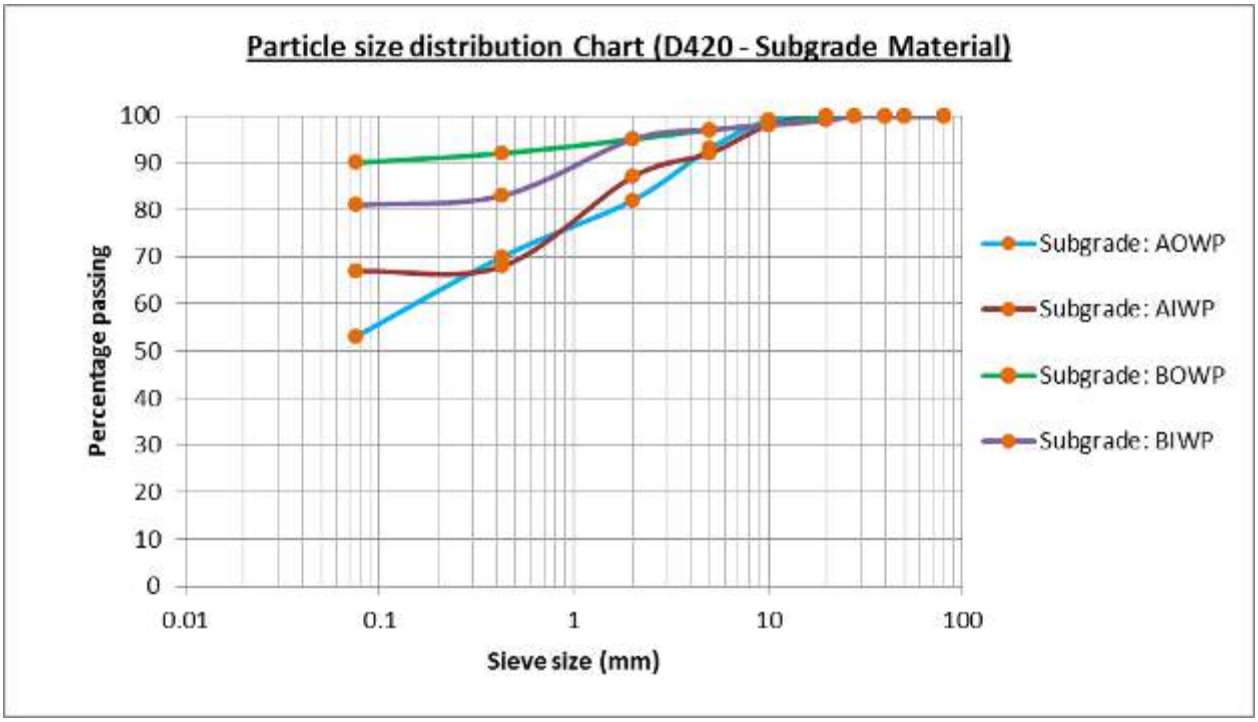


Figure 9-8: Particle size distribution for subgrade material (D420)

9.8.5 Atterberg Limits

Table 9-10 below shows the index properties of each pavement layer, including the subgrade. The materials generally have high plasticity.

Table 9-10: Atterberg limits at test pit

Layer	Liquid Limit	Plastic Limit	Plasticity Index	Linear Shrinkage
Road D420 – Panel A - OWP				
Base	51	26	25	12
Sub-base	53	25	28	14
Subgrade	67	37	30	15
Road D420 – Panel A – IWP				
Base	49	23	26	13
Sub-base	53	30	23	12
Subgrade	62	32	30	14
Road D420 – Panel B - OWP				
Base	49	26	23	11
Sub-base	47	21	26	13
Subgrade	64	38	26	14
Road D420 – Panel B - IWP				
Base	49	27	22	11
Sub-base	43	23	20	11
Subgrade	55	21	26	14

9.8.6 Laboratory CBR

Table 9-11 shows the 4-day soaked CBR (AASHTO T180 for base and sub-base, and AASHTO T99 for subgrade) of each layer, including the subgrade. The values are very low for the required pavement layers.

Table 9-11: Laboratory CBR (D420)

4-day soaked CBR (%) (D420)				
Layer	**Panel A**		**Panel B**	
	OWP	**IWP**	**OWP**	**IWP**
Base	13	12	14	15
Sub-base	8	15	4	6
Subgrade	5	19	4	4

9.9 Visual Condition Assessment

9.9.1 Pavement Defects Assessment

The main surface defects on this road are potholes and cracks as shown in Table 9-12 .

Table 9-12: Visual condition assessment of D420

Fig No	Location (Km)	Defect assessment and description	Photos illustrating the pavement distress & defect
Fig 1	Km 0+000 – 0+100 Main carriage way	No visible defect on the carriage way	

Fig 2	Km 0+084RHS	-Potholes developing on the main carriage way inner wheel path	
Fig 3	Km 0+100 -0+125	-Potholes and alligator cracks on the surface covering and area of about 2m by 20m^2 -Faded road marking	
Fig 4	Km 0+100 – 0+126 RHS	-Water crossing over the carriage way due to blocked drain -Blocked and silted side drain	

Fig 5	Km 0+177LHS	-Potholes and alligator cracks on the outer wheel path	
Fig 6	Km 0+200 – 0+230 LHS	-Localized disintegration of ac layer leading to the potholes on the LHS carriage way on the shoulders and outer wheel path -Silted side drain and access culvert	
Fig 7	Km 0+455RHS	-Potholes on the RHS lane on the inner wheel a path covering 100mm by 50mm -Surface appears rough and course	

Fig 8	Km 0+660-0+665LHS	-Silted shoulders and edge extending to main carriage way -Soaking of the shoulders and edge with erosion deposits from a poorly placed access culvert	
Fig 9	Km 0+716 -0+750 LHS lane	-Disintegration and alligator cracks of asphalt layer leading raveling ,potholes ,stripping and crack sealing done on the carriage way Km 0+716-0+750	
Fig 10	Km 0+752Centerline	-Pothole at the centerline covering 0.3m by 0.2m and a depth of 30mm	

Fig 11	Km 0+890 -0+920	-Stripping and raveling on the LHS lane covering approximately 30m long and 3.m width	
Fig 12	Km 0+984 -1+000 main carriage way	-No visible defect on the main carriage way -Desilted drain and access culvert	

9.9.2 Present Serviceability Rating

The computed PSR for this road section is 3.9, as shown in Table 9-13, which is regarded as "Good".

Table 9-13: Present Serviceability Rating D420

Road :	Karega – Gathara - Ithumbi Road D420								
Section:	Km 0+000 - Km 1+ 000 main carriage way								
Pavement Structure:	Date of survey							11/12/2016	
Surfacing	Asphalt concrete mix								
Base	Emulsion stabilized base								
Sub-base	Lateritic gravel								
		A	**B**	**C**	**D**	**E**	**F**	**G**	**Point summary**
	Point score								

Sub- Section	Length (Km)	General appearance	Surface texture	Bitumen condition	Pot holes	Surface irregularity	Rutting	Cracking	Sum of (∑) Points A-G Max: 40	Average points	%	Remarks	PSR
1. Km 0+000 - 0+500	0.500	4.5	4.5	5.0	0.0	4.5	5.0	3.0	26.5	3.8	66.3	**Good**	**3.8**
2. Km 0+500- 1+000	0.500	4.5	4.5	5.0	1.0	4.5	5.0	3.0	27.5	3.9	68.8	**Good**	**3.9**
Average PSR		**4.5**	**4.5**	**5**	**0.5**	**4.5**	**5**	**3**	**27**	**3.86**	**67.5**	**Good**	**3.9**

9.10 Rainfall

Rainfall measured during the baseline period is shown in Table 9-14.

Table 9-14: Precipitation at D419

Precipitation (mm) at Karega – Gathara - Ithumbi Road (D420)										
2016					**2017**					
AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE
1.6	216.0	14.8	5.2	24.4	0	26.7	44.0	79.2	87.0	7.0

10 Gakoigo Jn - Maragua River Road D421

10.1 Site Description

This Road starts at Gakoigo Junction and descends up to Maragua River, a total of 3.3 km. The road is windy as it's built on a slope. It is located in Murang'a County. Figure 10-1 shows a map of the site location.

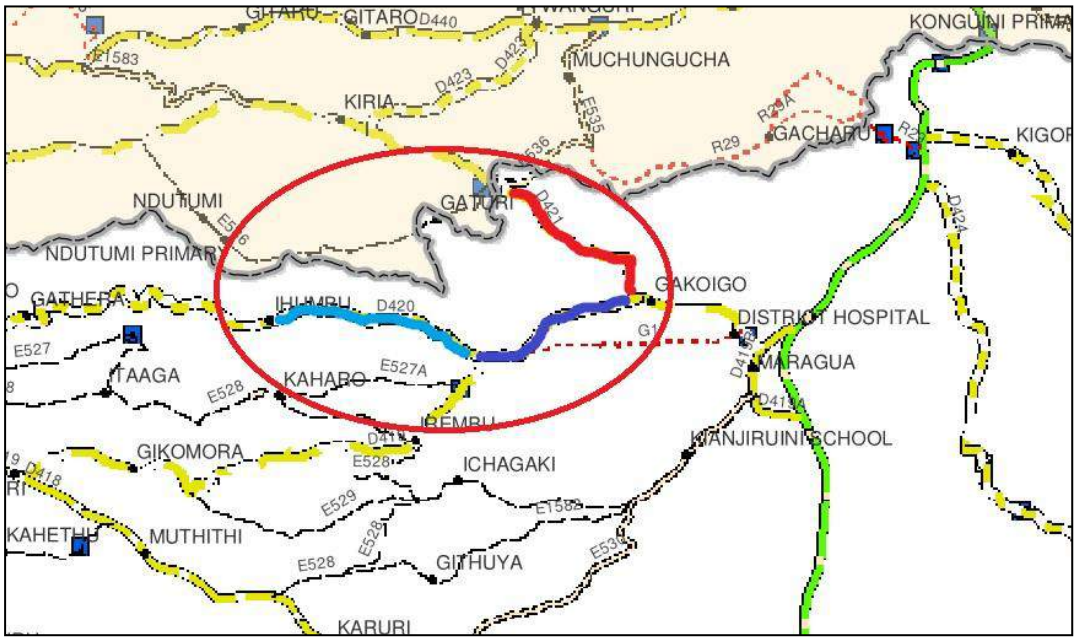


Figure 10-1: Location of Gakiogo Jn - Maragua River Road (D421), marked in red

10.2 Pavement Description

Figure 10-2 shows a representation of the designed pavement structure.

20 mm Cold Mix Asphalt	
150 mm Emulsion treated lateritic gravel base	
250 mm Lateritic gravel sub-base	
Subgrade	

Figure 10-2: Designed pavement structure (D421)

10.3 Traffic Survey

10.3.1 Classified Traffic Counts

Table 10-1 shows a summary of the traffic count. The road has a very high population of motorcycle users.

Table 10-1: Traffic volume summary (D421)

Vehicle Type	Daily Volume (vpd)
Motorcycles	**1,602**
Cars	**163**

Minibus	**74**
Bus	**9**
Light Goods Vehicle	**62**
Medium Goods Vehicle	**40**
Heavy Goods Vehicle	**2**
ADT	**1,952**

10.3.2 Axle Load Survey

Table 10-2 shows the ESA by vehicle type, and the computed ESA/day.

Table 10-2: Traffic ESA (D421)

Vehicle Type	**ESA/day**
Bus[1]	XXX
Medium Goods Vehicles	4.34
Heavy Goods Vehicles	1.52
Articulated Heavy Goods Vehicles	0.07
Design ESA/day	**5.93**

Note 1: Although Buses were counted during the traffic counts, they were not present during the axle load survey.

10.4 Rutting

Table 10-3 shows the maximum rut depth left and right of each chainage point. The average value of 9 mm is acceptable for LVSRs.

Table 10-3: Maximum rut depth (D421)

Chainage	**LHS Rut in mm**	**RHS Rut in mm**
0+000	4	5
0+050	6	7
0+100	2	12
0+150	9	6
0+200	7	7
0+250	12	9
0+300	9	7
0+350	12	5
0+400	4	8
0+425	12	7
0+440	12	3
0+455	7	2
0+470	3	4
0+485	8	9
0+500	12	7
0+515	12	5
0+530	12	7
0+545	12	12

0+560	11	7
0+575	12	3
0+600	7	5
0+650	12	4
0+700	5	12
0+750	10	6
0+800	10	7
0+850	12	9
0+900	6	5
0+950	7	6
1+000	12	1
Average	**9**	**7**

10.5 Deflection/Stiffness

Table 10-4 shows the central deflection D_0 and the base, sub-base and subgrade stiffness measured at each point.

Table 10-4: Deflection and stiffness (D421)

Chainage (m)	Lane No.	Stiffness			Normalized Deflections at Geophone Locations (µm) D_0
		EBase (MPa)	ESubbase (MPa)	ESubgrade (MPa)	
0+000	1	412	84	141	878
0+100	1	1075	195	117	833
0+200	1	1031	177	152	729
0+300	1	1244	208	120	870
0+401	1	338	84	125	829
0+425	1	435	89	149	697
0+455	1	452	90	149	775
0+485	1	525	37	199	640
0+515	1	1337	236	124	789
0+545	1	1059	180	140	750
0+575	1	1978	307	69	1038
0+600	1	2007	307	76	1016
0+700	1	1094	194	96	929
0+800	1	1086	186	129	809
0+900	1	993	171	121	897
1+000	1	1336	224	105	869
0+050	2	261	54	78	1080
0+150	2	309	65	109	871
0+251	2	1023	177	98	941
0+350	2	1518	266	86	788
0+440	2	374	81	130	834

0+470	2	521	101	173	709
0+500	2	1098	191	116	799
0+530	2	273	187	111	598
0+560	2	1218	204	137	832
0+650	2	1179	206	125	922
0+750	2	1127	192	121	747
0+850	2	1243	213	143	819
0+950	2	963	175	130	750
0+050	3	1084	187	123	781
0+150	3	1220	205	133	846
0+250	3	925	165	135	884
0+350	3	336	54	102	860
0+440	3	414	84	140	755
0+470	3	1660	269	142	805
0+500	3	614	124	193	702
0+530	3	1051	191	161	691
0+561	3	358	65	114	806
0+650	3	1124	195	97	894
0+750	3	987	178	143	791
0+850	3	1020	181	144	809
0+951	3	430	96	148	800
0+000	4	193	148	90	780
0+100	4	1170	198	189	766
0+200	4	382	85	132	809
0+300	4	1157	197	115	792
0+400	4	471	87	156	776
0+425	4	342	74	121	835
0+455	4	449	92	148	827
0+485	4	608	108	189	717
0+515	4	1608	274	89	885
0+545	4	363	36	154	757
0+575	4	1234	206	108	912
0+600	4	408	28	194	776
0+700	4	1107	196	111	850
0+800	4	371	77	128	784
0+900	4	1062	189	107	865
1+000	4	1169	196	148	843

All the deflection outputs from the FWD for all the sensors (D_0 up to D_6) for all the test locations are presented in the Appendix section of the report. Figure 10-3 shows the central deflection for each wheel path along the road. The deflection shows a high variability as for all the previous roads.

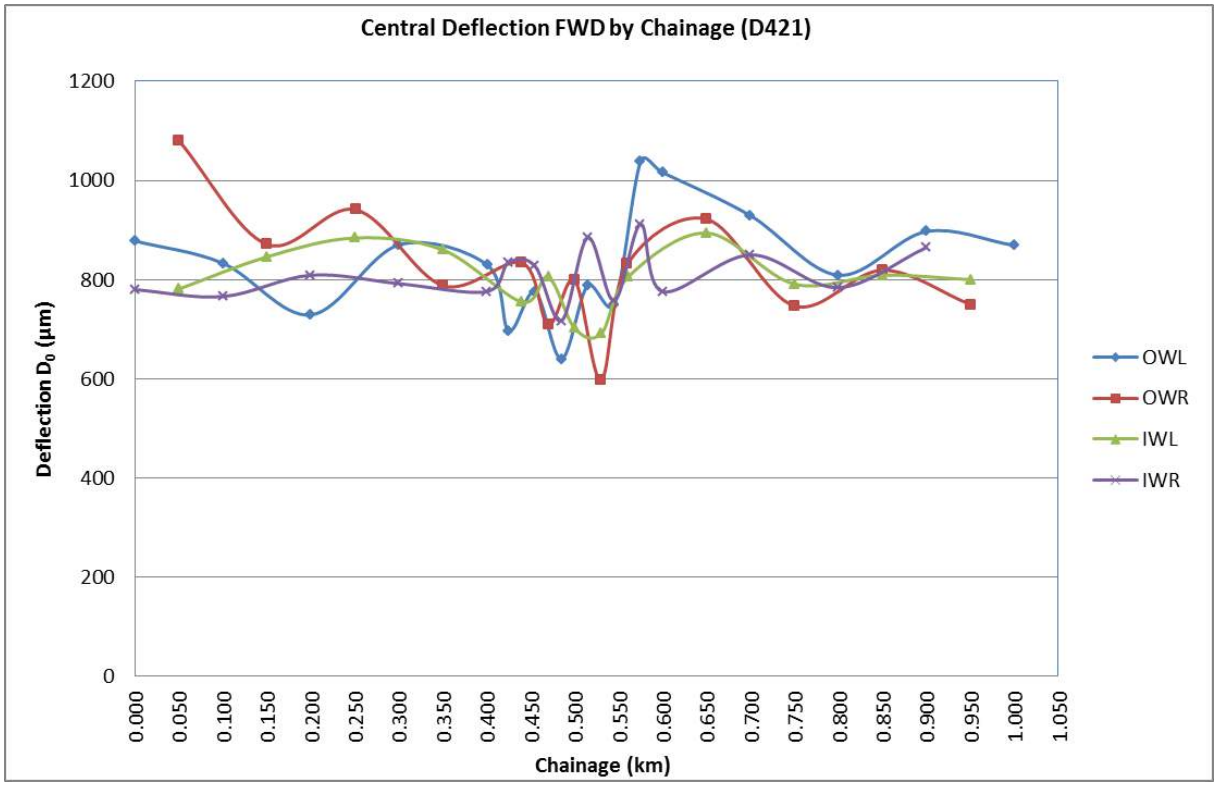


Figure 10-3: Central deflection by chainage (D421)

10.6 DCP Measurements

Table 10-5 shows the DN and DSN values by layer for each test point. The values are spread either side of the specification.

Table 10-5: DN and DSN values (D421)

Chainage (m)	Specifications	≤3.2	≤6.0	≤12	≤19	≤25	DSN800
	Position	0-150	150-300	300-450	450-600	600-800	≥100
0+000	RHS	6.9	16.4	16.1	24.1	38.3	67
0+050	LHS	6.3	2.6	3.9	8.1	14.7	204
0+100	RHS	6.2	10.1	19.8	20.8	20.9	86
0+150	LHS	4.1	2.2	3.3	5.7	7.0	248
0+200	RHS	5.2	3.6	5.3	9.0	16.9	153
0+250	LHS	4.9	5.1	6.2	14.9	14.2	161
0+250	LHS	4.9	5.1	6.2	14.9	14.2	161
0+300	RHS	3.8	2.3	4.1	7.8	13.4	228
0+400	RHS	4.7	6.6	4.7	5.9	7.8	176
0+406	RHS	5.5	6.3	5.3	11.3	15.4	133
0+413	OWR	5.0	4.8	4.8	11.7	13.7	139
0+413	IWR	4.1	2.1	2.2	3.7	7.8	271
0+413	CL	2.1	2.4	2.4	4.5	8.7	281
0+413	IWL	2.5	2.4	1.9	5.6	13.8	290
0+413	OWL	2.5	4.2	5.0	13.2	18.8	158
0+577	IWL	5.5	13.4	23.2	29.2	39.5	59

0+577	OWL	3.9	4.9	7.9	12.2	17.0	121
0+577	CL	4.4	3.5	7.0	7.9	17.7	153
0+577	IWR	4.7	4.2	6.7	14.7	18.4	122
0+577	OWR	4.9	3.9	7.1	10.5	16.8	122
0+580	LHS	5.4	10.7	20.2	27.8	39.1	62
0+650	LHS	3.9	4.6	4.6	5.2	13.1	160
0+700	RHS	5.4	4.2	5.7	9.9	14.8	130
0+750	LHS	3.1	2.4	2.6	5.3	9.8	267
0+800	RHS	3.9	3.1	5.2	10.3	18.1	238
0+850	LHS	3.1	3.9	7.6	8.1	15.6	162
0+900	RHS	5.1	5.7	7.3	10.1	12.4	124
0+950	LHS	4.5	2.7	4.5	6.7	9.0	187
1+000	RHS	5.9	4.7	6.8	3.9	9.5	163

10.7 Roughness Measurements

Roughness values shown in Table 10-6 and

Table 10-7 are within the expected range for LVSRs. Figure 10-4 shows the roughness of each lane along the road section.

Table 10-6: Roughness values including bumps (D421)

Gakoigo Jn - Maragua River Road (D421)			
LHS		RHS	
Chainage	IRI	Chainage	IRI
0+000-0+050	2.6	0+000-0+100	3.0
0+050-0+150	3.0	0+100-0+300	5.1
0+150-0+250	4.3	0+300-0+400	6.3
0+250-0+440	6.3	0+400-0+425	6.3
0+440-0+470	6.3	0+425-0+485	3.7
0+470-0+500	3.7	0+485-0+515	3.7
0+500-0+0+561	3.7	0+515-0+545	3.7
0+561-0+650	2.0	0+545-0+600	2.0
0+650-0+750	4.5	0+600-0+700	4.5
0+750-0+951	5.7	0+700-0+800	3.3
		0+800-1+000	5.4

Table 10-7: Roughness values excluding bumps (D421)

Gakoigo Jn - Maragua River Road (D421)			
LHS		RHS	
Chainage	IRI	Chainage	IRI
0+000-0+050	4.2	0+000-0+100	4.2
0+050-0+150	4.2	0+100-0+300	3.4
0+150-0+250	3.4	0+300-0+400	3.4
0+250-0+440	3.4	0+400-0+425	3.4
0+440-0+470	3.4	0+425-0+485	3.4

0+470-0+500	3.4	0+485-0+515	3.4
0+500-0+0+561	3.4	0+515-0+545	3.4
0+561-0+650	4.2	0+545-0+600	4.2
0+650-0+750	3.4	0+600-0+700	3.4
0+750-0+951	3.4	0+700-0+800	3.4
		0+800-1+000	3.4

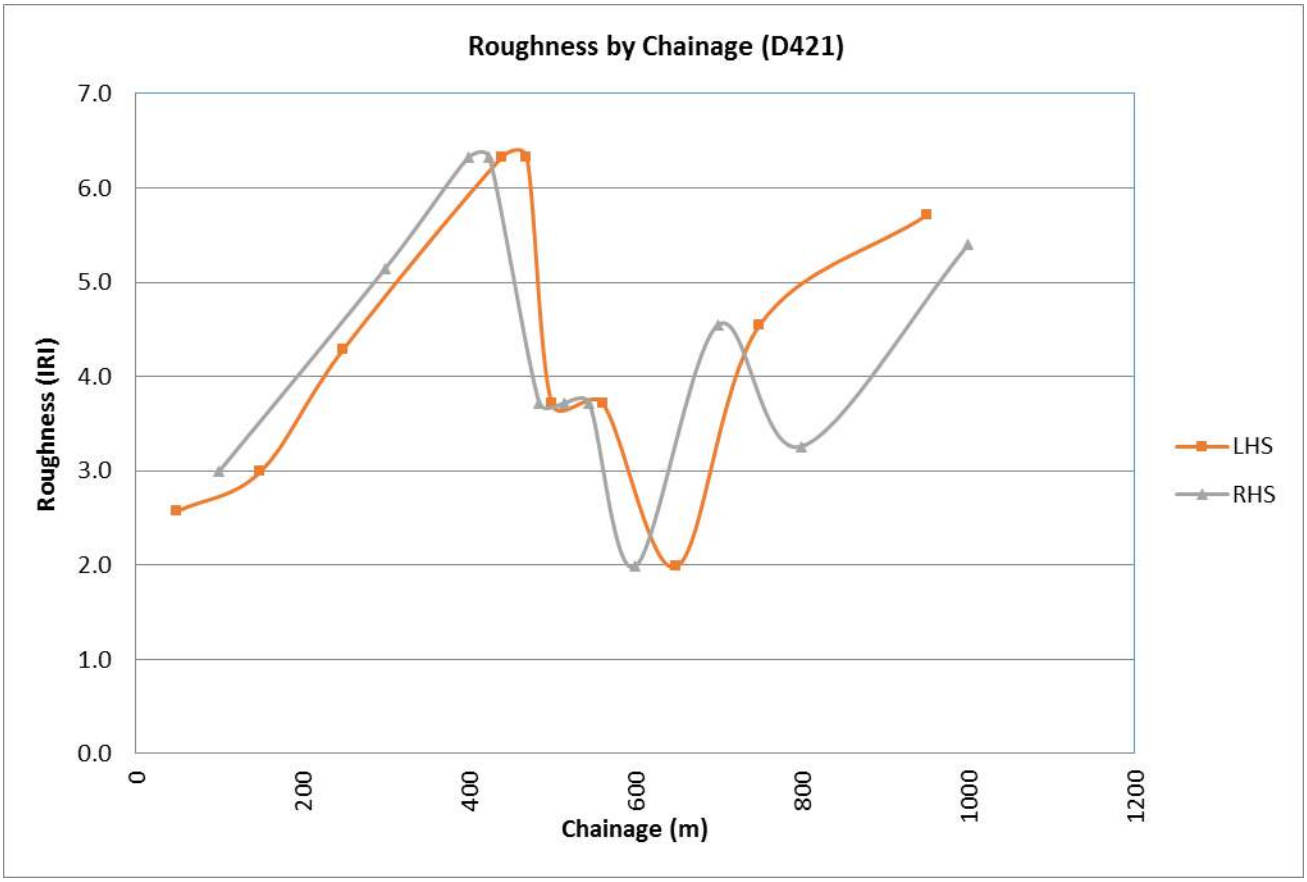


Figure 10-4: Roughness values including bumps by chainage (D421)

10.8 Test Pits

10.8.1 DN Values

Table 10-8 shows the DN of each layer in the structure measured before excavation of the test pit. Test Pit A is does not meet the specification at base level but meets sub-base level specifications. Test Pit B does not meet both base and sub-base specifications.

Table 10-8: DN values at test pit (D421)

Depth (mm)	Specifications	DN values (mm/blow)	
		Pit A @ 0+406	Pit B @ 0+580
0 – 150	≤3.2	5.5	5.4

150 – 300	≤6.0	6.3	10.7
300 – 450	≤12	5.3	20.2
450 – 600	≤19	11.3	27.8
600 – 800	≤25	15.4	39.1
DSN800	≥100	133	62

All DCP test details are presented in the Appendix section of the report.

10.8.2 Layer Thicknesses

Figure 10-5 shows an illustration of the measured layer thicknesses and pavement material descriptions.

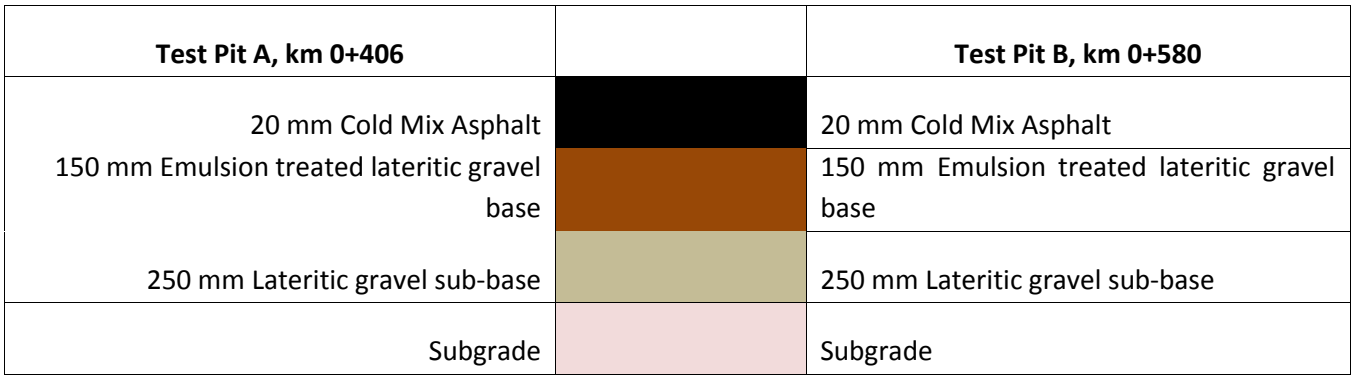


Figure 10-5: Layer thicknesses at test pit (D421)

10.8.3 Densities and Moisture Content

Table 10-9 shows the dry density, the MDD, the in-situ moisture content and the OMC (AASHTO T180 for base and sub-base, and AASHTO T99 for subgrade) of each pavement layer, including the subgrade.

Table 10-9: Density and moisture content at test pit (D421)

Panel	Wheel Path	Layer	MDD (kg/m^3)	In-situ Moisture Content (%)	OMC (%)	Relative Moisture Content (FMC/OMC)
Panel A	OWP	Base	1700	12.2	15.2	0.80
		Sub-base	1715	24.0	18.3	1.31
		Subgrade	1300	26.2	31.0	0.85
	IWP	Base	1660	24.4	15.6	1.56
		Sub-base	1780	20.3	16.8	1.21
		Subgrade	1300	25.8	29.6	0.87
Panel B	OWP	Base	1580	18.8	29.0	0.65
		Sub-base	1700	19.1	15.6	1.22
		Subgrade	1285	31.8	30.8	1.03
	IWP	Base	1650	13.8	18.6	0.74
		Sub-base	1685	21.0	17.8	1.18
		Subgrade	1280	28.0	33.0	0.85

10.8.4 Particle Size Distribution

The plots in Figure 10-6, Figure 10-7, and Figure 10-8 show the particle size distribution for each layer. The base material generally fit within the envelope, except for two locations that are slightly finer.

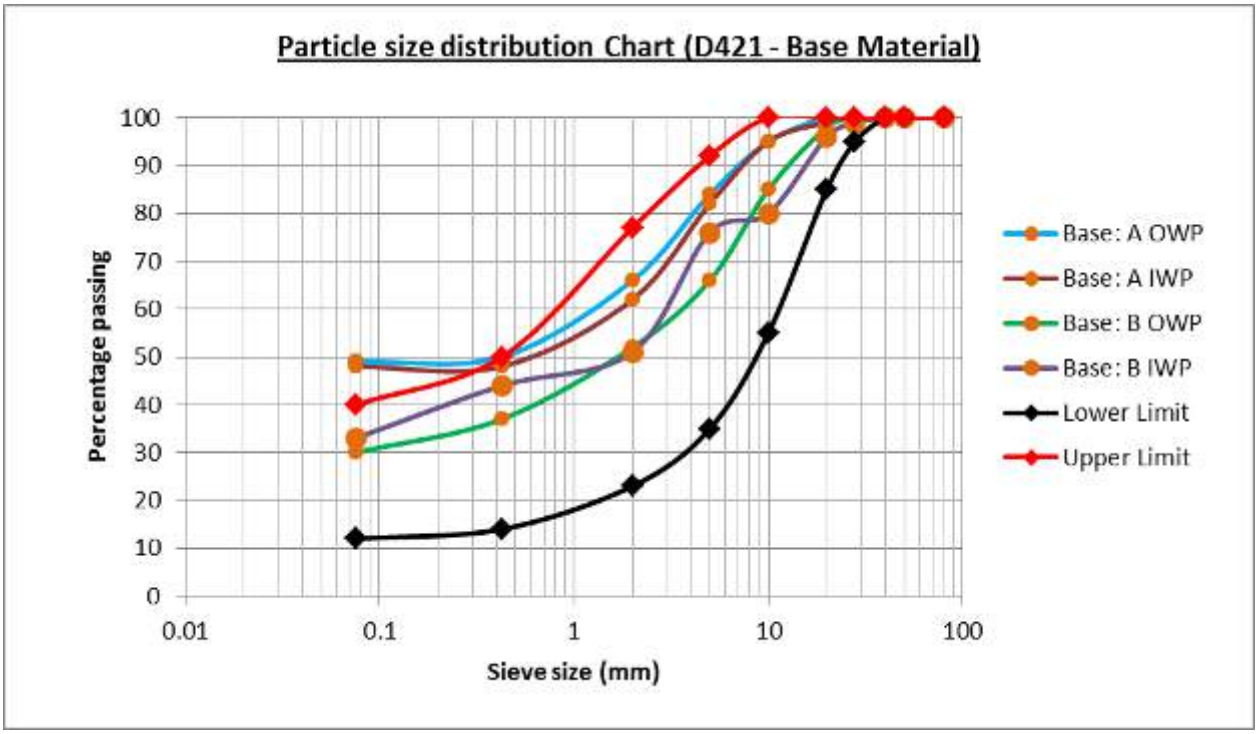


Figure 10-6: Particle size distribution for base material (D421)

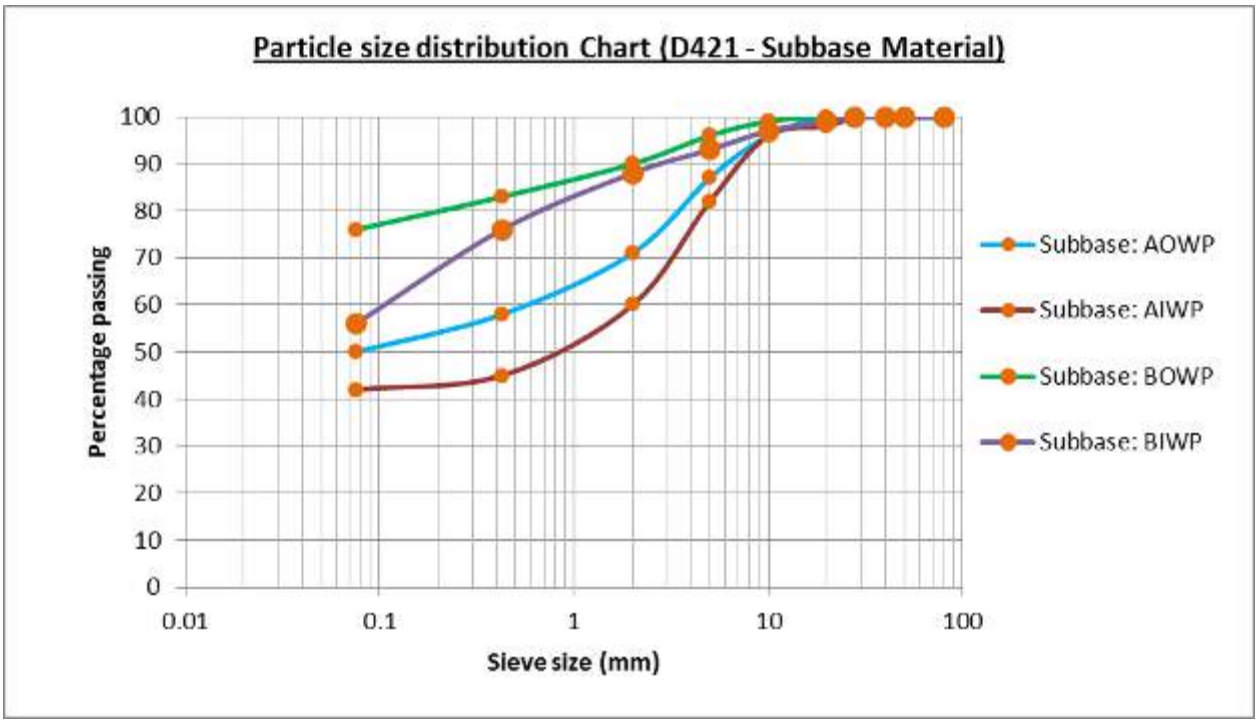


Figure 10-7: Particle size distribution for subbase material (D421)

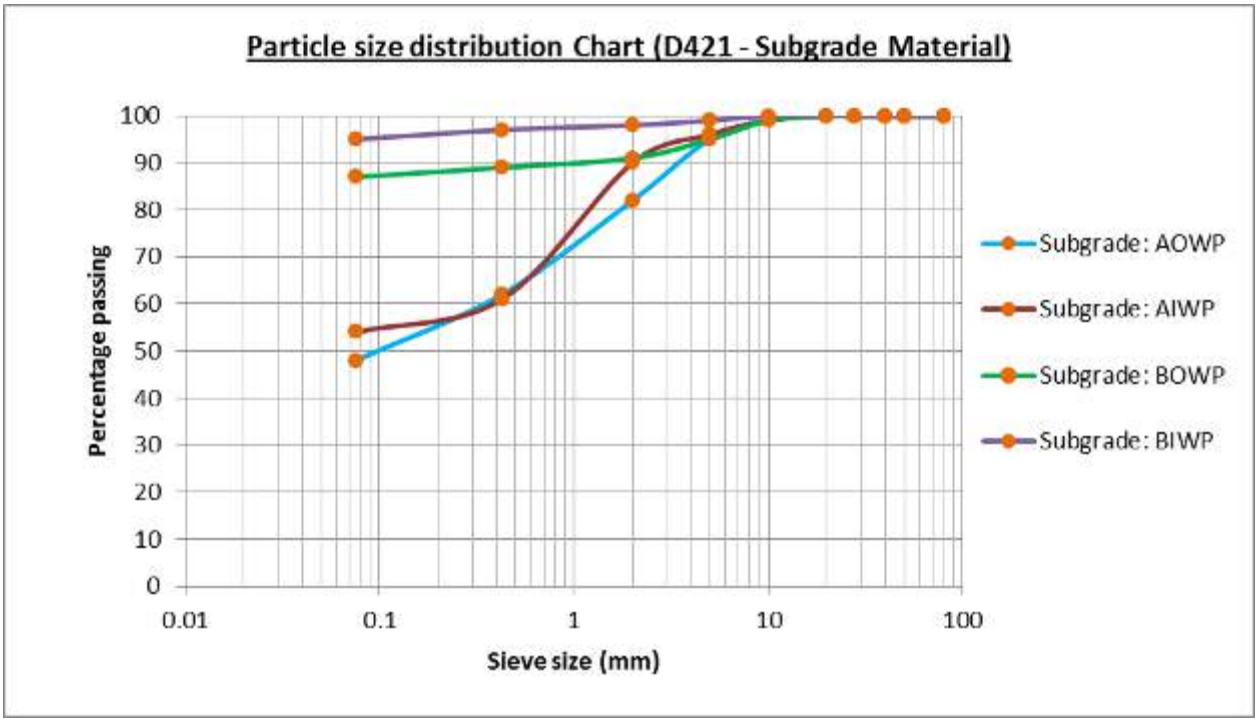


Figure 10-8: Particle size distribution for subgrade material (D421)

10.8.5 Atterberg Limits

Table 10-10 shows the index properties of each pavement layer, including the subgrade. The materials are of high plasticity.

Table 10-10: Atterberg limits at test pit (D421)

Layer	Liquid Limit	Plastic Limit	Plasticity Index	Linear Shrinkage
Road D421 – Panel A - OWP				
Base	42	28	14	7
Sub-base	43	23	20	9
Subgrade	52	31	21	10
Road D421 – Panel A – IWP				
Base	45	27	18	9
Sub-base	38	30	8	4
Subgrade	60	28	32	16
Road D421 – Panel B - OWP				
Base	42	19	23	11
Sub-base	48	24	24	12
Subgrade	59	35	24	12
Road D421 – Panel B - IWP				
Base	56	37	19	9
Sub-base	50	37	13	7
Subgrade	49	22	27	13

10.8.6 Laboratory CBR

Table 10-11 shows the 4-day soaked CBR (AASHTO T180 for base and sub-base, and AASHTO T99 for subgrade) of each layer, including the subgrade. The CBR values are very low to be suitable for sub-base or base.

Table 10-11: Laboratory CBR (D421)

4-day soaked CBR (%) (D421)				
Layer	**Panel A**		**Panel B**	
	OWP	**IWP**	**OWP**	**IWP**
Base	15	13	30	16
Sub-base	16	7	9	7
Subgrade	4	5	4	3

10.9 Visual Condition Assessment

10.9.1 Pavement Defects Assessment

There are no major defects as can be seen from Table 10-12.

Table 10-12: Visual condition assessment of D421

Fig No	Location (Km)	Defect assessment and description	Photos illustrating the pavement distress & defect
Fig 1	**Km 0+000 – 0+100 main carriage way**	No visible defect on the carriage way	

Fig 2	**Km 0+150 – 0+250 main carriage way**	No visible defect on the carriage way	
Fig 3	**Km 0+600 – 0+650 main carriage way**	Slight stripping on the carriage way	
Fig 4	**Km 0+720 – 0+740** **Main carriage way**	-Poor longitudinal joint visible at the centerline	

Fig 5	**Km 0+753 – 0+760 LHS**	-Vegetation towards the shoulders hindering free flow of water to the side drain -Silted access culvert	
Fig 6	**Km 0+754 – 0+758 RHS**	-Blocked and silted side drain and access culvert	
Fig 7	**Km 0+850 – 0+950 LHS**	Silted due to the collapsing side slope	

10.9.2 Present Serviceability Rating

The value of the PSR shown in Table 10-13 is 4.8 which is regarded as “Very Good”.

Table 10-13: Present Serviceability Rating (D421)

Road :	Gakoigo - Maragwa River Road (D421)												
Section:	Km 0+000 - Km 1+ 000 main carriage way												
Pavement Structure:	**Date of Survey**								11/11/2016				
Surfacing	Asphalt concrete mix												
Base	Emulsion stabilised lateritic gravel												
Sub-base	Lateritic gravel												
		A	**B**	**C**	**D**	**E**	**F**	**G**	**Point summary**				
	Point score												
Sub- Section	Length (Km)	General appearance	Surface texture	Bitumen condition	Pot holes	Surface irregularity	Rutting	Cracking	Sum of (∑) Points A-G Max: 40	Average points	%	Remarks	PSR
1. Km 0+000 - 0+500	0.5	5.0	4.5	5.0	5.0	5.0	5.0	4.5	34	4.9	85.0	**V.Good**	**4.9**
2. Km 0+500- 1+000	0.5	5.0	4.5	4.0	5.0	5.0	5.0	4.5	33	4.7	82.5	**V.Good**	**4.7**
Average PSR		**5**	**4.5**	**4.5**	**5**	**5**	**5**	**4.5**	**33.5**	**4.79**	**83.8**	**V.Good**	**4.8**

10.10 Rainfall

The rainfall measured during the baseline period is shown in Table 10-14.

Table 10-14: Precipitation at D421

Precipitation (mm) at Gakoigo - Maragwa River Road (D421)										
2016					**2017**					
AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE
1.6	216.0	14.8	5.2	24.4	0	26.7	44.0	79.2	87.0	7.0

11 Muthuaini-Mununga ini Road D435

11.1 Site Description

D435 is 9 km from Nyeri town. It starts at Ihururu town centre and goes downhill 600 m in length. Below is a map of the site location. Figure 11-1 shows the location map of the road.

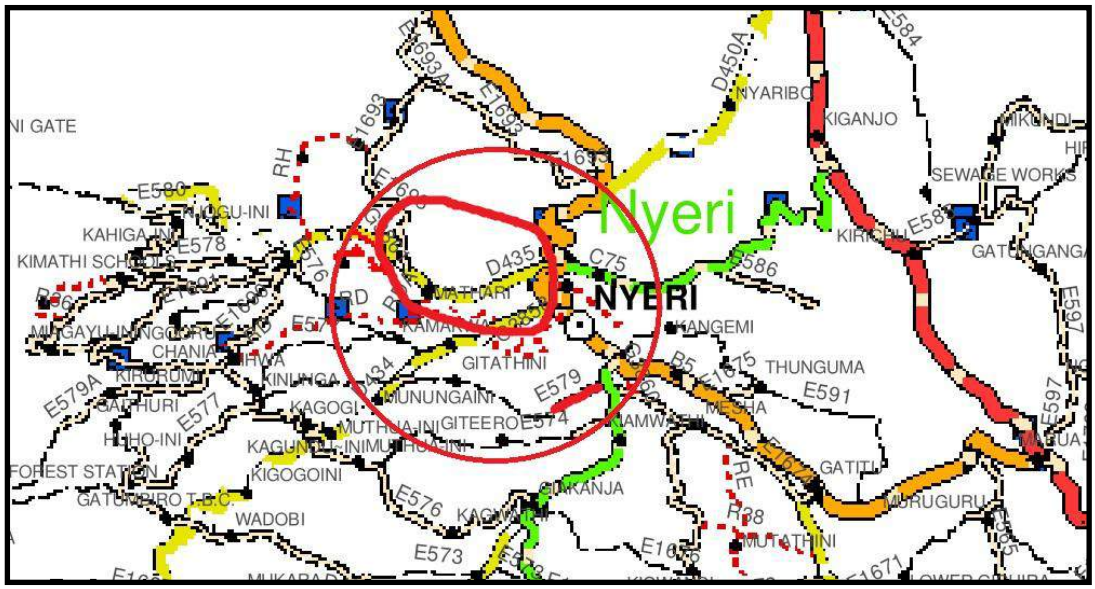


Figure 11-1: Location of Muthuaini - Mununga ini Road (D435), circled in red

11.2 Pavement Description

Figure 11-2 is a representation of the designed pavement structure.

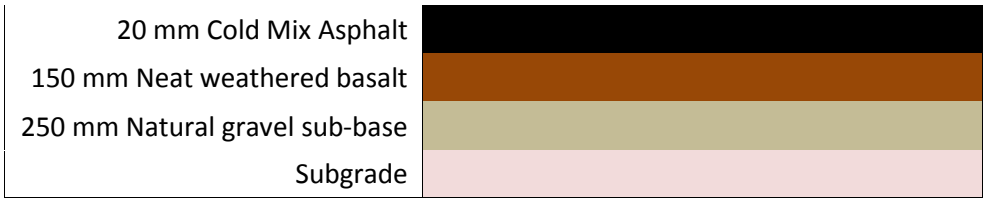


Figure 11-2: Designed pavement structure (D435)

11.3 Traffic Survey

11.3.1 Classified Traffic Counts

Table 11-1 shows a summary of the traffic count. The motorcycle volumes are lower than that in many other roads, but still the leading type of vehicle on this road.

Table 11-1: Traffic volume summary (D435)

Vehicle Type	Daily Volume (vpd)
Motorcycles	495
Cars	191
Minibus	33

Bus	0
Light Goods Vehicle	38
Medium Goods Vehicle	17
Heavy Goods Vehicle	3
ADT	**777**

11.3.2 Axle Load Survey

Table 11-2 shows the ESA by vehicle type, and the computed ESA/day. Medium goods on this road mainly carrying logs and tea leaves.

Table 11-2: Traffic ESA (D435)

Vehicle Type	**ESA/day**
Bus	0.00
Medium Goods Vehicles	18.85
Heavy Goods Vehicles[1]	XXX
Design ESA/day	**18.85**

Note 1: Although HGV's were counted during the traffic counts, they were not present during the axle load survey.

11.4 Rutting

Table 11-3 shows the maximum rut depth left and right of each chainage point. The average value of 16 mm is in the critical range but still provides good service.

Table 11-3: Maximum rut depth (D435)

Chainage	**LHS Rut in mm**	**RHS Rut in mm**
0+000	8	4
0+050	8	10
0+100	5	9
0+150	12	9
0+200	18	15
0+225	13	9
0+240	14	7
0+255	23	22
0+270	22	20
0+285	18	9
0+300	28	18
0+315	12	19
0+330	12	21
0+340	12	20
0+360	24	9
0+375	6	8
0+400	9	11
0+450	17	21
0+500	17	9
0+550	18	28
0+600	28	20
Average	**16**	**15**

11.5 Deflection/Stiffness

Table 11-4 shows the D_0 and the base, sub-base and subgrade stiffness measured at each point.

Table 11-4: Deflection and stiffness (D435)

Chainage (m)	Lane No.	Stiffness			Normalized Deflections at Geophone Locations (µm) D_0
		EBase (MPa)	ESubbase (MPa)	ESubgrade (MPa)	
0+003	1	300	200	214	388
0+099	1	300	200	153	437
0+200	1	343	583	116	439
0+225	1	2437	435	124	282
0+255	1	1059	252	186	500
0+285	1	729	252	152	466
0+315	1	495	1203	141	323
0+345	1	986	242	189	434
0+375	1	593	249	144	608
0+500	1	1163	349	242	428
0+600	1	943	227	168	474
0+050	2	669	253	142	608
0+150	2	300	200	98	518
0+240	2	586	127	268	351
0+270	2	713	262	153	468
0+300	2	892	242	178	409
0+330	2	269	189	154	537
0+360	2	300	200	118	433
0+400	2	1217	266	207	429
0+449	2	300	200	126	426
0+550	2	290	87	167	596
0+051	3	478	344	139	645
0+150	3	300	200	98	589
0+240	3	422	464	134	400
0+270	3	714	307	173	443
0+300	3	300	200	158	385
0+330	3	943	268	193	438
0+360	3	483	652	127	362
0+401	3	972	216	171	443
0+450	3	467	306	133	468
0+551	3	528	88	229	409
0+000	4	469	111	277	418
0+051	4	484	332	140	647
0+100	4	300	200	121	468
0+200	4	430	498	159	374
0+225	4	738	3896	115	290

0+255	4	1160	282	216	429
0+285	4	1111	261	212	428
0+315	4	484	87	208	431
0+345	4	547	96	260	372
0+375	4	387	940	99	458
0+500	4	1143	550	266	408
0+600	4	300	200	134	485

All the deflection outputs from the FWD for all the sensors (D_0 up to D_6) for all the test locations are presented in the Appendix section of the report. Figure 11-3 shows a plot of the central deflection for each wheel path along the road. The deflection values are highly variable with chainage.

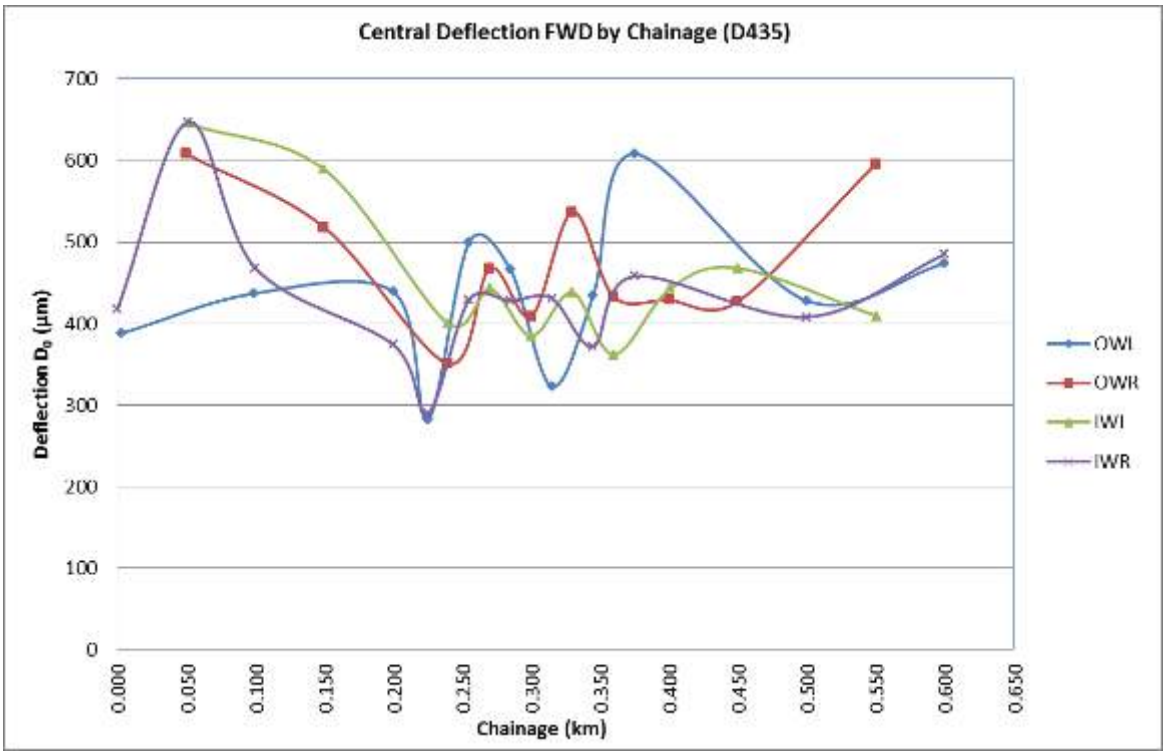


Figure 11-3: Central deflection by chainage (D435)

11.6 DCP Measurements

Table 11-5 shows the DN and DSN values by layer for each test point. The values are spread either side of the specification limits.

Table 11-5: DN and DSN values (D435)

Chainage (m)	Specifications	≤3.2	≤6.0	≤12	≤19	≤25	DSN800
	Position	0-150	150-300	300-450	450-600	600-800	≥100
0+000	CL	4.1	4.2	6.7	9.1	4.2	182
0+050	RHS	5.3	6.9	6.8	7.6	5.7	151
0+100	CL	7.7	4.2	15.6	16.7	21.3	100
0+150	RHS	4.5	5.6	9.3	9.1	10.0	157

0+200	RHS	5.2	6.6	5.1	7.5	11.1	141
0+214	OWL	2.3	4.3	4.1	8.5	5.7	297
0+214	IWL	2.0	2.9	2.8	1.9	2.0	425
0+214	CL	1.2	2.1	2.5	2.7	3.0	705
0+214	IWR	2.1	4.5	2.9	5.8	8.8	353
0+214	OWR	1.2	5.3	3.5	5.9	5.4	338
0+250	RHS	3.0	3.9	4.7	6.6	6.3	235
0+300	CL	3.0	3.9	4.7	6.6	6.5	235
0+390	OWL	6.8	6.3	11.6	6.5	7.0	117
0+390	IWL	1.3	0.2	0.2	0.2	0.2	150
0+390	CL	4.8	12.8	7.9	5.4	5.3	163
0+390	IWR	3.3	3.2	3.8	6.9	4.5	248
0+390	OWR	3.4	12.8	7.9	5.5	5.3	217
0+400	CL	8.0	10.1	13.1	6.3	7.5	116
0+400	RHS	1.7	5.7	6.4	5.4	6.0	355
0+500	CL	1.6	5.9	6.1	5.4	6.2	386

11.7 Roughness Measurements

The roughness values shown in Table 11-6 and
Table 11-7 are within the expected range for LVSRs. Figure 11-4 shows the roughness of each lane along the road section.

Table 11-6: Roughness values including bumps (D435)

Muthuaini – Mununggaini (D435)			
LHS		RHS	
Chainage	IRI	Chainage	IRI
0+000-0+051	7.2	0+000-0+050	7.2
0+050-0+099	7.2	0+050-0+150	3.5
0+099-0+225	3.5	0+150-0+240	3.5
0+225-0+240	3.5	0+240-0+300	3.7
0+240-0+255	3.5	0+300-0+330	3.7
0+255-0+285	3.7	0+330-0+360	3.7
0+285-0+300	3.7	0+360-0+400	2.8
0+300-0+345	3.7	0+400-0+449	2.0
0+345-0+360	3.7	0+449-0+550	2.6
0+360-0+375	3.7		
0+375-0+450	2.8		
0+450-0+500	2		

Table 11-7: Roughness values excluding bumps (D435)

Muthuaini – Mununggaini (D435)			
LHS		RHS	
Chainage	IRI	Chainage	IRI

0+000-0+051	3.9	0+000-0+050	3.9
0+050-0+099	3.9	0+050-0+150	4.9
0+099-0+225	4.9	0+150-0+240	4.9
0+225-0+240	4.9	0+240-0+300	4.9
0+240-0+255	4.9	0+300-0+330	4.9
0+255-0+285	4.9	0+330-0+360	4.9
0+285-0+300	4.9	0+360-0+400	4.9
0+300-0+345	4.9	0+400-0+449	4.9
0+345-0+360	4.9	0+449-0+550	4.9
0+360-0+375	4.9		
0+375-0+450	4.9		
0+450-0+500	4.9		

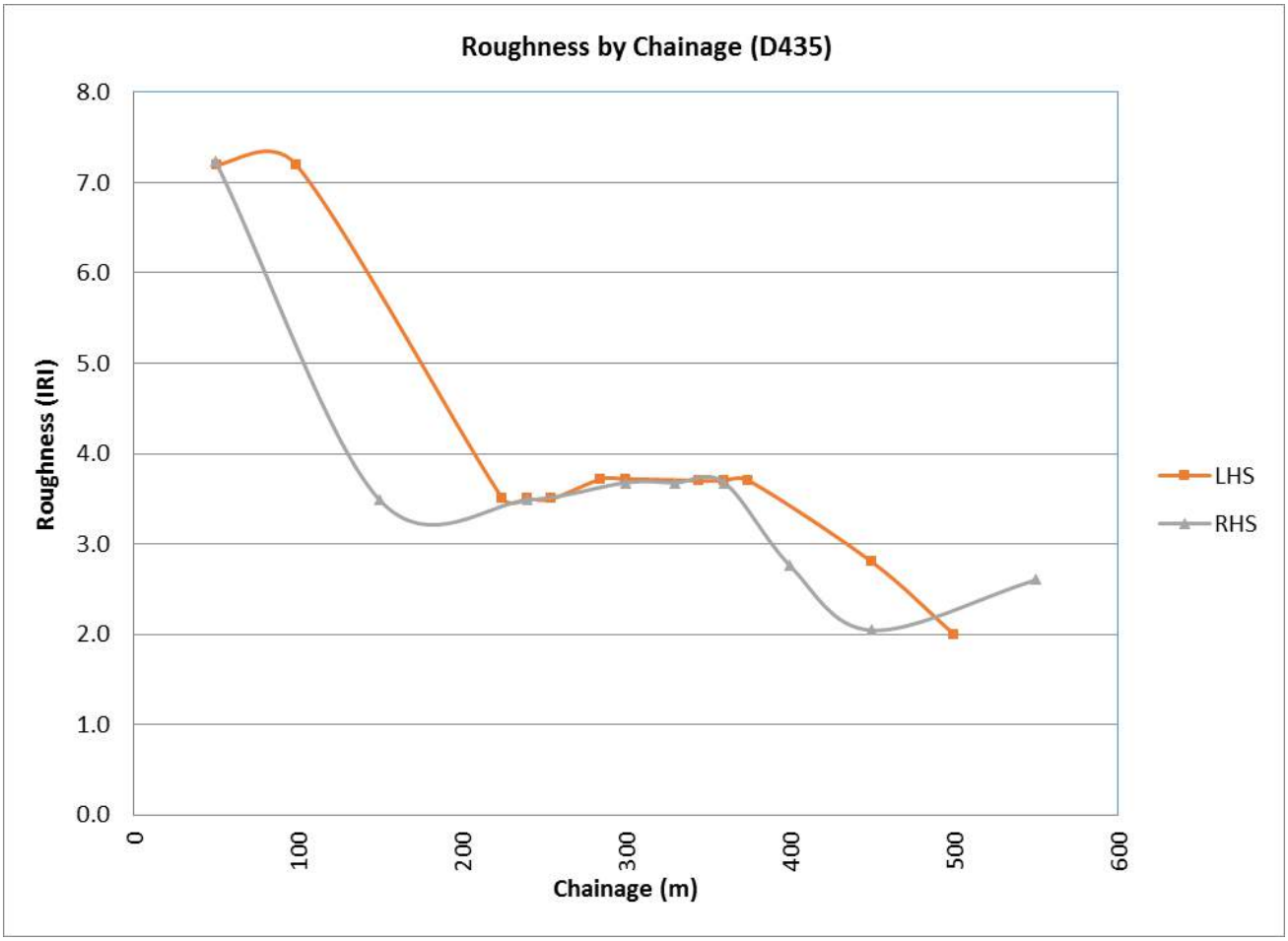


Figure 11-4: Roughness values including bumps by chainage (D435)

11.8 Test Pits

11.8.1 DN Values

Table 11-8 shows the DN of each layer in the structure measured before excavation of the test pits. The values are well within the specification limits.

Table 11-8: DN values at test pit (D435)

Depth (mm)	Specifications	DN values (mm/blow)	
		Pit @ 0+250	Pit @ 0+300
0 – 150	≤3.2	3.0	3.0
150 – 300	≤6.0	3.9	3.9
300 – 450	≤12	4.7	4.7
450 – 600	≤19	6.6	6.6
600 – 800	≤25	6.3	6.5
DSN800	≥100	235	235

All DCP test details are presented in the Appendix section of the report.

11.8.2 Layer Thicknesses

Figure 11-5 shows the pavement materials and the measured layer thicknesses at the test pits.

Test Pit A, km 0+250		**Test Pit B, km 0+300**
20 mm Cold Mix Asphalt		20 mm Cold Mix Asphalt
250 mm Neat weathered basalt base		250 mm Neat weathered basalt base
150 mm Natural gravel sub-base		150 mm Natural gravel sub-base
Subgrade		Subgrade

Figure 11-5: Layer thicknesses at test pit (D435)

11.8.3 Densities and Moisture Content

Table 11-9 shows the dry density, the MDD, the in-situ moisture content and the OMC (AASHTO T180 for base and sub-base, and AASHTO T99 for subgrade) of the pavement layers, including the subgrade. The IMC values are close to the OMC.

Table 11-9: Density and moisture content at test pit (D435)

Panel	Wheel path	Layer	MDD (kg/m^3)	In-situ Moisture Content (%)	OMC (%)	Relative Moisture Content (FMC/OMC)
Panel A	**OWP**	**Base**	2095	8.0	8.3	0.96
		Sub-base	1730	9.1	12.1	0.75
		Subgrade	1350	13.1	26.0	0.50
	IWP	**Base**	2100	7.9	8.1	0.98
		Sub-base	1745	16.3	11.6	1.41
		Subgrade	1330	19.3	24.5	0.79
Panel B	**OWP**	**Base**	2065	8.0	9.4	0.85
		Sub-base	1695	19.4	14.2	1.37

		Subgrade	1365	21.6	25.1	0.86
	IWP	**Base**	2070	7.7	8.6	0.90
		Sub-base	1670	17.6	14.6	1.21
		Subgrade	1370	21.8	28.5	0.76

11.8.4 Particle Size Distribution

The plots in Figure 11-6, Figure 11-7, and Figure 11-8 show the particle size distribution for each layer. The base materials lie close to the specification envelope but not entirely inside.

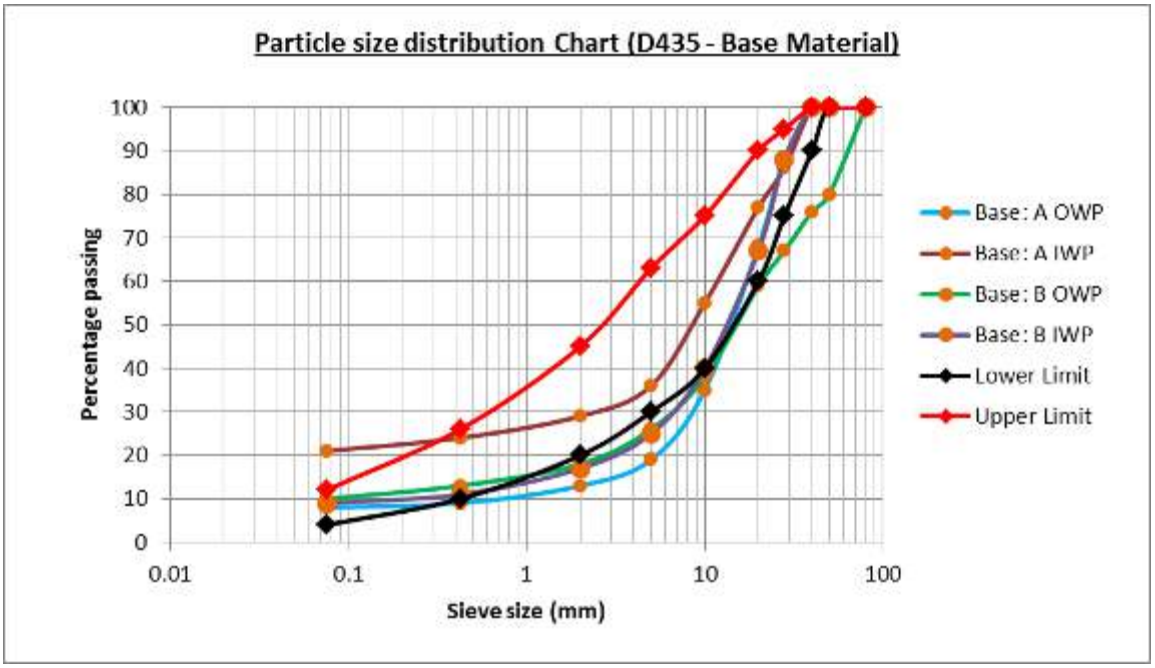


Figure 11-6: Particle size distribution for base material (D435)

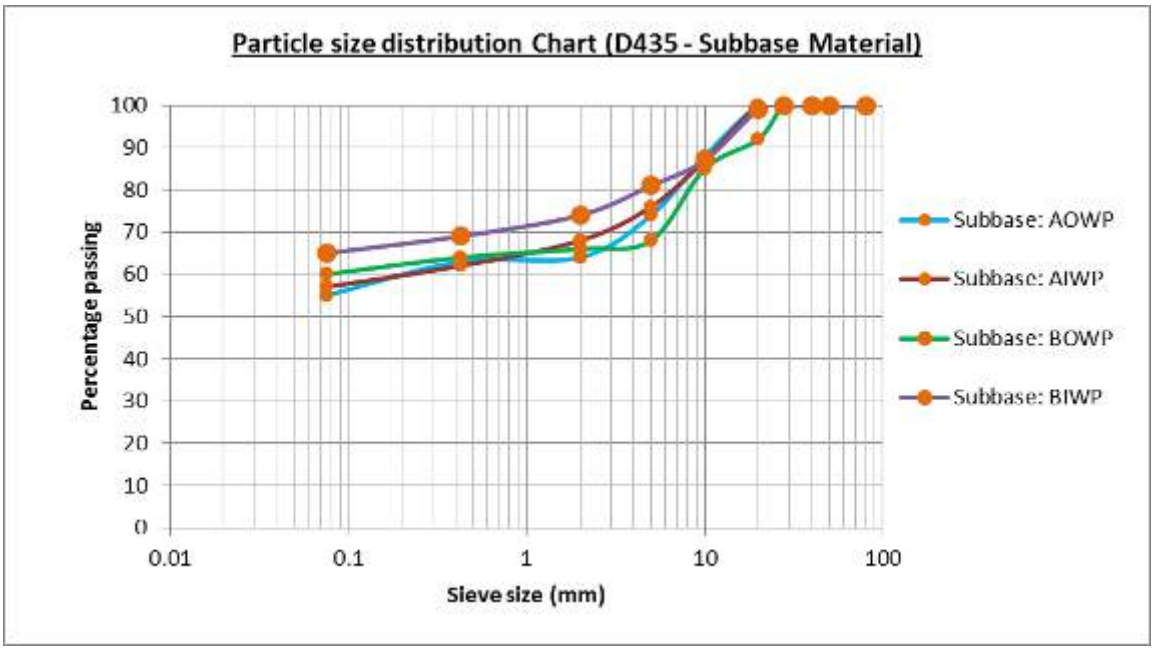


Figure 11-7: Particle size distribution for sub-base material (D435)

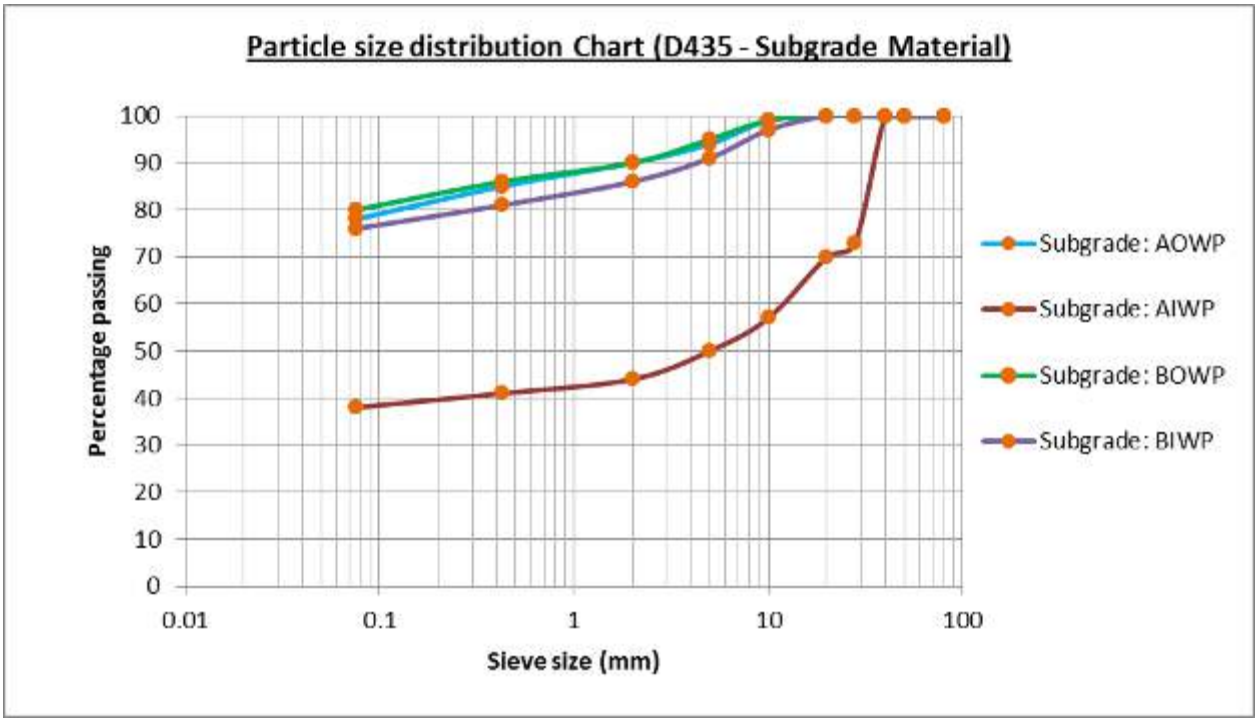


Figure 11-8: Particle size distribution for subgrade material (D435)

11.8.5 Atterberg Limits

Table 11-10 shows the index properties of each pavement layer including the subgrade. The materials have high plasticity.

Table 11-10: Atterberg limits at test pit (D435)

Layer	Liquid Limit	Plastic Limit	Plasticity Index	Linear Shrinkage

Road D435 – Panel A - OWP				
Base	50	26	24	12
Sub-base	52	25	27	14
Subgrade	69	35	34	16
Road D435 – Panel A – IWP				
Base	38	18	20	9
Sub-base	54	24	30	14
Subgrade	56	27	29	15
Road D435 – Panel B - OWP				
Base	41	23	18	9
Sub-base	42	17	25	13
Subgrade	48	22	26	13
Road D435 – Panel B - IWP				
Base	44	21	23	11
Sub-base	56	29	27	14
Subgrade	54	23	31	16

11.8.6 Laboratory DN / CBR

Table 11-11 shows the values of the 4-day soaked CBR (AASHTO T180 for base and sub-base, and AASHTO T99 for subgrade) of each layer, including the subgrade. The sub-base values are very low. The base was not tested for CBR because it is made up of very coarse stone.

Table 11-11: Laboratory CBR (D435)

4-day soaked CBR (%) (D435)				
Layer	**Panel A**		**Panel B**	
	OWP	**IWP**	**OWP**	**IWP**
Base	GCS	GCS	GCS	GCS
Sub-base	16	13	14	15
Subgrade	5	5	4	6

11.9 Visual Condition Assessment

11.9.1 Pavement Defects Assessment

The main surface defects on this road section are raveling and a few potholes as shown in Table 11-12.

Table 11-12: Visual condition assessment of D435

Fig No	Location (Km)	Defect assessment and description	Photos illustrating the pavement distress & defect

Fig 1	Km 0+028 – 0+030 at the centerline	-Localized loss of the asphalt concrete layer -Pothole covering an area of about (1.2m*1.0 m)1.2m^2	
Fig 2	Km 0+015- 0+057LHS drain	-Blocked and silted with waste debris	
Fig 3	Km 0+057 – 0+100	-Inconsistency of the mix causing potholes and stripping on the LHS carriage way -Pothole and area of about (0.1m*0.3m)m2	

Fig 4	Km 0+100 – 0+177	-No visible defect on the carriage way	
Fig 5	Km 0+058 – 0+150LHS drain	-Blocked and silted on the LHS drain	
Fig 6	Km 0+177 RHS	-Slight bleeding on the surface inner wheel path and extending to the centerline	

Fig 7	Km 0+180 RHS	-Localized loss of the asphalt concrete layer -Pothole covering an area of about (1.2m*1.0 m)1.2m^2 -Potholes developing on the carriage way -the surface texture looks very coarse	
Fig 8	Km 0+235RHS lane	-2no -Potholes on outer wheel path -approximate area of about A(1.6m*0.5m) and a depth 60mm	
Fig 9	Km 0+306 Inner wheel path	-Pothole on inner wheel path -area of about A(0.3m*0.3m) and a depth 50mm - Potholes developing on the carriage way -the surface texture looks very coarse	

Fig 10	**Km 0+322**	-Potholes developing on the carriage way -the surface texture looks very coarse	
Fig 11	**Km 0+357 RHS**	-Pothole on the outer wheel path	
Fig 12	Km 0+375 – 0+400 RHS lane	-Erosion deposits on shoulders hindering free flow of water to side drain km 0+375 - 0+400	

Fig 13	Km 0+400 – 0+455 RHS	-3No potholes on carriage way coving (1.0m*1.5m)m2 -Ravelling and extensive loss of surface texture leading to the development of potholes on the surface	
Fig 14	Km 0+520 – 0+540 LHS main carriage way	-The surface texture looks very coarse	
Fig 15	Km 0+530 – 0+550 main carriage way	-The surface texture looks very coarse especially on LHS lane -No side drain on the LHS	

11.9.2 Present Serviceability Rating

The value of the PSR computed in Table 11-13 is 4.1, which is regarded as "Good".

Table 11-13: Present Serviceability Rating D435

Road :	Muthuaini - Munugaini Road (D435)		
Section:	Km 0+000 - Km 0+550 main carriage way		
Pavement Structure:	**Date of Survey:**		11/11/2016

Surfacing	Cold mix asphalt												
Base	Neat weathered basalt												
Sub-base	Natural gravel												
		A	**B**	**C**	**D**	**E**	**F**	**G**	**Point summary**				
	Point score												
Sub- Section	Length (Km)	General appearance	Surface texture	Bitumen condition	Pot holes	Surface irregularity	Rutting	Cracking	Sum of (∑) Points A-G Max: 40	Average points	%	Remarks	PSR
1. Km 0+000 - 0+500	0.550	4.2	4.5	4.5	1.5	4.0	5.0	4.5	28.2	4.0	70.5	**Good**	**4.0**
Average PSR		**4.2**	**4.5**	**4.5**	**1.5**	**4.0**	**5.0**	**4.5**	**28.2**	**4.03**	**70.5**	**Good**	**4.1**

11.10 Rainfall Data

The rainfall measured during the baseline period is shown in Table 11-14.

Table 11-14: Precipitation at D435

Precipitation (mm) at Muthuaini – Munugaini Road (D435)										
2016					**2017**					
AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE
8.0	20.2	15.0	115.4	62.5	43.0	46.4	57.8	55.4	361.5	2.0

12 Kangari-Kinyona Road E511

12.1 Site Description

Road E511 is located in Murang'a County. It is starts some 4 km from Kangari town centre, at some place called Mairi. It is 900 m in length. Figure 12-1 shows the location map of the road.

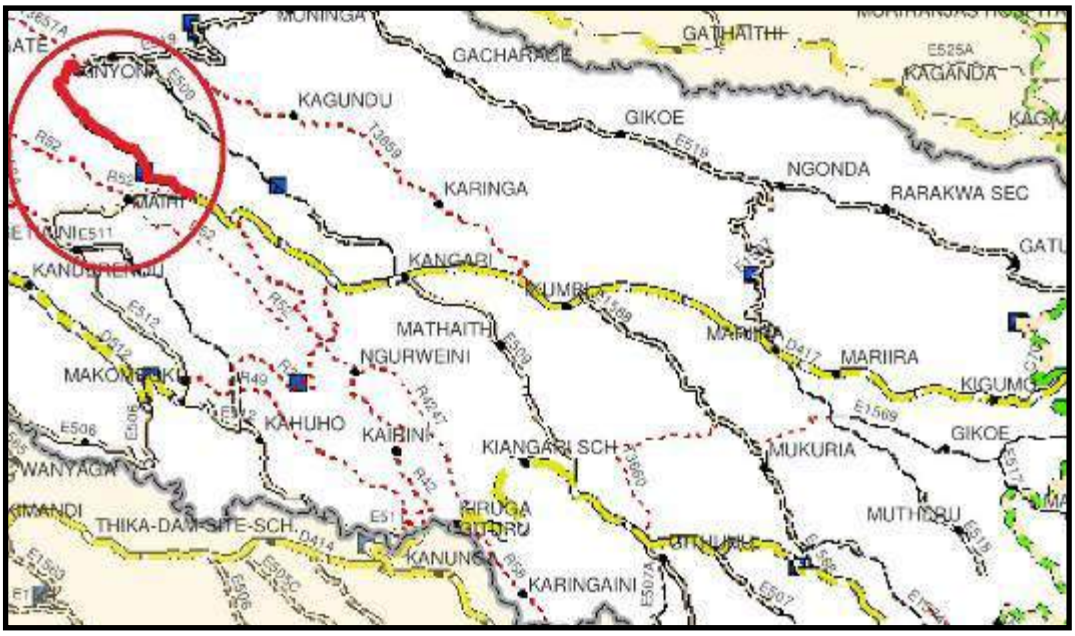


Figure 12-1: Location of Kangari – Kinyona Road (E511), marked in Red

12.2 Pavement Description

Figure 12-2 is a representation of the designed pavement structure.

Figure 12-2: Designed pavement structure (E511)

12.3 Traffic Survey

12.3.1 Classified Traffic Counts

Table 12-1 shows the summary of the traffic count. Motorcycles are again the largest users of this road.

Table 12-1: Traffic volume summary (E511)

Vehicle Type	Daily Volume (vpd)
Motorcycles	334
Cars	93
Minibus	62

Bus	0
Light Goods Vehicle	69
Medium Goods Vehicle	16
Heavy Goods Vehicle	13
ADT	**587**

12.3.2 Axle Load Survey

Table 12-2 shows a summary of ESA by vehicle type, and the computed ESA/day.

Table 12-2: Traffic ESA (E511)

Vehicle Type	**ESA/day**
Bus	0.00
Medium Goods Vehicles	8.32
Heavy Goods Vehicles	3.76
Design ESA/day	**12.08**

12.4 Rutting

Table 12-3 shows the maximum rut depth left and right of each chainage point. The average of 17 is critical for LVSRs.

Table 12-3: Maximum rut depth (E511)

Chainage	**LHS Rut in mm**	**RHS Rut in mm**
0+000	9	14
0+055	12	12
0+100	20	17
0+145	11	11
0+160	15	9
0+200	9	6
0+250	12	12
0+300	15	20
0+350	9	12
0+400	12	15
0+450	12	12
0+500	14	12
0+550	10	27
0+600	12	12
0+650	28	7
0+700	28	30
0+750	23	10
0+800	25	7
0+850	35	6
Average	**17**	**14**

12.5 Deflection/Stiffness

Table 12-4 shows the central deflection D_0, and the base, sub-base and subgrade stiffness measured at each point.

Table 12-4: Deflection and stiffness (E511)

Chainage (m)	Lane No.	Stiffness			Normalized Deflections at Geophone Locations (µm) D_0
		EBase (MPa)	ESubbase (MPa)	ESubgrade (MPa)	
0+000	1	171	150	35	1255
0+025	1	87	120	23	2301
0+055	1	261	188	45	1111
0+085	1	58	115	19	2716
0+115	1	133	134	30	1597
0+145	1	237	188	37	1099
0+175	1	173	150	36	1293
0+200	1	122	130	26	1589
0+300	1	321	80	113	1100
0+400	1	316	85	120	914
0+500	1	166	145	33	1469
0+600	1	96	113	24	2166
0+700	1	1898	322	54	1409
0+801	1	1665	300	49	1148
0+900	1	1966	310	72	1046
0+040	2	125	144	31	1719
0+070	2	94	125	24	2263
0+100	2	85	120	24	2086
0+130	2	122	127	26	1863
0+159	2	1595	285	33	1625
0+250	2	1639	290	38	1383
0+348	2	1031	180	129	723
0+451	2	1627	290	43	1343
0+550	2	286	213	46	843
0+648	2	1875	296	34	1846
0+750	2	138	113	53	1119
0+850	2	259	187	47	1089
0+040	3	156	152	29	1435
0+070	3	82	123	24	2098
0+099	3	125	126	28	1783
0+130	3	1938	300	34	1597
0+160	3	212	177	37	1139
0+250	3	1981	294	30	1690
0+350	3	1190	209	122	1053

0+450	3	267	188	54	913
0+549	3	273	192	49	902
0+650	3	127	141	30	1953
0+750	3	157	131	46	1110
0+852	3	250	176	64	809
0+000	4	143	147	32	1411
0+025	4	102	120	23	2292
0+055	4	134	147	32	1475
0+084	4	101	122	25	1851
0+114	4	1959	300	29	1780
0+144	4	1938	297	36	1623
0+175	4	114	126	27	1772
0+200	4	115	125	26	1923
0+299	4	1985	311	60	1151
0+400	4	1094	196	110	780
0+499	4	167	145	35	1326
0+600	4	97	115	24	2378
0+700	4	219	171	41	1210
0+800	4	186	150	35	1297
0+900	4	330	34	124	897

The entire deflection outputs from the FWD for all the sensors (D_0 up to D_6) for all the test locations are presented in the Appendix section of the report. Figure 12-3 shows the central deflection for each wheel path along the road section. The values are highly variable.

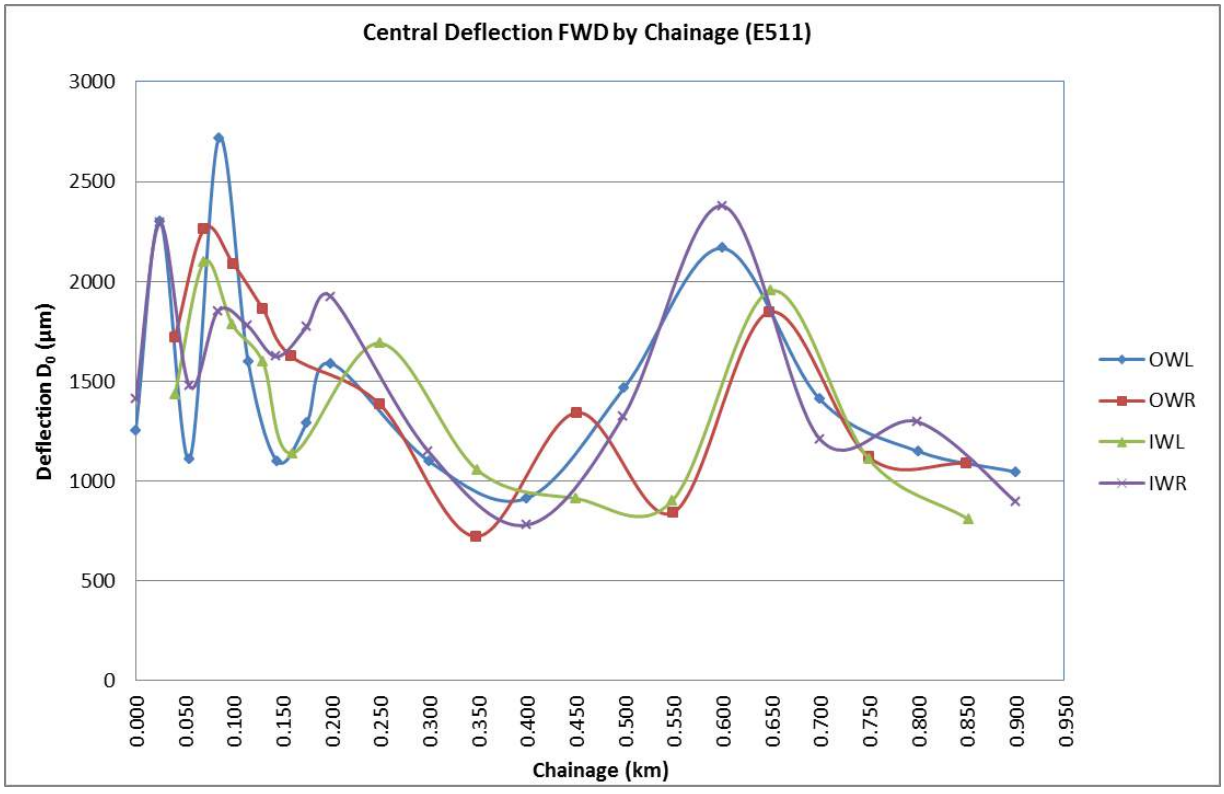


Figure 12-3: Central deflection by chainage (E511)

12.6 DCP Measurements

Table 12-5 shows the DN and DSN values by layer for each test point. The values lie either side of the specification limits.

Table 12-5: DN and DSN values (E511)

Chainage (m)	Specifications	≤3.2	≤6.0	≤12	≤19	≤25	DSN800
	Position	0-150	150-300	300-450	450-600	600-800	≥100
0+007	OWL	6.2	10.6	22.8	28.5	34.9	58
0+007	IWL	4.0	7.6	21.6	28.5	34.6	109
0+007	CL	3.9	2.2	8.3	12.7	15.0	182
0+007	IWR	2.0	1.2	1.2	1.2	1.2	642
0+007	OWR	3.0	5.2	14.2	16.6	18.0	145
0+012	RHS	3.9	12.1	28.0	32.7	37.5	71
0+183	OWL	4.2	3.6	5.7	17.9	21.7	130
0+183	IWL	3.4	7.6	17.6	29.9	32.4	93
0+183	CL	3.6	2.1	15.7	27.3	31.8	187
0+183	IWR	3.4	1.7	11.0	26.8	24.5	279
0+183	OWR	8.3	11.8	18.0	32.8	38.3	52
0+190	CL	4.2	5.6	11.5	25.8	33.8	99
0+200	CL	4.7	6.9	20.3	29.8	45.1	72
0+250	RHS	3.7	2.4	12.5	25.8	18.7	155
0+300	CL	5.8	15.7	20.1	26.6	31.8	62
0+350	RHS	4.1	3.2	5.7	8.4	12.5	160
0+400	CL	16.5	10.7	30.5	36.3	42.8	38
0+450	RHS	16.5	10.7	30.5	36.3	42.8	38
0+500	CL	4.5	9.6	2.6	8.4	7.9	247
0+550	RHS	6.5	35.7	15.8	7.4	8.7	145
0+600	CL	7.8	18.6	28.0	31.0	35.0	45
0+650	RHS	2.6	6.6	12.8	16.4	23.5	118
0+700	CL	2.6	8.6	17.4	16.7	12.5	120
0+750	CL	3.9	5.7	2.7	4.3	11.8	202
0+800	RHS	3.0	9.3	7.6	10.3	25.9	128

12.7 Roughness Measurements

The roughness values are shown in Table 12-6 and Table 12-7. The former includes values with humps and the latter values where hump locations have been subjectively removed. The values are within the range expected for LVSRs. Figure 12-4 shows the roughness of each lane along the road section.

Table 12-6: Roughness values (including humps) E511

Kangari - Kinyona (E511)		
	LHS (IRI)	RHS (IRI)

0+000-0+020	1.9	3.9
0+020-0+040	2.5	2.9
0+040-0+060	2.2	2.9
0+060-0+080	1.7	3.0
0+080-0+100	1.7	8.0
0+100-0+120	2	2.9
0+120-0+140	2	2.9
0+140-0+160	1.6	8.0
0+160-0+180	1.6	3.0
0+180-0+200	1.9	4.8
0+200-0+220	2.8	2.9
0+220-0+240	2.5	8.0
0+240-0+260	2.5	2.9
0+260-0+280	2.2	3.9
0+280-0+300	2.5	3.2
0+300-0+320	2	2.9
0+320-0+340	1.9	8.0
0+340-0+360	1.7	2.9
0+360-0+380	1.9	3.0
0+380-0+400	2	8.0
0+400-0+420	3.8	2.0
0+420-0+440	2.3	2.9
0+440-0+460	2.8	8.0
0+460-0+480	2.3	8.0
0+480-0+500	2.5	2.6
0+500-0+520	2.8	2.2
0+520-0+540	2.5	8.0
0+540-0+560	2	2.0
0+560-0+580	2.9	3.0
0+580-0+600	2.9	2.5
0+600-0+620	3	1.9
0+620-0+640	3.3	2.0
0+640-0+660	2.8	2.5
0660-0+680	1.7	2.6
0+680-0+700	2	2.8
0+700-0+720	2.3	2.0
0+720-0+740	2.6	2.9
0+740-0+760	1.4	1.9
0+760-0+780	2.3	2.9
0+780-0+800	2.5	2.3
0+800-0+820	4.1	2.0
0+820-0+840	2.3	2.6
0+840-0+860	1.9	2.5
0+860-0+880	2.5	2.3

0+880-0+900		2.5

Table 12-7: Roughness values (excluding humps) E511

Kangari - Kinyona (E511)		
	LHS (IRI)	RHS (IRI)
0+000-0+020	1.6	1.6
0+020-0+040	1.6	1.6
0+040-0+060	1.6	1.6
0+060-0+080	2	1.6
0+080-0+100	2	1.6
0+100-0+120	1.6	1.6
0+120-0+140	1.6	1.6
0+140-0+160	2	1.6
0+160-0+180	2	1.6
0+180-0+200	1.6	1.6
0+200-0+220	1.6	1.6
0+220-0+240	1.6	1.6
0+240-0+260	1.6	1.6
0+260-0+280	1.6	1.6
0+280-0+300	1.6	1.6
0+300-0+320	1.6	1.6
0+320-0+340	1.6	1.6
0+340-0+360	2	1.6
0+360-0+380	1.6	1.6
0+380-0+400	1.6	1.6
0+400-0+420	1.6	1.6
0+420-0+440	1.6	1.6
0+440-0+460	1.6	1.6
0+460-0+480	1.6	1.6
0+480-0+500	1.6	1.6
0+500-0+520	1.6	1.6
0+520-0+540	1.6	1.6
0+540-0+560	1.6	1.6
0+560-0+580	1.6	1.6
0+580-0+600	1.6	1.6
0+600-0+620	1.6	1.6
0+620-0+640	1.6	1.6
0+640-0+660	1.6	1.6
0660-0+680	2	1.6
0+680-0+700	1.6	1.6
0+700-0+720	1.6	1.6
0+720-0+740	1.6	1.6
0+740-0+760	2	1.6
0+760-0+780	1.6	1.6

0+780-0+800	1.6	1.6
0+800-0+820	1.6	1.6
0+820-0+840	1.6	1.6
0+840-0+860	1.6	1.6
0+860-0+880	1.6	1.6
0+880-0+900		1.6

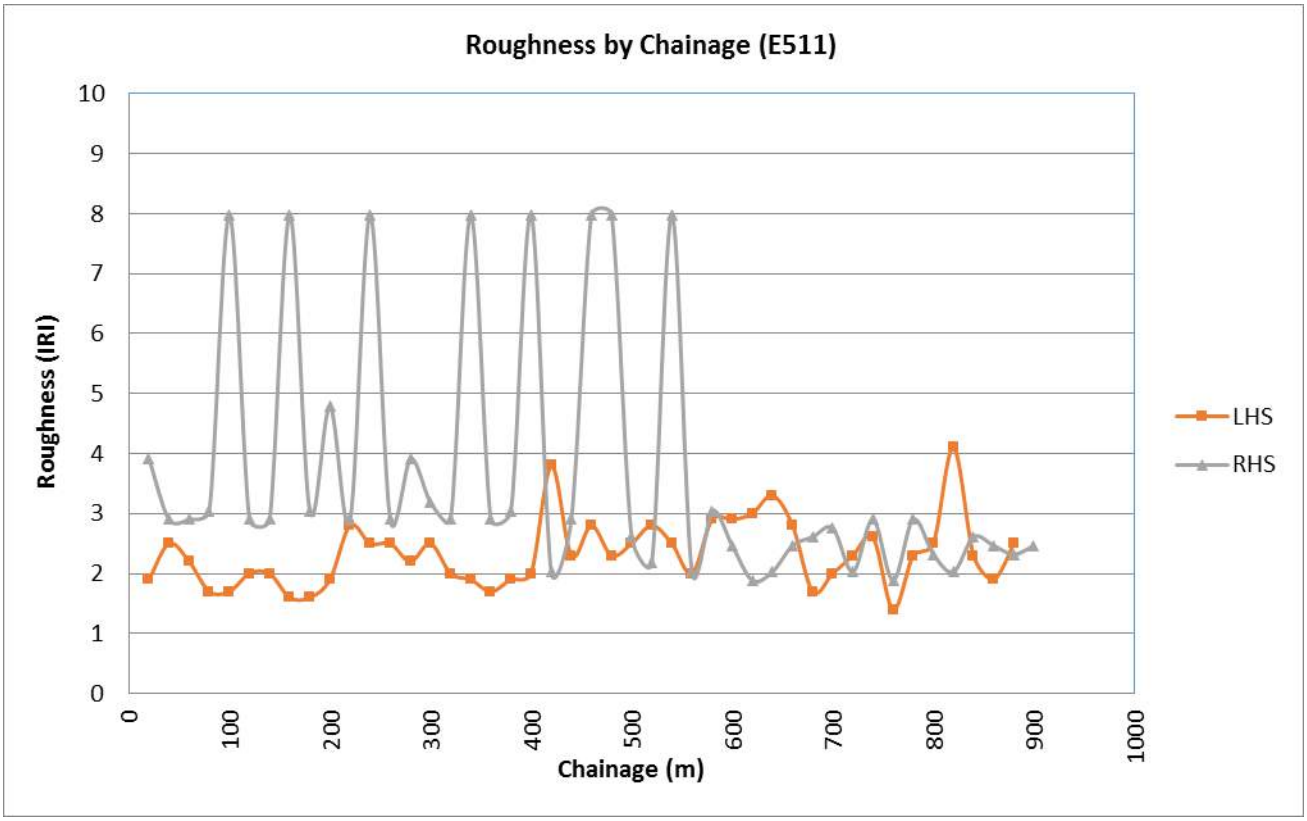


Figure 12-4: Roughness values including humps by chainage (E511)

12.8 Test Pits

12.8.1 DN Values

Table 12-8 shows the DN of each layer in the structure measured before excavation of the test pits. The values do not meet the specifications by a large margin.

Table 12-8: DN values at test pits (E511)

Depth (mm)	Specifications	DN values (mm/blow)	
		Pit A @ 0+012	Pit B @ 0+190
0 – 150	≤3.2	3.9	4.2
150 – 300	≤6.0	12.1	5.6
300 – 450	≤12	28.0	11.5
450 – 600	≤19	32.7	25.8
600 – 800	≤25	37.5	33.8

DSN800	≥100	71	99

The rest of the DCP test details are presented in the Appendix section of the report.

12.8.2 Layer Thicknesses

Figure 12-5 is an illustration of the measured pavement layer thickness and description of the materials used.

Figure 12-5: Layer thicknesses at test pit

12.8.3 Densities and Moisture Content

Table 12-9 shows the dry density, the MDD, the in-situ moisture content and the OMC (AASHTO T180 for base and sub-base, and AASHTO T99 for subgrade) for each layer, including the subgrade. Some of the IMC values were not available. But those available are less than OMC.

Table 12-9: Density and moisture content at test pit (E511)

Panel	Wheel Path	Layer	MDD (kg/m^3)	In-situ Moisture Content (%)	OMC (%)	Relative Moisture Content (FMC/OMC)
Panel A	OWP	Base	1780	-	13.2	-
		Sub-base	1730	-	14.6	-
		Subgrade	1325	25.3	30.0	0.84
	IWP	Base	1740	16.8	17.8	0.94
		Sub-base	1690	-	17.3	-
		Subgrade	1300	24.5	35.6	0.69
Panel B	OWP	Base	1765	-	15.3	-
		Sub-base	1770	-	17.2	-
		Subgrade	1290	21.6	34.6	0.62
	IWP	Base	1795	-	16.2	-
		Sub-base	1800	12.1	16.3	0.74
		Subgrade	1365	22.2	34.0	0.65

12.8.4 Particle Size Distribution

The plots in Figure 12-6, Figure 12-7, and Figure 12-8 show the particle size distribution for each layer. The base materials fit within specification envelope. At Pit B, OWP, the material is gap graded at 2 – 5 mm sieves.

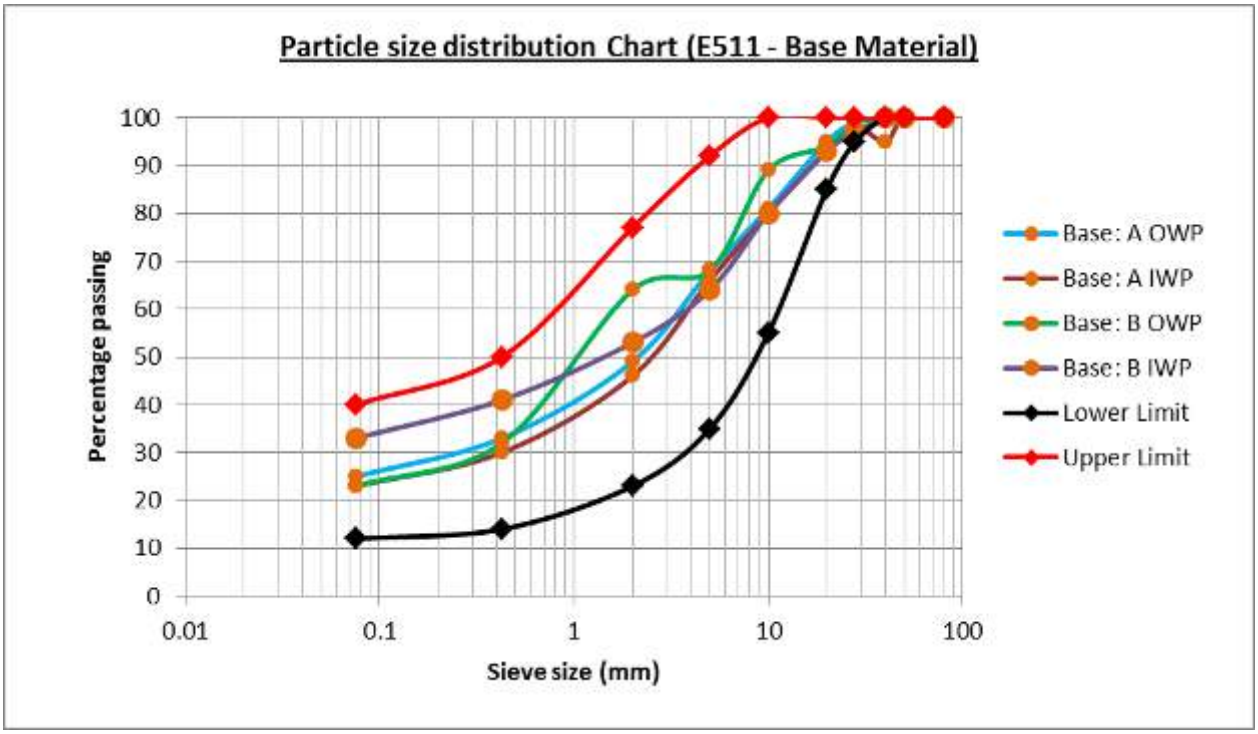


Figure 12-6: Particle size distribution for base material (E511)

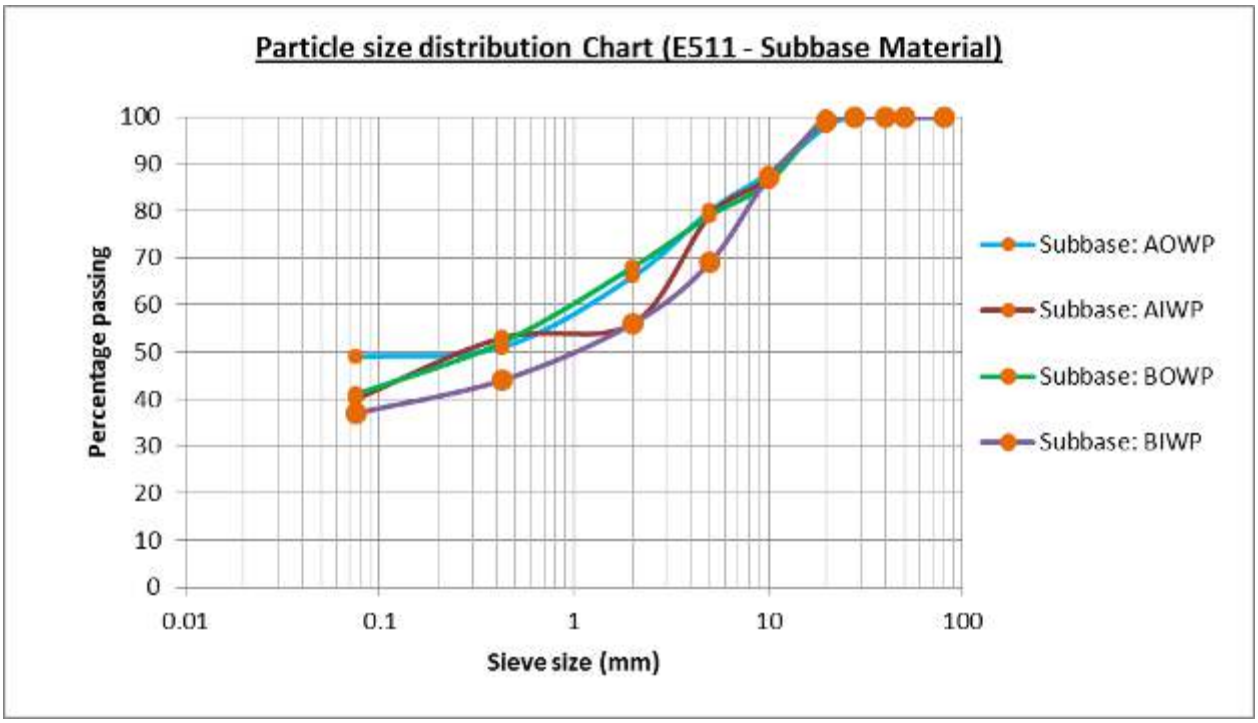


Figure 12-7: Particle size distribution for sub-base material (E511)

Figure 12-8: Particle size distribution for subgrade material (E511)

12.8.5 Atterberg Limits

Table 12-10 shows the index properties of each pavement layer including the subgrade. The base materials have medium plasticity but the sub-base and subgrade have high plasticity.

Table 12-10: Atterberg limits at test pit (E511)

Layer	Liquid Limit	Plastic Limit	Plasticity Index	Linear Shrinkage
Road E511 – Panel A - OWP				
Base	40	23	17	9
Sub-base	56	40	16	8
Subgrade	54	26	28	14
Road E511 – Panel A – IWP				
Base	52	25	27	14
Sub-base	59	31	28	14
Subgrade	47	23	24	13
Road E511 – Panel B - OWP				
Base	40	23	17	9
Sub-base	38	18	20	9
Subgrade	58	30	28	14
Road E511 – Panel B - IWP				
Base	48	13	15	7
Sub-base	52	34	18	9
Subgrade	50	26	24	12

12.8.6 Laboratory CBR

Table 12-11 shows the 4-day soaked CBR (AASHTO T180 for base and sub-base, and AASHTO T99 for subgrade) of each layer, including the subgrade. The values are significantly lower than the minimum required for base and sub-base layers.

Table 12-11: Laboratory CBR (E511)

4-day soaked CBR (%) (E511)				
Layer	**Panel A**		**Panel B**	
	OWP	**IWP**	**OWP**	**IWP**
Base	25	20	24	25
Sub-base	21	19	21	20
Subgrade	4	8	8	13

12.9 Visual Condition Assessment

12.9.1 Pavement Defects Assessment

The main defects on this road section are slight bleeding and limited alligator cracks as shown in Table 12-12. The surfacing is mostly good.

Table 12-12: Visual condition assessment of E511

Fig No	Location (Km)	Defect assessment and description	Photos illustrating the pavement distress & defect
Fig 1	Km 0+000 – 0+050 centerline	-Bleeding on the main carriage way at the centerline	

Fig 2	Km 0+070 – 0+080 RHS	-Bleeding on the main carriage way -Blocked side drain hindering free flow of water along the side drain	
Fig 3	Km 0+080 - 0+096 LHS main carriage way	-Extensive alligator cracks and deformation and depression on the outer wheel path 12m long -Silted and narrow drain hindering free flow of water along the drain	
Fig 4	Km 0+094 – 0+100 RHS	-Extensive alligator cracks on the outer wheel path -Deformation and depression on the outer wheel path of about -Area - 4m by 6m ($24m^2$)	

Fig 5	Km 0+060 – 0+175 RHS main carriage way	-Bleeding on the inner wheel path on the RHS lane	
Fig 6	Km 0+190 - 0+220 LHS	-Silt deposit on the side drain and shoulders extending towards the carriage way	
Fig 7	Km 0+270 – 0+300 RHS	-Extensive alligator cracks on the outer wheel path causing deformation and alligator cracks at the edge -silted side drain	

Fig 8	Km 0+030 - 0+320LHS	-Extensive alligator cracks on the outer wheel path causing deformation and alligator cracks at the edge -Silted side drain hindering free flow of water along the drain and enhancing accumulation of deposits	
Fig 9	Km 0+320 – 0+360 LHS main carriage way	-Alligator cracks ,Edge deformation ,subsidence and edge breaking -Eroded and silted side drain	
Fig 10	Km 0+320 – 0+440 LHS main carriage way	-Edge deformation ,subsidence breaking and cracking -Too thin ac layer	

Fig 11	Km 0+533 – 0+600 both sides	-Blocked and silted with waste debris side drain	
Fig 12	0+601 – 0+613 LHS	-Silted side drain and Vegetated side slope allowing the accumulation of erosion deposits on shoulders and edge	
Fig 13	Km 0+590- 0+650LHS	-Silted side drain forcing water to overflow across the carriage way -Silted edge	

Fig 14	Km 0+590- 0+650LHS	-Edge subsidence ,deformation , alligator cracks and outer wheel path failure -Blocked with erosion deposits	
Fig 15	Km 0+730 – 0+750 LHS	-Collapsing side slope causing blockage on the side drain	
Fig 16	Km 0+768 – 0+800 main carriage way	-Pavement deformation, depression and failure	

Fig 17	Km 0+850 – 0+900 LHS	-Eroded side slope and edge braking -Collapsing side slope	

12.9.2 Present Serviceability Rating

The computed PSR for this section is about 4.8 as shown in Table 12-13, which is regarded as "Very Good".

Table 12-13: Present Serviceability Rating (E511)

Road :	Kangari - Kinyona Road (E511)												
Section:	Km 0+000 - Km 1+ 000 main carriage way												
Pavement Structure:	**Date of Survey:**								11/12/2016				
Surfacing	Cold mix asphalt												
Base	Neat laterite base												
Sub-base	Natural gravel												
		A	**B**	**C**	**D**	**E**	**F**	**G**	**Point summary**				
	Point score												
Sub- Section	Length (Km)	General appearance	Surface texture	Bitumen condition	Pot holes	Surface irregularity	Rutting	Cracking	Sum of (∑) Points A-G Max: 40	Average points	%	Remarks	PSR
1. Km 0+000 - 0+500	0.500	5.0	4.5	5.0	5.0	5.0	5.0	4.5	34	4.9	85.0	**V.Good**	**4.9**
2. Km 0+500- 1+000	0.500	5.0	4.5	4.0	5.0	5.0	5.0	4.5	33	4.7	82.5	**V.Good**	**4.7**
Average PSR		**5**	**4.5**	**4.5**	**5**	**5**	**5**	**4.5**	**33.5**	**4.79**	**83.8**	**0**	**0**

12.10 Rainfall Data

The rainfall data collected during the baseline period is shown in Table 12-14. There was no data collected from January 2017.

Table 12-14: Precipitation at E511

Precipitation (mm) at Kangari – Kinyona Road (E511)										
2016					2017					
AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE
54.4	18.2	62.8	280.6	114.0	XX	XX	XX	XX	XX	XX

13 Jn C70 Ruring'u-D434 Kinunga Road E579

13.1 Site Description

This road is located in Nyeri County. It starts at Ruring'u junction, 5 km from Nyeri Town, and goes up to Gitathini, a total of 5.3 km sealed length. Figure 13-1 shows the road location map.

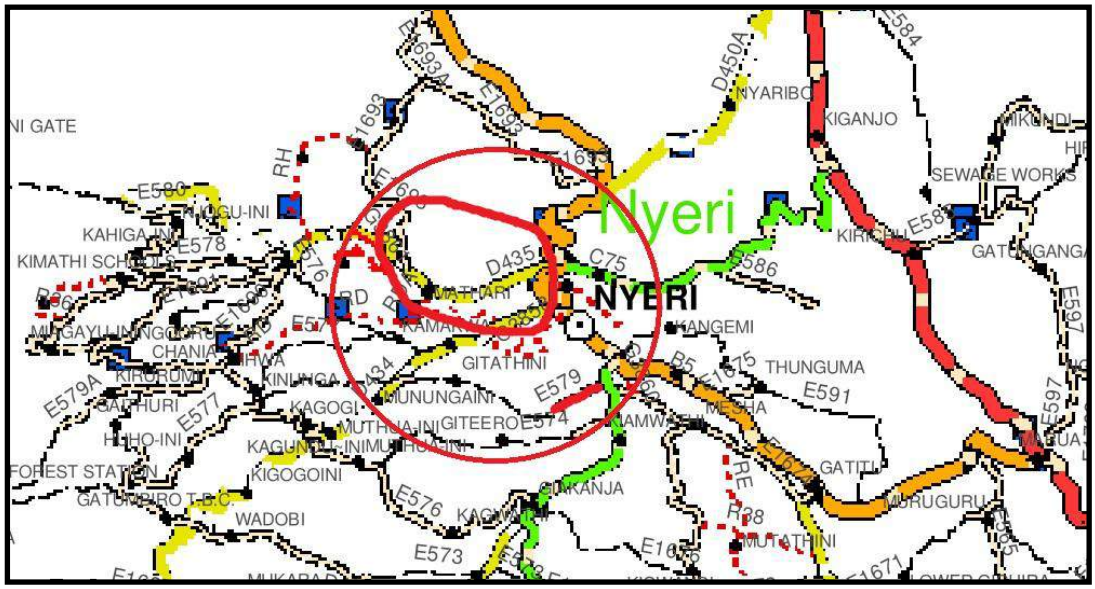


Figure 13-1: Location of Jn C70 Ruring'u – D434 Kinunga Road (E579), marked in red

13.2 Pavement Description

Table 13-1 shows the designed pavement structure.

20 mm Cold Mix Asphalt	
150 mm Graded crushed stone base	
200 mm Neat Granular sub-base	
Subgrade	

Table 13-1: Designed pavement structure (E579)

13.3 Traffic Survey

13.3.1 Classified Traffic Counts

Table 13-2 shows a summary of the traffic count. Motorcycles are the largest uses of the road.

Table 13-2: Traffic Volume Summary

Vehicle Type	Daily Volume (vpd)
Motorcycles	1,035
Cars	1,323
Minibus	476

Bus	10
Light Goods Vehicle	168
Medium Goods Vehicle	59
Heavy Goods Vehicle	1
ADT	**3,072**

13.3.2 Axle Load Survey

Table 13-3 shows the ESA by vehicle type, and the computed ESA/day.

Table 13-3: Traffic ESA (E579)

Vehicle Type	**ESA/day**
Bus	0.13
Medium Goods Vehicles	55.82
Heavy Goods Vehicles[1]	XXX
Design ESA/day	**55.95**

Note 1: Although HGV's were counted during the traffic counts, they were not present during the axle load survey.

13.4 Rutting

Table 13-4 shows the maximum rut depth left and right of each chainage point. The average of 8 mm is acceptable for LVSRs.

Table 13-4: Maximum rut depth (E579)

Chainage	**LHS Rut in mm**	**RHS Rut in mm**
0+000	10	8
0+050	8	6
0+100	10	6
0+150	10	9
0+200	12	6
0+250	12	11
0+300	6	4
0+350	7	5
0+400	12	5
0+425	10	9
0+440	7	2
0+455	1	2
0+470	8	12
0+485	3	8
0+500	8	7
0+515	7	5
0+530	9	5
0+545	5	7
0+560	3	12
0+575	2	8
0+600	4	12

0+650	2	6
0+700	8	7
0+750	6	3
0+800	3	8
0+850	9	2
0+900	12	9
0+950	5	12
1+000	7	3
Average	**8**	**7**

13.5 Deflection/Stiffness

Table 13-5 shows the central deflection D_0, and the base, sub-base and subgrade stiffness measured at each point.

Table 13-5: Deflection and stiffness (E579)

Chainage (m)	Lane No.	Stiffness			Normalized Deflections at Geophone Locations (µm) D_0
		EBase (MPa)	ESubbase (MPa)	ESubgrade (MPa)	
0+000	1	1816	320	96	541
0+100	1	300	200	125	553
0+200	1	300	200	102	548
0+301	1	680	68	166	533
0+399	1	315	36	186	741
0+440	1	347	62	116	791
0+471	1	1322	225	132	609
0+500	1	441	45	132	716
0+530	1	431	79	141	674
0+560	1	416	57	146	691
0+600	1	394	59	94	852
0+700	1	394	63	125	748
0+801	1	234	168	108	628
0+900	1	583	83	178	542
1+000	1	537	66	97	755
0+050	2	1113	193	96	757
0+150	2	300	200	111	543
0+250	2	556	35	187	636
0+350	2	148	117	61	1061
0+425	2	2049	307	78	886
0+451	2	433	88	99	766
0+485	2	419	55	131	714
0+515	2	302	60	103	882
0+545	2	405	66	117	750

0+575	2	488	56	116	715
0+650	2	464	69	120	714
0+750	2	392	59	115	786
0+850	2	300	200	107	630
0+950	2	418	626	113	437
0+050	3	400	48	147	719
0+150	3	619	92	143	583
0+250	3	269	185	96	611
0+353	3	356	60	93	872
0+425	3	476	82	120	689
0+455	3	981	175	159	636
0+485	3	503	69	157	610
0+515	3	394	40	122	800
0+545	3	424	93	148	702
0+575	3	506	52	139	658
0+650	3	364	91	121	1153
0+752	3	440	44	117	793
0+850	3	1891	329	132	455
0+950	3	498	62	282	493
0+000	4	517	103	133	613
0+100	4	1191	210	158	505
0+200	4	505	51	202	557
0+299	4	331	64	101	877
0+400	4	408	70	135	703
0+441	4	471	48	146	660
0+470	4	454	49	145	682
0+500	4	415	59	138	681
0+530	4	288	37	147	823
0+560	4	373	40	121	816
0+600	4	2500	300	79	856
0+700	4	300	200	106	617
0+800	4	236	169	120	631
0+900	4	364	493	102	524
1+000	4	2105	362	101	524

All the deflection outputs from the FWD for all the sensors (D_0 up to D_6) for all the test locations are presented in the Appendix section of the report. Figure 13-2 shows the central deflection of each wheel path along the road. The values are highly variable.

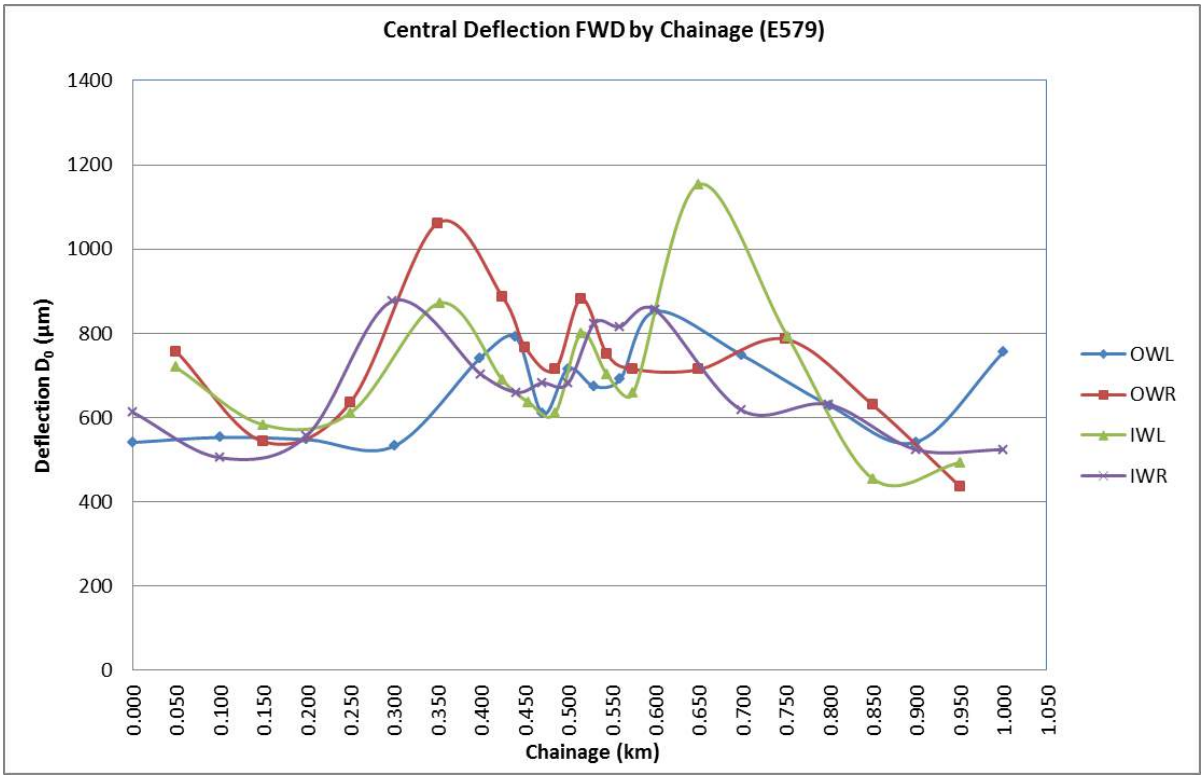


Figure 13-2: Central deflection by chainage (E579)

13.6 DCP Measurements

Table 13-6 below shows the DN and DSN values of each layer for each test point. Most of the values meet the specification requirements.

Table 13-6: DN and DSN values (E579)

Chainage (m)	Specifications	≤3.2	≤6.0	≤12	≤19	≤25	DSN800
	Position	0-150	150-300	300-450	450-600	600-800	≥100
0+000	RHS	2.4	5.0	5.2	8.3	8.6	191
0+050	LHS	4.0	5.2	4.9	7.5	7.2	163
0+100	RHS	3.6	6.3	14.1	16.5	9.0	117
0+150	LHS	4.7	3.3	6.4	13.4	10.1	142
0+200	RHS	4.9	4.7	3.1	5.1	3.4	224
0+250	LHS	1.9	3.2	5.2	7.4	9.2	248
0+300	RHS	5.2	6.0	8.4	11.0	21.8	101
0+350	LHS	2.3	3.8	6.4	9.0	8.7	192
0+400	LHS	3.9	2.7	4.3	9.1	11.1	179
0+404	OWR	3.9	7.2	10.5	21.8	19.4	100
0+404	IWR	2.8	3.5	2.5	9.5	12.2	207
0+404	CL	3.0	4.4	2.7	4.9	7.4	225
0+404	IWL	2.7	2.9	1.8	5.5	6.9	269
0+404	OWL	5.9	12.8	9.1	14.5	13.5	95
0+407	RHS	2.7	4.4	5.2	9.0	19.9	170
0+596	OWR	3.3	4.2	4.5	4.1	8.2	210

0+596	IWR	3.5	3.2	3.7	4.1	6.0	225
0+596	CL	3.8	3.1	4.5	3.5	4.0	235
0+596	IWL	3.6	4.5	4.0	3.5	5.2	220
0+596	OWL	4.2	5.4	3.8	6.9	5.5	195
0+600	LHS	3.3	5.1	5.5	4.9	5.7	181
0+650	LHS	6.2	5.0	4.1	4.0	6.5	175
0+700	RHS	7.0	4.6	3.3	4.7	7.2	175
0+750	LHS	2.7	3.2	3.1	3.6	5.0	265
0+800	RHS	3.7	5.7	7.3	11.6	9.8	131
0+850	LHS	4.5	6.0	6.9	16.6	19.5	120
0+900	RHS	4.6	9.3	4.9	9.3	13.8	130
0+950	LHS	3.4	7.4	8.7	6.5	10.8	146
1+000	RHS	3.1	6.4	5.8	4.4	6.1	179

13.7 Roughness Measurements

The roughness values are shown in Table 12-6Table 13-7 and

Table 13-8Table 12-7. The former includes values with humps and the latter values where hump locations have been subjectively removed. The values are within the range expected for LVSRs. Figure 13-3Figure 12-4 shows the roughness of each lane along the road section.

Table 13-7: Roughness values including humps (E579)

Ruring'u – Kinunga Road (E579)			
LHS		RHS	
Chainage	IRI	Chainage	IRI
0+000-0+100	3.8	0+000-0+100	3.8
0+100-0+200	3.6	0+100-0+200	3.6
0+200-0+301	4.2	0+200-0+299	4.2
0+301-0+440	6.9	0+299-0+400	6.9
0+440-0+471	6.9	0+400-0+441	6.9
0+471-0+500	4.3	0+441-0+470	6.9
0+500-0+560	4.3	0+470-0+500	4.3
0+560-0+600	3.7	0+500-0+530	4.3
0+600-0+700	2.8	0+530-0+560	3.7
0+700-0+900	7.0	0+560-0+600	3.7
0+900-1+000	3.0	0+600-0+700	2.8
		0+700-0+800	5.6
		0+800-0+900	7.0
		0+900-1+000	3.0

Table 13-8: Roughness values excluding humps (E579)

Ruring'u – Kinunga Road (E579)			
LHS		RHS	
Chainage	IRI	Chainage	IRI

0+000-0+100	4.9	0+000-0+100	4.9
0+100-0+200	4.9	0+100-0+200	4.9
0+200-0+301	4.9	0+200-0+299	4.9
0+301-0+440	3.9	0+299-0+400	3.9
0+440-0+471	3.9	0+400-0+441	3.9
0+471-0+500	3.9	0+441-0+470	3.9
0+500-0+560	3.9	0+470-0+500	3.9
0+560-0+600	4.9	0+500-0+530	3.9
0+600-0+700	4.9	0+530-0+560	4.9
0+700-0+900	3.9	0+560-0+600	4.9
0+900-1+000	4.9	0+600-0+700	4.9
		0+700-0+800	3.9
		0+800-0+900	3.9
		0+900-1+000	4.9

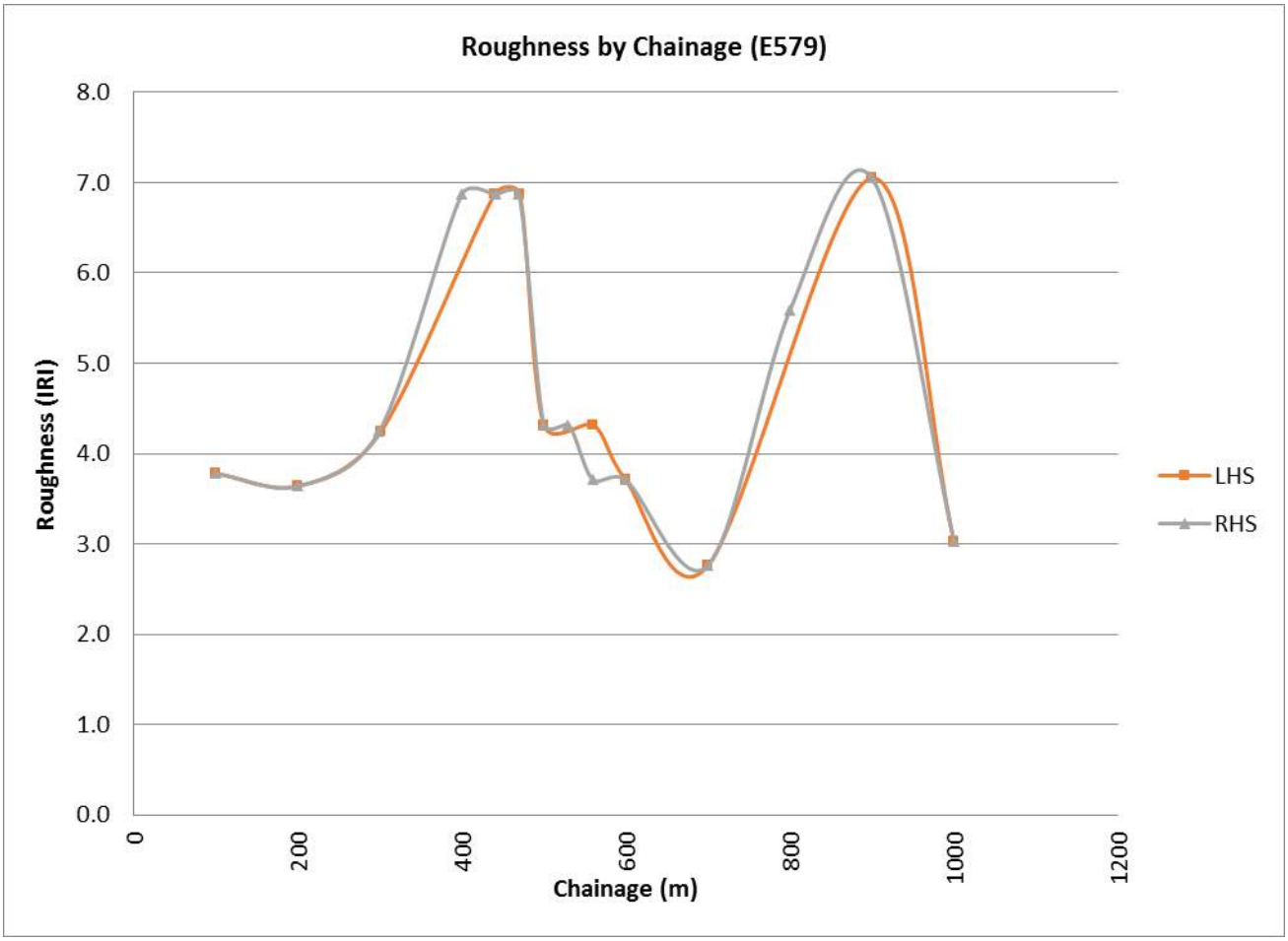


Figure 13-3: Roughness values including humps by chainage (E579)

13.8 Test Pits

13.8.1 DN Values

Table 13-9 shows the DN of each layer in the structure measured before excavation of the test pits. The values all meet the specification limits.

Table 13-9: DN values at test pit (E579)

Depth (mm)	Specifications	DN values (mm/blow)	
		Pit A @ 0+407	Pit B @ 0+600
0 – 150	≤3.2	2.7	3.3
150 – 300	≤6.0	4.4	5.1
300 – 450	≤12	5.2	5.5
450 – 600	≤19	9.0	4.9
600 – 800	≤25	19.9	5.7
DSN800	≥100	170	181

The complete DCP test details are presented in the Appendix section of the report.

13.8.2 Layer Thicknesses

Figure 13-4 shows the measured layer thicknesses at test pit and description of the pavement layers.

Test Pit A, km 0+407		Test Pit B, km 0+600
20 mm Cold Mix Asphalt		20 mm Cold Mix Asphalt
150 mm Graded crushed stone base		150 mm Graded crushed stone base
200 mm Neat Granular sub-base		200 mm Neat Granular sub-base
Subgrade		Subgrade

Figure 13-4: Layer thicknesses at test pit (E579)

13.8.3 Particle Size Distribution

The plots in Figure 13-5, Figure 13-6, and Figure 13-7 below show the particle size distribution for each layer. The base materials mostly lie outside the specification envelope.

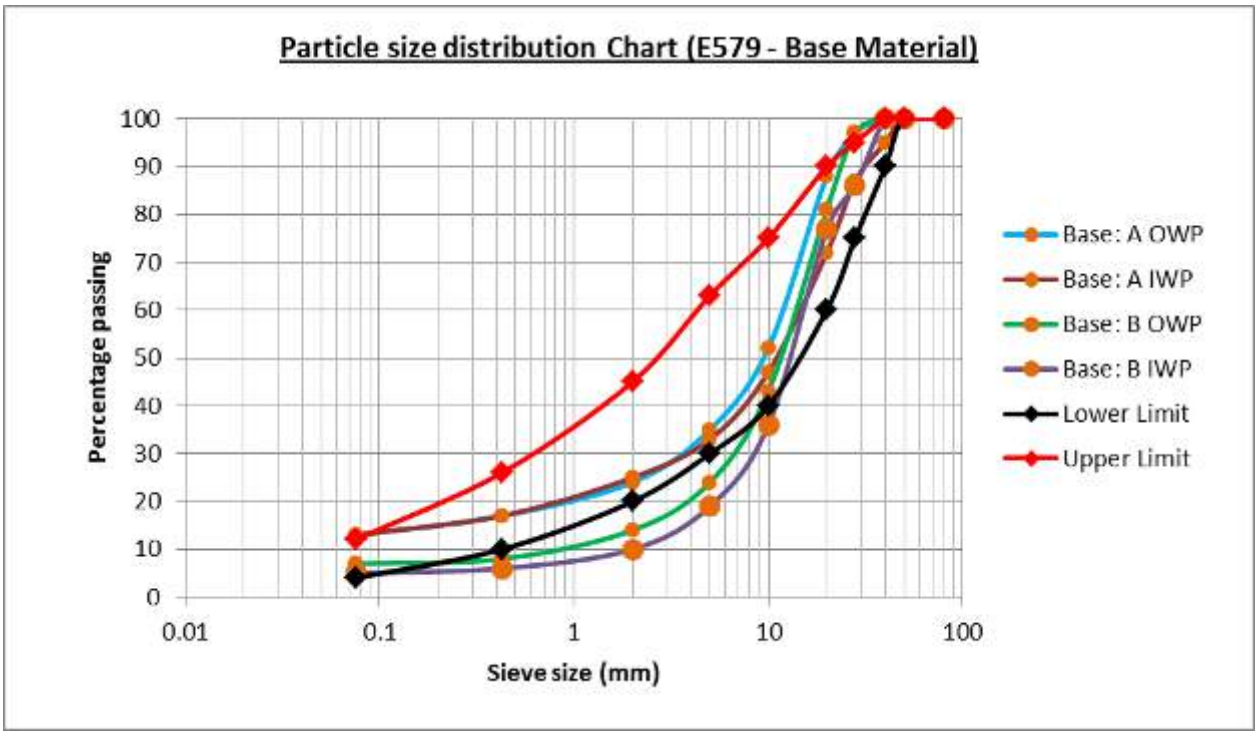


Figure 13-5: Particle size distribution for base material (E579)

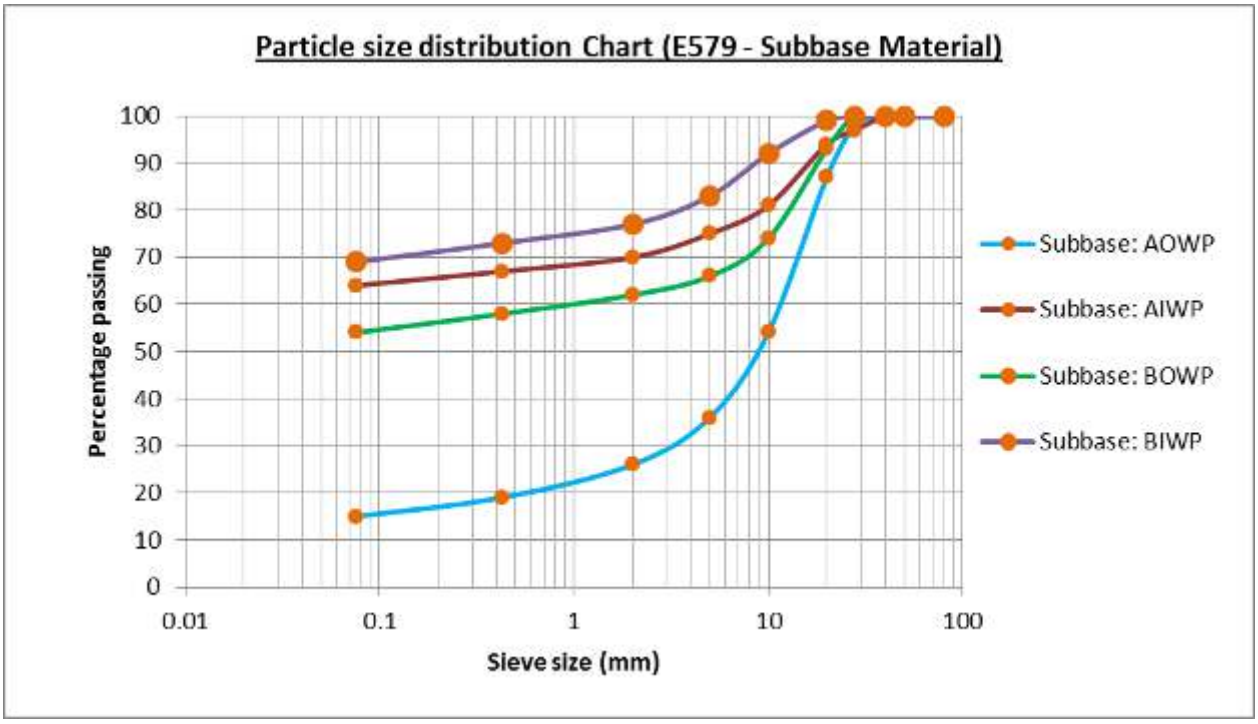


Figure 13-6: Particle size distribution chart for sub-base material (E579)

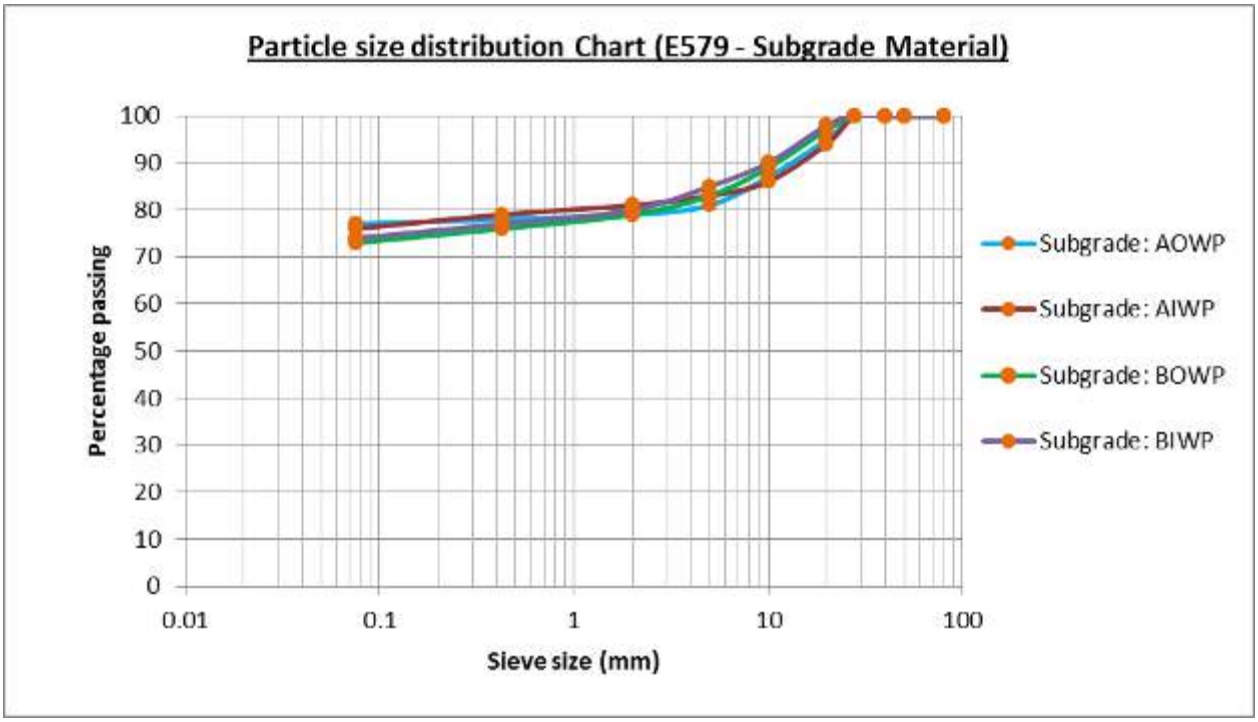


Figure 13-7: Particle size distribution chart for subgrade material (E579)

13.8.4 Atterberg Limits

Table 13-10 shows the index properties of each pavement layer including the subgrade. The plasticity of all the materials in the different layers is high.

Table 13-10: Atterberg limits at test pit (E579)

Layer	Liquid Limit	Plastic Limit	Plasticity Index	Linear Shrinkage
Road E579 – Panel A - OWP				
Base	46	22	24	11
Sub-base	52	30	22	11
Subgrade	54	25	29	15
Road E579 – Panel A – IWP				
Base	45	21	24	12
Sub-base	54	25	29	15
Subgrade	69	35	34	16
Road E579 – Panel B - OWP				
Base	39	21	18	9
Sub-base	54	25	29	15
Subgrade	67	33	34	17
Road E579 – Panel B - IWP				
Base	46	22	24	11
Sub-base	54	25	29	15
Subgrade	60	27	33	16

13.8.5 Laboratory CBR

Table 13-11 shows the 4-day soaked CBR (AASHTO T180 for base and sub-base, and AASHTO T99 for subgrade) of each layer, including the subgrade. The values for the sub-base are low. The base material was not tested for CBR due to its coarse nature.

Table 13-11: Laboratory CBR (E579)

4-day soaked CBR (%) (E579)				
Layer	**Panel A**		**Panel B**	
	OWP	**IWP**	**OWP**	**IWP**
Base	GCS	GCS	GCS	GCS
Sub-base	12	15	13	12
Subgrade	6	7	6	4

13.9 Rainfall Data

The precipitation measured during the baseline period is shown in Table 13-12.

Table 13-12: Precipitation at E579

Precipitation (mm) at Ruring'u – Kinunga Road (E579)										
2016					**2017**					
AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE
7.4	23.4	27.0	65.8	35.5	63.0	24.2	39.8	100.7	216.8	6.0

14 Future Monitoring

14.1 Roads

The roads to be studied in the first monitoring survey include:

1. Wamwangi – Karatu Road D379 – Kiambu County
2. Kangari – Kinyona Road E511 – Murang'a County
3. Lord – Kona Bahati Road D382 – Nyandarua County
4. Muthuaini – Mununggaini Road D435 – Nyeri County

14.2 Tests

The tests to be carried out include:

1. Classified traffic counts
2. Axle load survey
3. Visual Condition survey
4. Rut depth measurement
5. Deflection measurement
6. DCP tests
7. Base layer moisture content
8. Test pits and laboratory testing
9. Drainage assessment

For the first round of monitoring, the following tests have been completed; visual condition survey, rut depth measurement, Deflection, DCP, trial pits for moisture samples, base moisture and drainage assessment. In addition to the above, we have collected surfacing samples for grading and bitumen content tests.

The traffic counts started in the final week of the month of July. Finally the axle load survey is set to be done in August as suggested by Mtrd. The rainfall data that was available has been collected from the field and included in this final report.

14.3 Monitoring Schedule

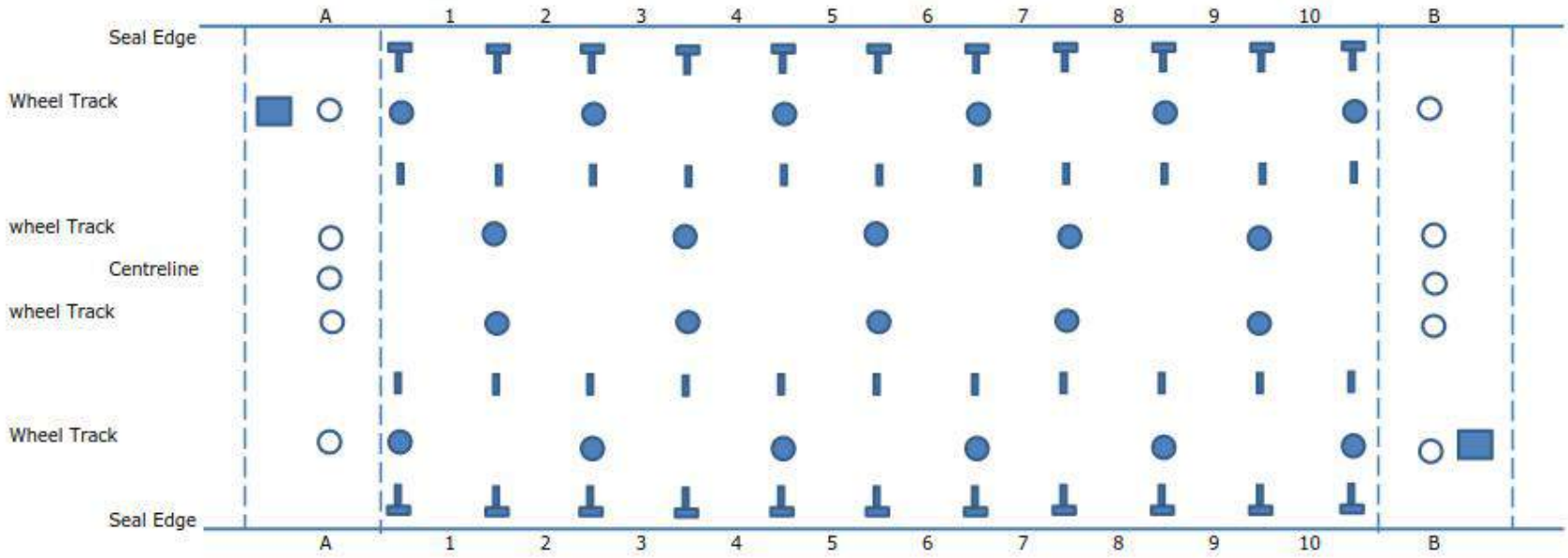
ACROSS AFRICA CONSULTANTS LIMITED

ACTIVITY SCHEDULE - MONITORING AND EVALUATION OF LOW VOLUME ROADS TRIAL SECTION IN KENYA - MONITORING SURVEY

S/N	Road Section	JULY																																AUGUST						
		WEEK 2													WEEK 3								WEEK 4							WEEK 5							WEEK 6							WEEK 7						
		27-Jun	28-Jun	29-Jun	30-Jun	01-Jul	02-Jul	03-Jul	04-Jul	05-Jul	06-Jul	07-Jul	08-Jul	09-Jul	10-Jul	11-Jul	12-Jul	13-Jul	14-Jul	15-Jul	16-Jul	17-Jul	18-Jul	19-Jul	20-Jul	21-Jul	22-Jul	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	01-Aug	02-Aug	03-Aug	04-Aug	05-Aug	06-Aug	07-Aug	08-Aug	09-Aug	10-Aug	11-Aug	12-Aug	13-Aug
1	**D435 Nyeri**																																														
	Mobilizing																																														
	Axle Load Survey																																														
	Traffic count																																														
	DCP Test																																														
	Trial Pits																																														
	VCS																																														
	Rut Depth Measurement																																														
	Deflection																																														
	Demobilizing																																														
2	**D379 Kiambu**																																														
	Mobilizing																																														
	Axle Load Survey																																														
	Traffic count																																														
	DCP Test																																														
	Trial Pits																																														
	VCS																																														
	Rut Depth Measurement																																														
	Deflection																																														
	Demobilizing																																														
3	**E511 Murang'a**																																														
	Mobilizing																																														
	Axle Load Survey																																														
	Traffic count																																														
	DCP Test																																														
	Trial Pits																																														
	VCS																																														
	Rut Depth Measurement																																														
	Deflection																																														
	Demobilizing																																														
4	**D382 Nyandarua**																																														
	Mobilizing																																														
	Axle Load Survey																																														
	Traffic count																																														
	DCP Test																																														
	Trial Pits																																														
	VCS																																														
	Rut Depth Measurement																																														
	Deflection																																														
	Demobilizing																																														
	Data Entry																																														
	Laboratory Testing																																														
	Analysis																																														
	Draft Report																																														
	Final Report																																														

15 Schematic Layout of LTPPs

LTTP Section Markings



NOT TO SCALE

Notes

a) Wheel tracks should have deflection test points marked but DO NOT MARK a continuous straight line along the wheel track
b) A and B are 25 m wide, 1 to 10 are 15 m wide
c) Total section length is 200 m
d) The edges of grids A and B must be marked fully across the road width
e) Grids A and B are mainly for trial pits, DCP tests, sampling for lab testing, layer thicknesses, layer moistures

FWD measurement point, on existing wheelpaths or if no wheel tracks visible then it should be estimated

Straight edge placement guidelines for measuring rut depths

Straight edge placement guidelines for measuring rut depths

FWD, DCP, and Base Moisture Content test locations **(TEMPORARY MARK WITH CHALK)**

FWD, DCP, and Trial-Pit locations **(TEMPORARY MARK WITH CHALK)**