Research for Community Access Partnership

First Monitoring Report for 4 Low-Volume Sealed Roads in Kenya

Final Report

Prepared for Kenya Materials Testing and Research Department (MTRD)

AFCAP Project – KEN2043C

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Abstract

The first monitoring round was conducted on four road sections. The monitoring span over six months. All the activities that were supposed to be carried out in the survey were done successfully during this period except for the axle load survey which was done in February 2018. Axle load survey was put on hold due to the abnormal traffic and the political activities during the period for the first monitoring round survey.

The surfacing of the roads showed varied performance. D379 and E511 are performing well save for edge break on E511 owing to heavy trucks plying the route towards the tunnel construction, which were unanticipated. D382 showed a lot of crocodile and alligator cracks maybe due to the thin layer of the surface. On the other hand, D435 exhibit ravelling due rainfall which was experienced during its construction.

The roads also behaved differently in as far as rutting is concerned. For instance, average rutting increased in D382 while it decreased in D435. The average rut in D379 and E511 remained almost constant.

Traffic experienced in all the roads was varied as well from previous survey. However, this could be attributed to the political activities during the time of the survey. In D382, we can attribute the change in traffic volume to a change in the economic activity of the area.

Key words

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

Acknowledgements

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Acronyms, Units and Currencies

$	United States Dollar (US$ 1.00 ≈ 92KShs)
AfCAP	Africa Community Access Partnership
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
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)

1 Executive Summary

The first monitoring round sought to investigate 4 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 (E511); Nyeri County (D435) and Nyandarua County (D382). 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 four roads, several tests and activities were carried out in a predetermined sequence. These included: Traffic counts; Visual Condition Surveys; Deflection tests; Rut depth measurements; DCP tests; In-situ 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. Axle load surveys was part of the first monitoring round though the exercise was carried out a little bit out of the intended period for first monitoring round. Nonetheless, the results are presented in this final version of the first monitoring round report. The long-extended cycle of the general election in Kenya caught up with our plans to carry out this axle load survey as the last activity in the first monitoring round, hence to avoid reporting abnormal traffic, it was postponed until the situation gets back to normal.

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 four roads had its own specific dominating defects, perhaps arising from the construction materials used, the prevailing weather conditions or 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 most 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 monitor the performance of the four roads. These include traffic surveys, rut depth measurements, deflection measurements, DCP tests, moisture content determination, trial pit sampling, 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 6.

2.3 Monitoring Period

The first monitoring round of the roads took place between June and November 2017. The monitoring period started just after the long rains, into the short rains and ended during the dry season. The rainfall data collected during this 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 first monitoring round was conducted on each road except for the axle load survey, which was conducted in February 2018. 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	Baseline Survey start date	Baseline Survey completion date
D379	1st July 2017	24th February 2018	16th May 2016	13th November 2016
D382	2nd July 2017	12th February 2018	19th May 2016	10th November 2016
D435	28th June 2017	16th February 2018	18th May 2016	11th November 2016
E511	29th June 2017	20th February 2018	20th May 2016	13th November 2016

Precise dates when the various surveys were conducted on each site are shown in Table 2-2.

Table 2-2: First monitoring round dates per site

Road Name	Road Number	Deflection/ Stiffness	Rut Depth	DCP	Axle Load Surveys	Traffic Counts	Test Pits	Visual Condition Assessment
Wamwangi - Karatu	D379	1st July 2017	1st July 2017	1st July 2017	22th February 2018– 24th February 2018	24th July 2017 - 30th July 2017	1st July 2017	1st July 2017
Lord – Kona Bahati	D382	2nd July 2017 – 3rd July 2017	3rd July 2017	3rd July 2017	10th February 2018– 12th February 2018	1st August 2017 - 7th August 2017	3rd July 2017	3rd July 2017
Muthuaini - Munungaini	D435	28th June 2017	28th June 2017	28th June 2017	14th February 2018– 16th February 2018	1st August 2017 - 7th August 2017	29th June 2017	28th June 2017
Kangari - Kinyona	E511	29th June 2017	30th June 2017	29th June 2017 - 30th June 2017	18th February 2018– 20th February 2018	24th July 2017 - 30th July 2017	30th June 2017	30th June 2017

3 Wamwangi-Karatu Road D379

3.1 Site Description

Road D379 is 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 3-1below shows the classified traffic count results collected.

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

Vehicle Type	Daily Volume (vpd)	Baseline Survey Results
Motorcycles	391	320
Cars	167	164
Minibus	22	10
Bus[1]	0	0
Light Goods Vehicle	41	17
Medium Goods Vehicle	3	5
Heavy Goods Vehicle	0	1
ADT	**624**	**517**

Note 1: Only three buses 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 390 per day. The volume of vehicles increased a great deal as compared to the results obtained during the baseline survey which was 517. This can be attributed to the political activities since it was during the times of campaigns for the general elections.

3.3.2 Axle Load Survey

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

Table 3-2: Traffic ESA (D379)

Vehicle Type	ESA/day	Baseline ESA/day
Bus[1]	1.15	0.06
Medium Goods Vehicles	0.29	4.54
Heavy Goods Vehicles	1.54	1.76
Articulated Heavy Goods Vehicles	0.00	0.00
Total ESA/day	**2.98**	**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. In arriving at the ESA/day values, we used ADT values obtained during the axle load survey and not those obtained from classified traffic count period. By using ADT obtained during the axle load survey, we can get more realistic results for the ESA/day, since no values obtained on different days are being used in the calculations.

The ESA/day obtained on the first monitoring round was lower as compared to that obtained during the baseline survey, which was 6.36. This can be attributed to a difference in season hence economic activities. Whereas the baseline survey was conducted in August 2016, the first monitoring round was done in February 2018.

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 3-3shows the maximum rut depth left hand side and right-hand side on the inner wheel paths and outer wheel paths 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 outer wheel paths is approximately 10 mm. The average rut for the inner wheel paths is 2mm. This is considered slight rutting, which poses no major deterrence to traffic flow. Of importance is that no ponding of water was observed in the ruts. The average Rut for outer wheel paths during the baseline survey was also 10mm. This means that there was no major change in rut between the two periods of survey.

Table 3-3: Rut depth (D379)

Chainage	LHS Rut in mm Outer Wheel Path	LHS Rut in mm Inner Wheel Path	RHS Rut in mm Inner Wheel Path	RHS Rut in mm Outer Wheel Path
0+000	11	4	7	12
0+025	27	0	10	13
0+040	17	2	3	18
0+055	8	1	0	10
0+070	11	2	0	12
0+085	13	4	2	6
0+100	8	1	0	1
0+115	9	2	2	7
0+130	8	1	0	7
0+145	8	0	1	10
0+160	8	3	1	3
0+175	3	0	2	9
0+200	0	0	2	3
0+250	16	2	2	10
0+300	13	0	1	6
0+350	9	7	3	13
Average	**11**	**2**	**2**	**9**

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 3-3 show the deflection of the pavement at D_0 and the base, sub-base and subgrade stiffness measured at each point. Annex 1-5 contains a detailed information on the same. 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+020	1	300	200	109	714
0+040	1	205	157	76	1128

0+070	1	235	165	92	892
0+100	1	300	200	113	791
0+115	1	300	200	109	782
0+130	1	246	175	88	914
0+145	1	1034	186	97	1017
0+160	1	206	147	88	1023
0+174	1	300	200	122	799
0+195	1	550	32	108	1044
0+201	1	1083	193	121	786
0+250	1	750	88	198	590
0+301	1	173	108	154	594
0+350	1	193	142	133	833
0+020	2	2069	343	80	835
0+025	2	300	200	101	833
0+041	2	1048	182	98	1009
0+071	2	211	156	86	1072
0+101	2	570	102	108	862
0+116	2	544	91	123	796
0+131	2	241	172	82	990
0+146	2	351	21	149	1177
0+161	2	1157	197	95	1041
0+175	2	588	38	129	892
0+195	2	159	120	74	1189
0+202	2	80	55	98	1086
0+251	2	419	43	181	880
0+302	2	449	62	130	856
0+352	2	535	106	132	960
0+021	3	223	159	80	1007
0+055	3	161	122	75	879
0+085	3	275	188	89	1037
0+117	3	235	176	87	898
0+147	3	552	109	100	1094
0+176	3	391	40	106	1189
0+195	3	1995	326	74	1182
0+252	3	406	69	114	948
0+020	4	235	168	90	1033
0+026	4	1106	197	117	845
0+056	4	487	61	97	970
0+086	4	223	164	87	990
0+195	4	266	185	115	839

Figure 3-3 shows a graphical representation of the central deflection by chainage. The values are highly variable for each lane along the road. As compared to values obtained in the baseline survey, the first monitoring round showed higher values of deflection.

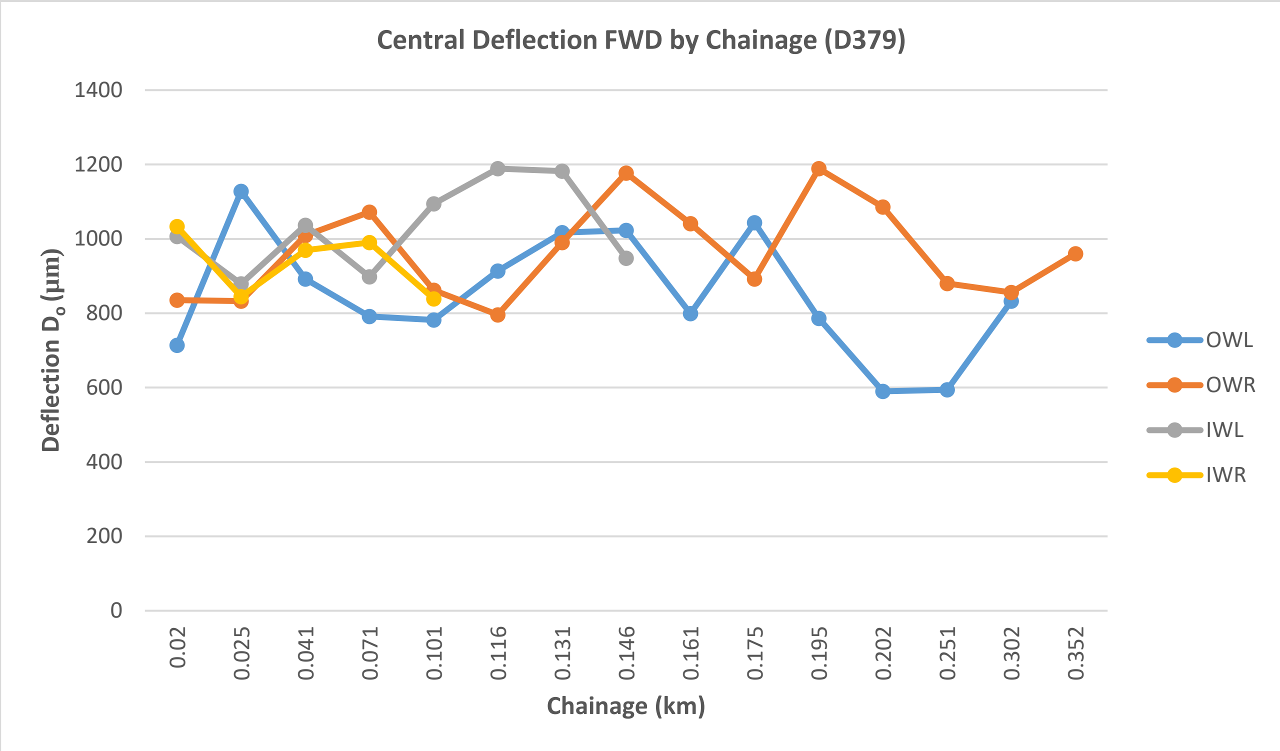


Figure 3-3: Central deflection by chainage (D379)

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 3-5shows the DN values by layer for each test point and DSN values for 800mm depth. The maroon shaded rows represent measurements taken at the test pit excavated at the LTPP. This convention is used throughout the document. The values in red denoted those that are above the specification requirement. It is evident that the values are within the specification requirement except the two points within the base layer.

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

Chainage (m)	Specifications	≤4.0	≤9.0	≤19	≤25	≤39	DSN800
	Position	0-150	150-300	300-450	450-600	600-800	≥73
0+000	LHS	4.6	6.5	7.3	11.3	14.7	104
0+020	LHS	2.0	2.4	5.6	9.4	13.4	196
0+020	IWR	1.5	3.1	6.2	9.3	10.0	209
0+020	IWL	2.2	2.2	4.8	7.0	16.6	202
0+020	OWL	2.2	2.9	3.7	6.7	10.5	202
0+020	OWR	5.0	5.0	9.9	24.2	28	89
0+195	OWR	4.2	4.2	6.9	11.2	17.5	118
0+195	IWL	2.1	3.2	5.9	7.3	15.0	178

0+195	IWR	2.9	2.9	5.8	11.3	14.4	157
0+195	OWL	1.5	2.5	4.7	9.5	9.6	229
0+250	OWR	2.2	3.9	4.6	7.0	11.5	179
0+350	IWR	2.1	2.5	3.2	7.0	11.4	218

The DCP measurements were done at the same points as the FWD tests to get a correlation between the two tests. A full analysis of the data will be provided in the final report after collecting several sets of data
FWD testing can provide the most comprehensive assessment of subgrade and pavement moduli as opposed to DCP tests. As compared to DCP values obtained in the baseline survey, these points mostly exhibit values which are within the specification requirements as opposed to the ones in baseline survey, which had more points above the specification requirements.

3.7 Roughness Measurements

This does not form part of the schedule of activities for the first monitoring round.

3.8 Test Pits

3.8.1 DN Values

Table 3-6 shows the DN values of each layer in the structure measured before excavation of the test pit. The values meet the recommended specifications.

Table 3-6: DN Values at test pits (D379)

Depth (mm)	**DN values (mm/blow)**		
	Specifications	**Pit A @ 0+020**	**Pit B @ 0+195**
0 – 150	≤4.0	2.2	1.5
150 – 300	≤9.0	2.9	2.5
300 – 450	≤19.0	3.7	4.7
450 – 600	≤25.0	6.7hd	9.5
600 – 800	≤39.0	10.5	9.6
DSN800	≥73.0	202	229

The other DCP test details are presented in the Appendix section of the report as Annex 1-2.

3.8.2 Layer Thicknesses

Figure 3-4 shows the measured layer thicknesses for the two test pit and description of the pavement materials.

Test Pit A, km 0+020		**Test Pit B, km 0+195**
25 mm Cold Mix Asphalt		20 mm Cold Mix Asphalt

160 mm Neat Laterite base		140 mm Neat laterite base
150 mm Granular subbase		150 mm Granular subbase
Subgrade		Subgrade

Figure 3-4: Layer thicknesses at test pit (D379)

3.8.3 Densities and Moisture Content

Table 3-7 shows the in-situ moisture content for each layer for the two test pits, including the subgrade. Samples were taken for testing to determine the OMC for the materials upon which the relative moisture contents (RMC) could be established . Some of the Field Moisture Content (FMC) values were not available. The missing values are mainly for the IWP which we were only taking the moisture content for the base. For each road, we had samples from two test pits. However, we took samples of base, sub-base and subgrade of only one panel whereas the other panel we only took the base samples for testing, hence the missing values represented by the colour coded cells. In some instances, we only observed the subgrade after the base meaning the sub-base material was missing. The relative moisture content for first monitoring round is generally low as compared to that of the baseline. This implies that the in-situ moisture content has reduced over time.

Table 3-7: Moisture Content at Test Pits (D379)

Panel	Wheel path	Layer	In-situ Moisture Content (%) LHS	Optimum Moisture Content (%)	Relative Moisture Content (FMC/OMC)	Baseline RMC (FMC/OMC)
Panel A	**OWP**	**Base**	9.8	17.2	0.57	0.72
		Sub-base	10.6	20.3	0.52	1.12
		Subgrade	25.2	32.0	0.79	0.94
	IWP	**Base**	7.2	13.5	0.53	0.88
		Sub-base				1.12
		Subgrade				0.91
Panel B	**OWP**	**Base**	7.2	18.3	0.39	0.87
		Sub-base	xxx	xxx	xxx	0.70
		Subgrade	25.0	34.4	0.73	0.91
	IWP	**Base**	8.3	16.9	0.49	0.83
		Sub-base				0.87
		Subgrade				0.86

Note 1: XXX denotes missing layer.

3.8.4 Particle Size Distribution

Figure 3-5 plots show the particle size distribution for the surfacing layer. The surfacing materials all fit into the specification envelope except for a small portion of the finer particles. The specifications are as per the LVSR Pavement Design Guideline.

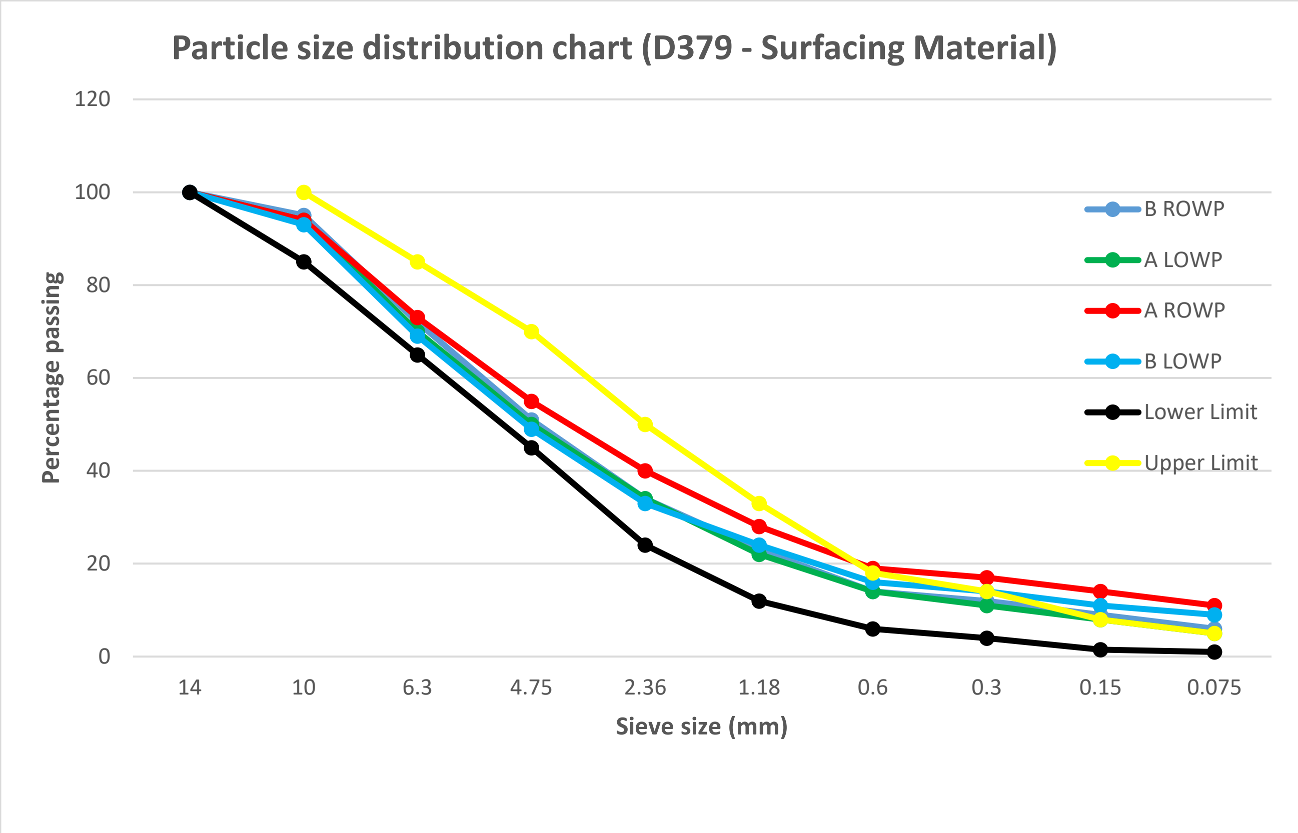


Figure 3-5: Particle size distribution of the base material (D379)

3.8.5 *Mass of Aggregate and Bitumen per Unit Area*

Surfacing samples were taken from an area of 0.09m^2 on the right and left-hand side of the outer wheel paths of the road carriageway. Table 3-8 shows the mass of aggregates and bitumen per unit area. Bitumen content by mass of the total mix is also represented in percentage.

Table 3-8: Mass of aggregate and bitumen per unit area (D379)

Core Location	Panel A		Panel B		Unit
	L OWP	R OWP	L OWP	R OWP	
Residual Binder Content	7.3	4.1	6.7	7.5	%
Mass of Aggregate per Unit Area	19.3	21.4	18.1	16.4	Kg/m^2
Mass of Bitumen per Unit Area	1.5	0.9	1.3	1.3	Kg/m^2

3.8.6 *Atterberg Limits*

This does not form part of the schedule of activities for the first monitoring round.

3.8.7 *Laboratory CBR*

This does not form part of the schedule of activities for the first monitoring round.

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 3-9 shows the defects assessment. No main defects were observed.

Table 3-9: 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	-Blocked drainage structure, light vegetation at the shoulder and sealed cracks at the carriage way	
Fig 2	Km 0+000-0+030 LHS	-Sealed longitudinal cracks on the carriage way	
Fig3	Km 0+050 main carriage way at the centreline	-Sealed longitudinal cracks and light vegetation at the side drains	

Fig 4	Km 0+130– 0+145 main carriage way at the centreline	-Sealed Longitudinal cracks and light vegetation at the side drains	
Fig 5	Km 0+160 – 0+175RHS	-Partially blocked culvert	
Fig6	km 0+220 – 0+300	-No visible defect from	

Fig 7	Km 0+330- 0+345	-Sealed Transverse cracks on carriage way RHS and light vegetation at the shoulders and side drains	

3.9.3 Present Serviceability Rating

Table 3-10 shows the PSR of the pavement. The value of 4.64 corresponds to a "Very Good" pavement. This value is slightly above what was obtained during the baseline survey, which was 4.6.

Table 3-10: Present Serviceability Rating (D379)

Road:	Wamwangi - Karatu Road (D379)												
Section:	Km 0+000 - Km 0+ 350 main carriage way												
Pavement Structure:	**Date of Survey:**									1/7/2017			
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	4.5	5.0	5.0	4.5	32.5	4.64	81.3	**V.Good**	**4.64**
Average PSR		**5**	**4.5**	**4**	**4**	**5**	**5**	**4.5**	**32.5**	**4.64**	**81.3**	**V.Good**	**4.64**

3.10 Rainfall Data

Precipitation over the first monitoring round survey period is shown in Table 3-11. The data were collected from a rain gauge that was installed at Wamwangi Secondary School. The months of April and May experienced heavy rainfall which is consistent with the trends within the region.

Table 3-11: Precipitation at D379

Precipitation (mm) at Wamwangi - Karatu D379										
2017										
JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER
55	40	93	260	200	52	20	29	11.5	75	147

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.

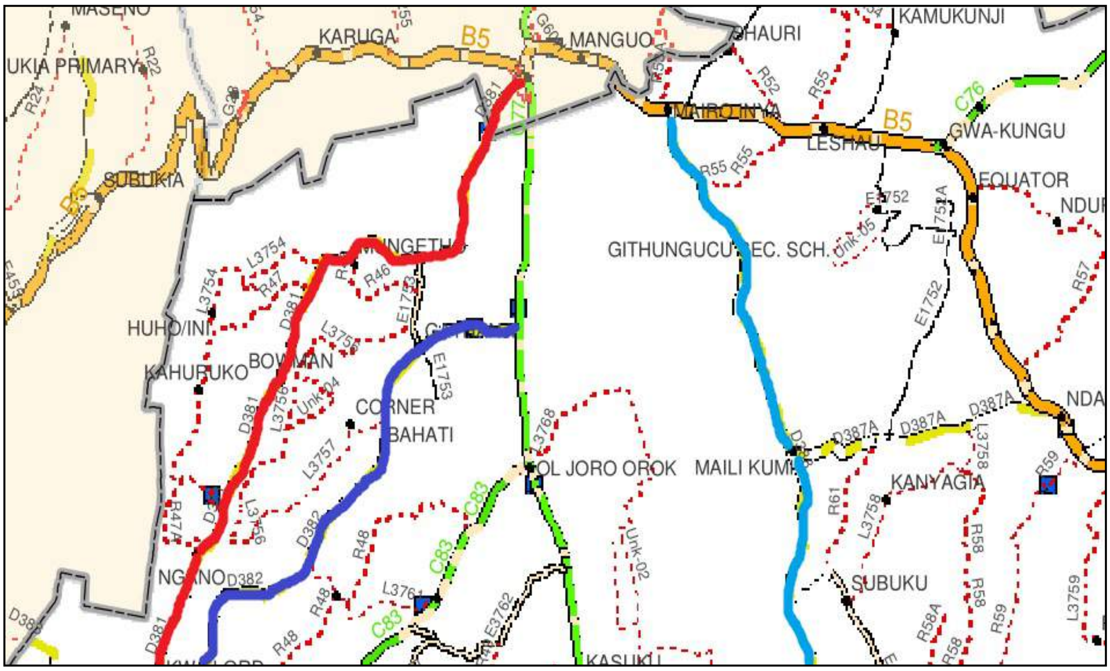


Figure 4-1:Location of Lord - Kona Bahati Road (D381), marked in red

4.2 Pavement Description

Figure 4-2 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 4-2: Designed pavement structure (D381)

4.3 Traffic Survey

4.3.1 Classified Traffic Counts

Table 4-1 shows the summary of the traffic count for the road.

Table 4-1: Traffic volume summary (D381)

Vehicle Type	Daily Volume (vpd)	Baseline Survey Results
Motorcycles	484	4703
Cars	157	617
Minibus	138	195
Bus	1	29
Light goods vehicles	68	134
Medium goods vehicles	4	103
Heavy goods vehicles[1]	0	9
ADT	**853**	**5791**

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

There was a clear decrease in the volume of vehicles between the two periods of data collection. The volume of vehicles during the baseline survey was 5791. The decrease can be attributed to the difference in agricultural season in the area. Whereas the baseline survey was conducted during the harvesting season and thus agricultural products were being transported to the markets and other areas, the season was different during the first monitoring round.

4.3.2 Axle Load Survey

Table 4-2shows the summary of ESA by vehicle type, and computed ESA/day

Table 4-2: Traffic ESA (D381)

Vehicle Type	ESA/day	Baseline ESA/day
Bus	6	1.34
Medium Goods Vehicles	4.06	27.25
Heavy Goods Vehicles	15.92	2.01
Articulated Heavy Goods Vehicles	0.00	XXX
Total ESA/day	**25.98**	**30.90**

Note 1: XXX shows that the vehicle type was not present during the time of 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.

4.4 Rutting

Table 4-3 shows the maximum rut depth left and right of each chainage point for the first monitoring round. The average value of rut on the outer wheel path is 14mm, which nears the critical limit of 20 mm. The critical value of 20mm applies to High Volume Roads. There is currently no critical value stated in the Kenya standards for LVSRs. The average rut for the inner wheel path is 4.5mm. As can be observed, the average rut increased on both sides of the road from 9 on the outer LHS and 8 on the outer RHS. Ponding of water in some sections of the road was observed. Statement on Trigger levels for rutting on LVSR

Table 4-3: Maximum rut depth (D381)

Chainage	LHS Rut in mm Outer Wheel Path	LHS Rut in mm Inner Wheel Path	RHS Rut in mm Inner Wheel Path	RHS Rut in mm Outer Wheel Path
0+000	10	5	4	13
0+050	19	3	14	18

0+100	6	7	7	12
0+150	13	10	3	22
0+200	9	4	2	12
0+250	8	0	9	11
0+300	8	2	10	10
0+350	10	1	3	2
0+400	16	3	0	4
0+425	42	4	3	30
0+440	15	5	2	11
0+445	7	3	2	6
0+470	18	0	2	20
0+485	16	2	2	18
0+500	8	2	1	17
0+515	19	1	0	14
0+530	12	6	7	14
0+545	12	8	12	19
0+560	3	8	8	14
0+575	10	6	9	9
0+600	1	3	6	13
0+650	16	9	3	25
0+700	12	4	2	20
0+750	7	2	8	15
0+800	9	13	8	13
0+850	17	2	5	20
0+900	5	0	9	16
0+950	14	4	9	14
Average	**12**	**4**	**5**	**15**

4.5 Deflection/Stiffness

Table 4-4shows 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+050	1	483	100	141	1163
0+100	1	1502	218	104	1280
0+150	1	798	124	184	1054
0+201	1	592	124	168	1215
0+251	1	1713	247	118	968
0+301	1	536	97	141	1074
0+352	1	1435	211	155	1133
0+400	1	1398	210	226	1020
0+410	1	588	122	153	1334

0+428	1	1661	240	141	908
0+443	1	1691	242	117	968
0+458	1	1624	242	129	1087
0+473	1	2133	290	121	877
0+488	1	1732	252	137	910
0+502	1	408	96	113	1388
0+518	1	1439	213	164	1116
0+533	1	1373	202	85	1567
0+548	1	783	134	190	898
0+563	1	1490	226	166	1072
0+577	1	787	141	177	1076
0+579	1	1572	230	92	1288
0+603	1	793	142	196	1106
0+653	1	331	33	142	1061
0+704	1	1573	224	131	1077
0+754	1	1312	197	108	1689
0+804	1	469	102	130	1144
0+854	1	1461	218	92	1450
0+904	1	329	79	95	1409
0+954	1	537	101	146	1063
0+403	2	1471	216	158	1127
0+505	2	1524	229	139	1166
0+580	2	2041	278	102	1213
0+606	2	1544	223	97	1228
0+907	2	1872	254	95	1584
0+051	3	811	137	208	976
0+101	3	1801	265	129	854
0+151	3	2021	274	148	996
0+202	3	492	111	147	1270
0+252	3	242	15	607	1242
0+302	3	964	153	221	1152
0+353	3	784	117	203	987
0+401	3	1383	209	195	1128
0+410	3	2094	286	173	806
0+410	3	1467	222	160	1089
0+429	3	530	112	137	1225
0+444	3	1750	254	94	1104
0+459	3	1600	236	103	1221
0+474	3	1512	221	149	1033
0+489	3	1574	234	122	1099
0+503	3	521	100	135	1261
0+520	3	683	132	180	1016
0+535	3	384	96	116	1388
0+550	3	459	108	131	1261
0+565	3	414	98	115	1385

0+578	3	1497	223	113	1302
0+579	3	1440	212	157	1141
0+604	3	1500	227	125	1248
0+654	3	421	98	127	981
0+705	3	1364	201	88	1729
0+756	3	346	88	108	1375
0+807	3	1544	230	122	1174
0+855	3	1603	234	92	1198
0+905	3	427	85	120	1847
0+956	3	399	91	115	1151
0+402	4	1426	212	135	1261
0+504	4	1495	224	138	1166
0+579	4	1964	266	97	1252
0+579	4	477	109	128	1322
0+605	4	1641	241	105	1201
0+655	4	342	83	98	1394
0+706	4	1324	197	98	1713
0+856	4	1541	233	84	1426
0+906	4	1425	211	88	1488

The complete deflection outputs from the FWD for all the sensors (D_0 up toD_6) for all the test locations are presented in the Appendix section of the report as Annex 1-5.Figure 4-3 shows the central deflection by chainage along the road. The deflection values are highly variable. The deflection values are almost within the same range as those obtained in the baseline survey.

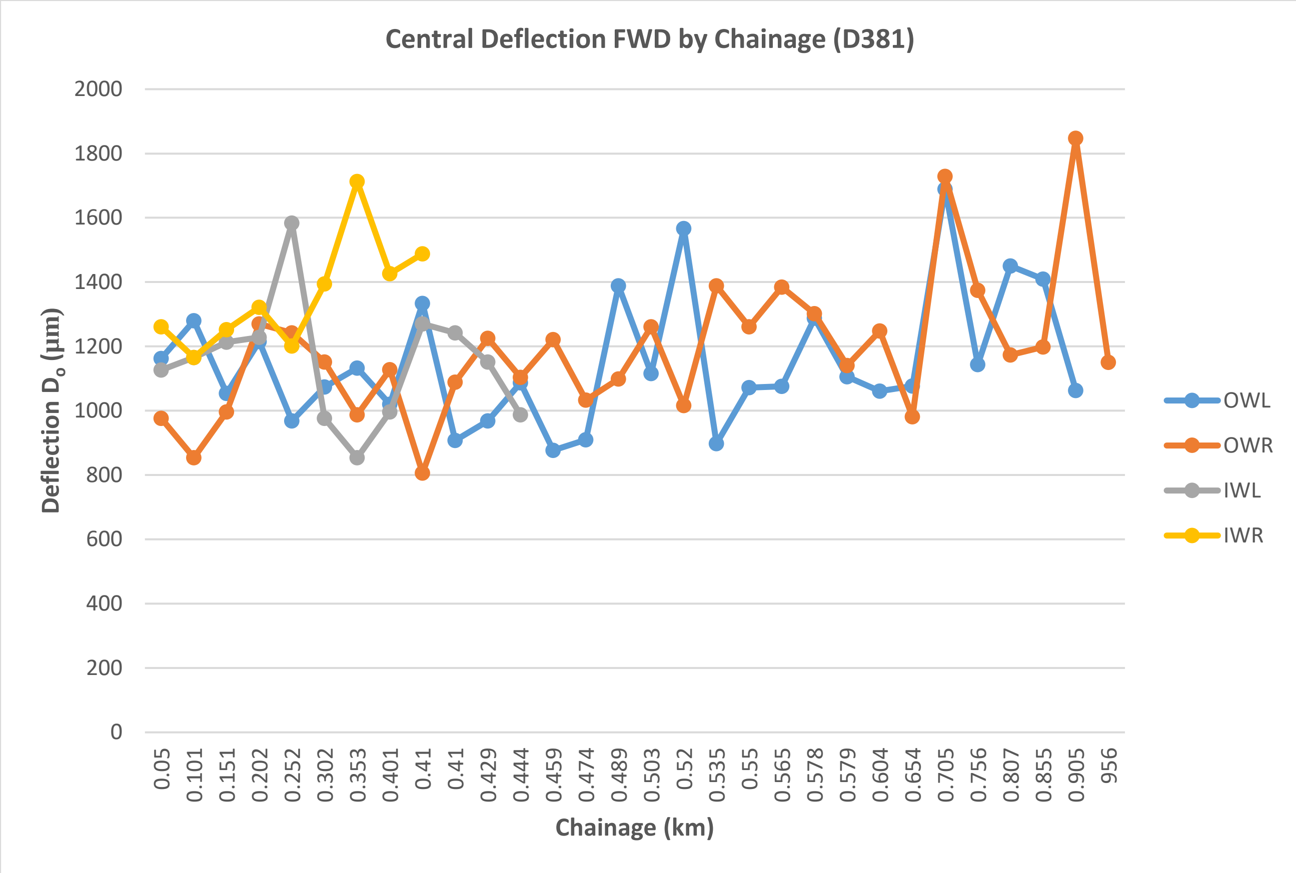


Figure 4-3: Central deflection by chainage (D381)

4.6 DCP Measurements

Table 4-5below shows the DN values by layer for each test point and DSN values for 800mm depth. The base layer has values which are generally above the specification requirement. The values in red denoted those ones which are above the specification requirement. The rest of the layers have DN values which are within the specification requirement. There are no major changes in the DCP values from those obtained in the baseline survey in matters above or below the specification requirements.

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

Chainage (m)	Specifications	≤4.0	≤9.0	≤19	≤25	≤39	DSN800
	Position	0-150	150-300	300-450	450-600	600-800	≥73
0+000	IWL	5.9	5.9	5.9	10.2	10.6	110
0+050	OWR	5.8	5.8	9.5	9.5	9.5	105
0+100	OWR	4.2	4.2	3.3	8.5	8.4	159
0+150	OWR	5.0	5.0	10.5	14.3	14.3	99
0+200	IWL	3.7	4.2	6.7	9.0	10.5	135
0+250	OWR	3.2	4.9	7.0	10.6	10.5	133
0+300	IWL	3.9	5.5	6.7	4.3	7.6	150
0+350	OWR	5.5	8.0	10.4	10.4	10.4	95
0+400	IWL	7.3	9.8	7.0	6.0	9.1	105
0+410		5.6	8.5	8.2	5.6	3.3	151

0+410	IWL	5.2	9.6	9.6	9.6	5.9	110
0+410	IWR	4.8	8.0	8.9	8.9	8.9	107
0+410	OWL	4.7	14.1	14.2	14.2	13.8	79
0+411	IWR	6.2	11.5	11.5	11.5	9.9	84
0+579	IWR	2.6	6.9	10.2	9.3	8.7	134
0+579	IWR	3.4	7.7	11.3	11.3	11.1	109
0+579	IWL	5.3	5.3	6.2	8.6	9.6	120
0+579	OWR	3.5	9.0	10.2	10.2	10.2	109
0+579	OWL	3.4	6.2	6.7	7.2	9.5	133
0+600	IWR	3.9	7.4	9.4	7.2	7.8	122
0+650	LHS	3.9	8.6	6.3	4.5	9.1	136
0+700	IWR	5.7	5.8	7.9	7.9	10.8	109
0+750	OWL	2.8	3.3	3.3	3.4	4.1	238
0+800	RHS	6.9	9.3	6.4	4.7	3.4	153
0+850	OWL	5.7	7.4	7.4	7.4	15.0	101
0+900	OWL	8.2	11.8	11.8	18.9	23.1	61
0+950	OWL	5.0	6.9	10.4	15.7	16.2	89

4.7 Roughness Measurements

This does not form part of the schedule of activities for the first monitoring round.

4.8 Test Pits

4.8.1 DN Values

Table 4-6shows the DN of each layer in the structure measured before excavation of the test pit. The values are generally within the specification limits, except for the base and sub-base.

Table 4-6: DN values at test pit (D381)

Depth (mm)	DN values (mm/blow)		
	Specifications	**Pit A @ 0+410**	**Pit B @ 0+579**
0 – 150	≤4.0	4.7	3.4
150 – 300	≤9.0	14.1	6.2
300 – 450	≤19.0	14.2	6.7
450 – 600	≤25.0	14.2	7.2
600 – 800	≤39.0	13.8	9.5
DSN800	≥73.0	79	133

The rest of the DCP details are presented in the Appendix section of the report as Annex 1-2.

4.8.2 Layer Thicknesses

Figure 4-4 is a representation of the measured layer thicknesses and materials descriptions for the two test pits.

Test Pit A, km 0+410		Test Pit B, km 0+579
20 mm Cold Mix Asphalt		20 mm Cold Mix Asphalt
150 mm Neat quarry waste base		150 mm Neat quarry waste base
150 mm Granular natural gravel sub-base		270 mm Granular natural gravel subbase
Subgrade		Subgrade

Figure 4-4: Layer thicknesses at test pits (D381)

4.8.3 Moisture Content

Table 4-7 shows the in-situ moisture content for each layer for the two test pits, including the subgrade. As the figures indicate, the relative moisture contents of the various sections of the road have not changed much over time. The specific RMC values between baseline and first monitoring round are close to one another. Samples were not taken from the layers that have been indicated in the colour coded cells.

Table 4-7: Moisture content at test pits (D381)

Panel	Wheel path	Layer	In-situ Moisture Content (%) LHS	Optimum Moisture Content (%)	Relative Moisture Content (FMC/OMC)	Baseline RMC (FMC/OMC)
Panel A	OWP	Base	18.0	16.2	1.11	1.44
		Sub-base	20.5	21.0	0.98	0.74
		Subgrade	20.8	25.3	0.82	0.87
	IWP	Base	17.6	17.6	1.00	1.00
		Sub-base				0.98
		Subgrade				0.92
Panel B	OWP	Base	15.3	16.1	0.95	1.07
		Sub-base	xxx	xxx	xxx	0.90
		Subgrade	21.4	21.6	0.99	1.01
	IWP	Base	16.0	19.6	0.82	0.80
		Sub-base				1.10
		Subgrade				1.02

Note 1: XXX denotes missing layer.

The sub-base and subgrade layers of this road recorded higher moisture content probably due to underground seepage from higher ground.

4.8.4 *Particle Size Distribution*

The plots in Figure 4-5 below illustrate the particle size distribution for the surfacing layer. The material generally lies within the envelope. An exception is material obtained from panel B on the right-hand side which has most of the particles outside but close to the specification envelope. The specification is obtained from LVSR Pavement Design Guidelines.

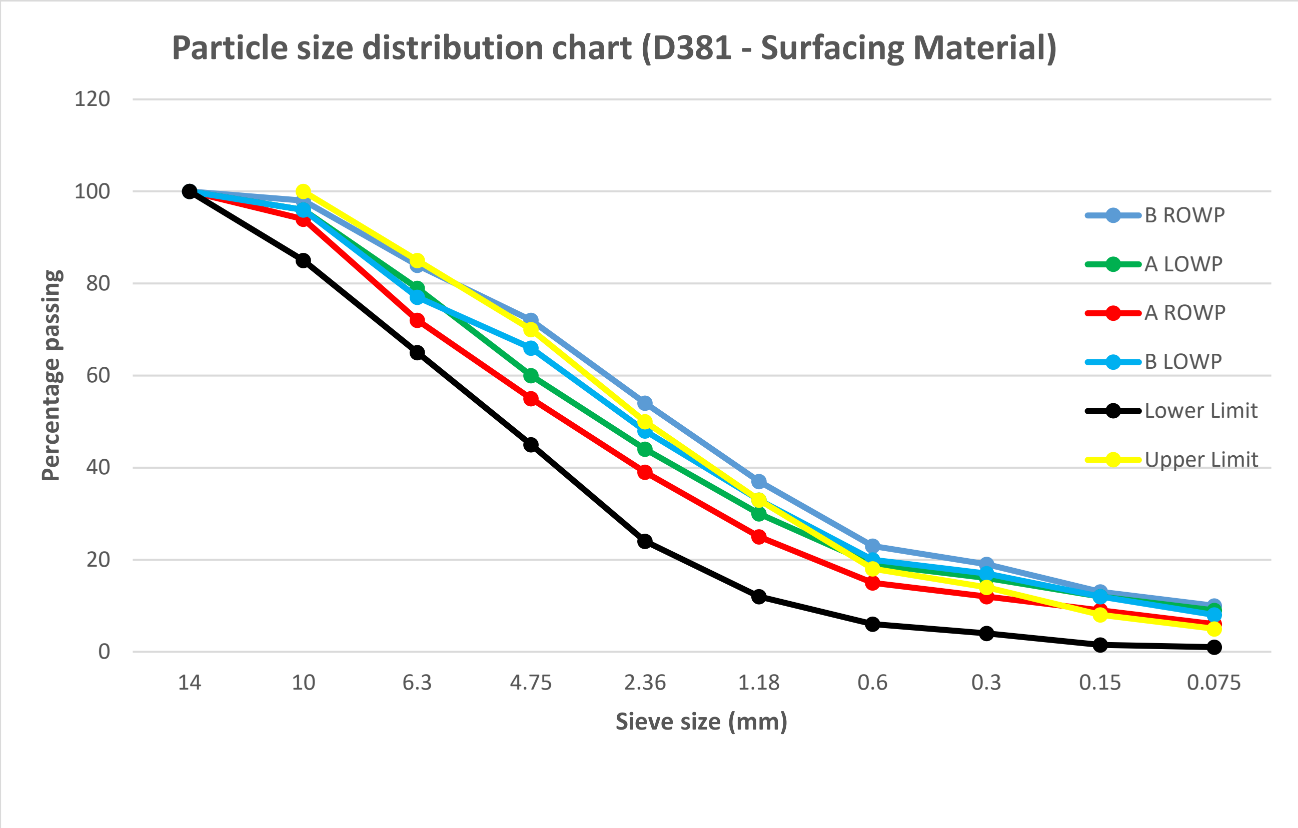


Figure 4-5: Particle size distribution for base material (D381)

4.8.5 *Mass of Aggregate and Bitumen per Unit Area*

Table 4-8 below shows the mass of aggregates and bitumen per unit area. Bitumen content by mass of the total mix is also represented in percentage. According to available records, this section was overlaid with a sand seal on top of the CMA, which contributed to the high bitumen content.

Table 4-8: Mass of aggregate and bitumen per unit area (D381)

Core Location	Panel A		Panel B		Unit
	L OWP	R OWP	L OWP	R OWP	
Residual Binder Content	7.8	7.7	7.3	6.3	%
Mass of Aggregate per Unit Area	28.1	23.8	27.3	22.1	Kg/m^2
Mass of Bitumen per Unit Area	2.4	2.0	2.1	1.5	Kg/m^2

4.8.6 *Atterberg Limits*

This does not form part of the schedule of activities for the first monitoring round.

4.8.7 Laboratory CBR

This does not form part of the schedule of activities for the first monitoring round.

4.9 Visual Condition Assessment

4.9.1 Pavement Defects Assessment

Table 4-9 shows the main pavement defects – alligator cracking in this case.

Table 4-9: Visual condition assessment on D381

Fig No	Location (Km)	Defect assessment and description	Photos illustrating the pavement distress & defect
Fig 1	Km 0+000 – 0+200 main carriage way	-Alligator cracks	
Fig 2	Km 0+080 main carriage way centreline	-Fatigue cracks and Pothole	

Fig 3	Km 0+050	-Partially blocked culvert	
Fig 4	Km 0+080	-Pothole developing due to thin surfacing	
Fig 5	Km 0+530 RHS	-Alligator cracks	

Fig6	Km 0+530 – 0+560 RHS	-Patch along the RHS edge	
Fig 7	Km 0+560 RHS	- Fatigue cracks	
Fig 8	Km 0+600 – 0+700	-Light vegetation and soil deposits in the RHS side drain	

Fig 9	Km 0+700 – 0+800	- Light vegetation on the LHS shoulder	
Fig10	Km 0+600-0+650 RHS	-Edge subsidence -Ponding of water in the rut.	
Fig 11	Km 0+650 – 0+800	-Fatigue cracks and deformation	

Fig 11	Km 0+800 – 0+850	-Pothole and Fatigue cracks	
Fig 12	Km 0+850 – 0+900 LHS outer wheel path	A long patch	
Fig 13	Km 0+900 – 0+950 RHS	Fatigue cracks deformation and eroded side drain	

4.9.2 Present Serviceability Rating

Table 4-10 shows the computation of the PSR. The value of 3.4 corresponds to a “Good” pavement. There was a decrease from the value obtained during the baseline survey, which was 3.5

Table 4-10: Present Serviceability Rating D381

Road:	TOTAL - KONAMBAYA (D381)												
Section:	Km 0+000 - Km 1+000 main carriage way												
Pavement Structure: **Survey:**						**Date of**			03/7/2017				
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	3.5	3.0	4.5	1.0	25.5	3.6	63.75	**Good**	**3.6**
2. Km 0+500 - 1+000	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**	**3.25**	**2.5**	**4.3**	**1.0**	**24.3**	**3.4**	**60.02**	**Good**	**3.4**

4.10 Rainfall Data

The rainfall data collected during the first monitoring round survey is shown in Table 4-11. No rains were witnessed in January and February. Long rains were experienced during the months of July through to September. Further collection of the rainfall data will give a clearer long-term comparison. This will be done after the third monitoring round.

Table 4-11: Precipitation on D381

Precipitation (mm) on Lord – Kona Bahati Road (D381)										
2017										
JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER
0	0	20.4	58.9	51.6	79.9	453	148.6	293.8	63	72.5

5 Muthuaini-Mununqaini Road D435

5.1 Site Description

D435 is 9 km from Nyeri town. It starts at Ihururu town center and goes downhill 600 m in length. Below is a map of the site location. Figure 5-1 shows the location map of the road. The road section is in Nyeri County.

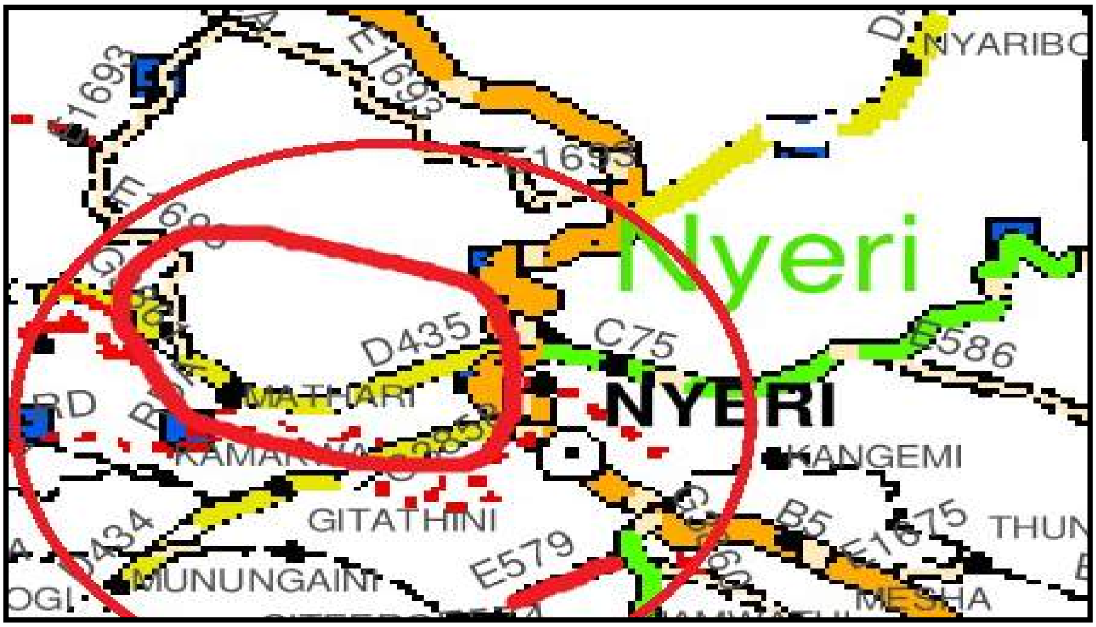


Figure 5-1: Location of Muthuaini - Mununqaini Road (D435), circled in red

5.2 Pavement Description

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

20 mm Cold Mix Asphalt	
150 mm Neat weathered basalt	
250 mm Natural gravel sub-base	
Subgrade	

Figure 5-2: Designed pavement structure (D435)

5.3 Traffic Survey

5.3.1 Classified Traffic Counts

Table 5-1 shows a summary of the traffic count. The motorcycle volumes are highest in this road as compared to the other three roads under study.

Table 5-1: Traffic volume summary (D435)

Vehicle Type	Daily Volume (vpd)	Baseline Survey Results
Motorcycles	589	495
Cars	195	191
Minibus	45	33

Bus[1]	0	0
Light Goods Vehicle	46	38
Medium Goods Vehicle	10	17
Heavy Goods Vehicle	1	3
ADT	**885**	**777**

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

The change in traffic volume per day between the baseline survey period and the first monitoring round is not that much comparatively with the first two roads. However, it is worth noting that the volume of vehicles increased slightly from 777 to 885. Motorcycles brought out the largest difference owing to the political activities during the time of survey for the first monitoring round.

5.3.2 Axle Load Survey

Table 5-2shows the summary of ESA by vehicle type, and computed ESA/day

Table 5-2: Traffic ESA (D435)

Vehicle Type	ESA/day	Baseline ESA/day
Bus[1]	0.08	0.00
Medium Goods Vehicles	12.4	18.85
Heavy Goods Vehicles	2.66	XXX
Articulated Heavy Goods Vehicles[2]	0.00	XXX
Total ESA/day	**15.14**	**18.85**

Note 1: Two buses used the route during the Survey
Note 2: AHGV did not use the route during the axle load survey.
Note 3: XXX shows that the vehicle type was not present during the time of 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.

The ESA/day decreased from the period of the baseline survey, which was 18.85. This was due to the decrease in medium goods vehicle during this period as opposed to during the baseline period when they were transporting logs and tea from farmers.

5.4 Rutting

Table 5-3 shows the maximum rut depth left and right of each chainage point. The average value of rut for the outer wheel path and outer wheel path is 11 mm, which is considered slight rutting, which poses no major deterrence to traffic flow. Compared to rut measured during the baseline survey, it is evident that the average rut reduced on both sides of the outer wheel paths of the road from an average of 16mm on the outer LHS and 15mm on the outer RHS. No ponding of water was observed.

Table 5-3: Maximum rut depth (D435)

Chainage	LHS Rut in mm Outer Wheel Path	LHS Rut in mm Inner Wheel Path	RHS Rut in mm Inner Wheel Path	RHS Rut in mm Outer Wheel Path
0+000	10	10	15	20
0+050	15	23	8	10
0+100	0	10	9	8
0+150	0	3	10	10

0+200	30	0	10	25
0+225	10	20	10	0
0+240	10	15	10	0
0+255	5	0	5	15
0+270	3	17	8	22
0+285	20	4	10	15
0+300	10	20	9	9
0+315	10	20	8	8
0+330	10	10	15	4
0+345	10	12	10	12
0+360	10	15	15	10
0+375	10	15	10	20
0+400	18	5	25	15
0+450	8	20	10	20
0+500	5	10	0	10
0+550	5	10	10	10
Average	**10**	**12**	**10**	**12**

5.5 Deflection/Stiffness

Table 5-4 shows the D_0 and the base, sub-base and subgrade stiffness measured at each point.

Table 5-4: Deflection and stiffness (D435)

Chainage (m)	**Lane No.**	**Stiffness**			**Normalized Deflections at Geophone Locations (µm)**
		EBase (MPa)	**ESubbase (MPa)**	**ESubgrade (MPa)**	**D_0**
0+000	1	518	148	214	493
0+007	1	700	504	175	491
0+049	1	702	276	164	716
0+100	1	719	94	137	692
0+150	1	300	200	115	645
0+200	1	300	200	199	501
0+225	1	593	1477	138	416
0+251	1	450	251	123	738
0+272	1	617	295	156	539
0+302	1	504	334	149	571
0+332	1	961	263	183	499
0+376	1	300	200	122	585
0+377	1	421	267	113	844
0+452	1	300	200	127	610
0+504	1	903	802	292	403
0+001	2	300	200	199	500
0+050	2	842	264	171	712

0+101	2	476	439	123	526
0+150	2	300	200	115	641
0+201	2	300	200	138	526
0+226	2	532	1267	142	373
0+257	2	300	200	127	620
0+273	2	678	278	157	504
0+303	2	622	290	152	553
0+333	2	300	200	152	540
0+374	2	300	200	112	612
0+378	2	565	1144	153	368
0+453	2	452	260	125	627
0+505	2	300	200	414	435
0+002	3	430	91	246	548
0+049	3	562	87	164	748
0+051	3	231	171	128	725
0+151	3	300	200	123	605
0+200	3	300	200	143	602
0+227	3	831	2058	162	293
0+258	3	653	278	159	573
0+286	3	724	267	167	776
0+317	3	408	989	143	429
0+347	3	300	200	160	545
0+363	3	300	200	130	554
0+403	3	516	394	161	471
0+503	3	300	200	187	555
0+554	3	748	235	153	691
0+004	4	1136	410	212	310
0+152	4	300	200	118	671
0+242	4	548	640	163	398
0+287	4	442	337	135	645
0+318	4	300	200	129	575
0+348	4	1050	255	197	506
0+352	4	300	200	141	583
0+404	4	300	200	180	456
0+555	4	513	231	128	789

All the deflection outputs from the FWD for all the sensors (D_0 up toD_6) for all the test locations are presented in the Appendix section of the report as Annex 1-5.Figure 5-3 shows a plot of the central deflection by chainage along the road.

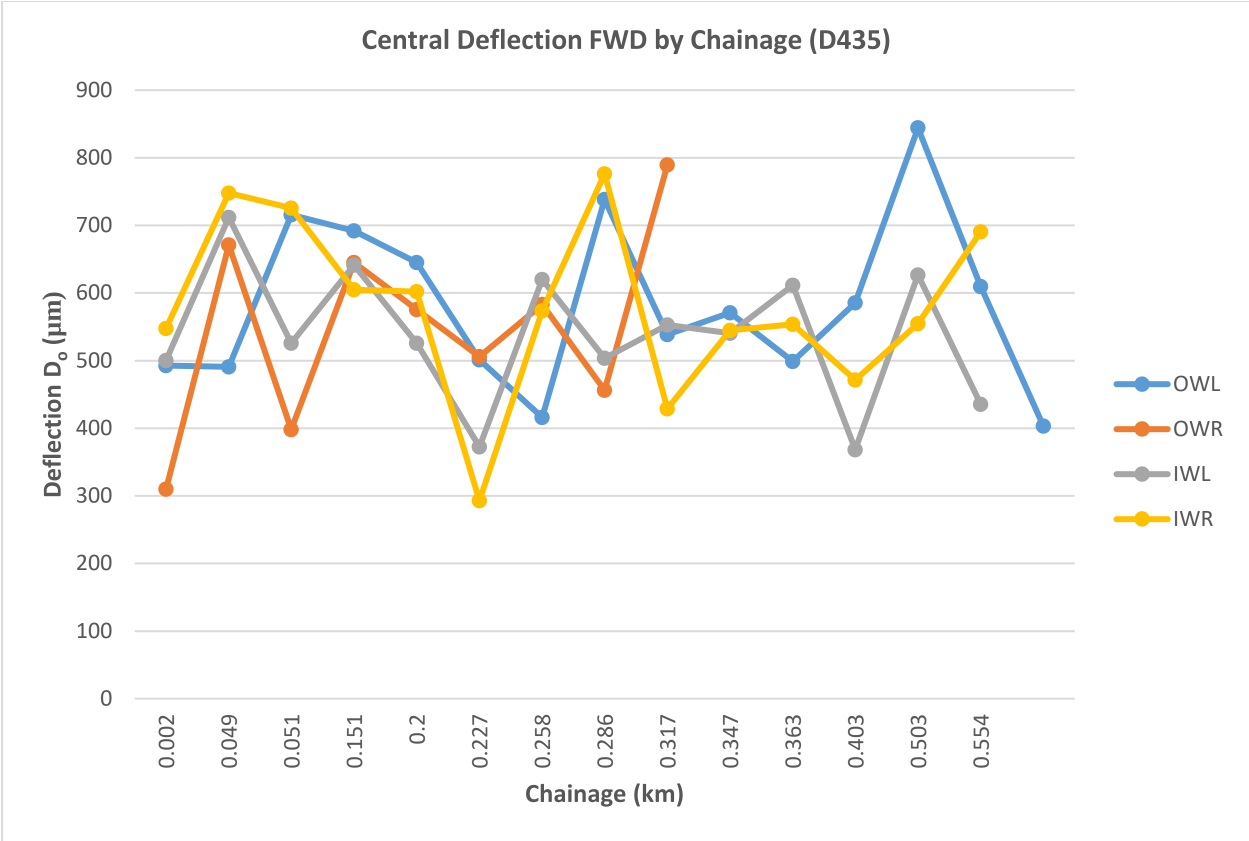


Figure 5-3: Central deflection by chainage (D435)

5.6 DCP Measurements

Table 5-5 shows the DN values by layer for each test point and DSN values for 800mm depth. The values are within the specification requirement. As compared to DCP values obtained in the baseline survey, these points mostly exhibit values which are within the specification requirements as opposed to the ones in baseline survey, which had more points above the specification requirements.

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

Chainage (m)	Specifications	≤4.0	≤9.0	≤19	≤25	≤39	DSN800
	Position	0-150	150-300	300-450	450-600	600-800	≥73
0+000	LHS	6.6	4.4	10.6	16.3	23.1	89
0+050	RHS	3.5	3.7	13.2	13.2	13.2	122
0+100	LHS	2.6	2.6	9.3	15.5	21.6	151
0+150	RHS	3.1	4.9	6.8	8.0	8.0	145
0+200	CL	1.4	2.0	2.7	2.7	6.0	328
0+200	IWR	1.1	2.2	2.2	3.3	9.4	336
0+200	LHS	1.6	3.3	4.8	7.5	7.5	217
0+200	OWR	1.5	2.8	1.9	1.2	1.2	524
0+220	RHS	1.5	4.4	4.7	3.6	2.1	303
0+380	OWR	0.8	1.6	3.4	5.7	8.7	375
0+380	IWL	0.9	1.6	4.0	7.0	7.0	346
0+380	OWL	0.9	3.7	6.0	8.0	8.0	276

0+500	RHS	2.5	4.4	7.7	9.2	9.2	152

5.7 Roughness Measurements

This does not form part of the schedule of activities for the first monitoring round.

5.8 Test Pits

5.8.1 DN Values

Table 5-6 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 5-6: DN values at test pit (D435)

Depth (mm)	**Specifications**	**DN values (mm/blow)**	
		Pit @ 0+200	**Pit @ 0+380**
0 – 150	≤4.0	1.5	0.9
150 – 300	≤9.0	2.8	3.7
300 – 450	≤19.0	1.9	6.0
450 – 600	≤25.0	1.2	8.0
600 – 800	≤39.0	1.2	8.0
DSN800	≥73.0	524	276

All DCP test details are presented in the Appendix section of the report as Annex 1-2.

5.8.2 Layer Thicknesses

Figure 5-4 shows the pavement materials and the measured layer thicknesses as measured at the test pits.

Test Pit A, km 0+200		**Test Pit B, km 0+380**
25 mm Cold Mix Asphalt		25mm Cold Mix Asphalt
200 mm Neat weathered basalt base		150 mm Neat weathered basalt base
150 mm Natural gravel sub-base		150 mm Natural gravel sub-base
Subgrade		Subgrade

Figure 5-4: Layer thicknesses at test pit (D435)

5.8.3 Moisture Content

Table 5-7 shows the in-situ moisture content for base and sub-base, and subgrade of the pavement layers. For the IWP, only the base sample was taken for testing. However, the other missing values were due to their absence as we observed during the sampling process. Whereas some of the RMC values have gone up, others have come down from the time of the baseline survey. Samples were not taken from the layers that have been indicated in the colour coded cells.

Table 5-7: Moisture content at test pit (D435)

Panel	Wheel path	Layer	In-situ Moisture Content (%) LHS	Optimum Moisture Content (%)	Relative Moisture Content (FMC/OMC)	Baseline RMC (FMC/OMC)
Panel A	OWP	Base	8.1	8.3	0.98	0.96
		Sub-base	14.3	12.1	1.18	0.75
		Subgrade	15.8	26.0	0.61	0.50
	IWP	Base	8.0	8.1	0.99	0.98
		Sub-base				1.41
		Subgrade				0.79
Panel B	OWP	Base	4.8	9.4	0.51	0.85
		Sub-base	xxx	xxx	xxx	1.37
		Subgrade	18.0	25.1	0.72	0.86
	IWP	Base	5.1	8.6	0.59	0.90
		Sub-base				1.21
		Subgrade				0.76

Note 1: XXX denotes missing layer.

5.8.4 Particle Size Distribution

The plots in Figure 5-5show the particle size distribution for the surface layer. The surfacing materials lie within the specification envelope. The specification is obtained from LVSR Pavement Design Guidelines.

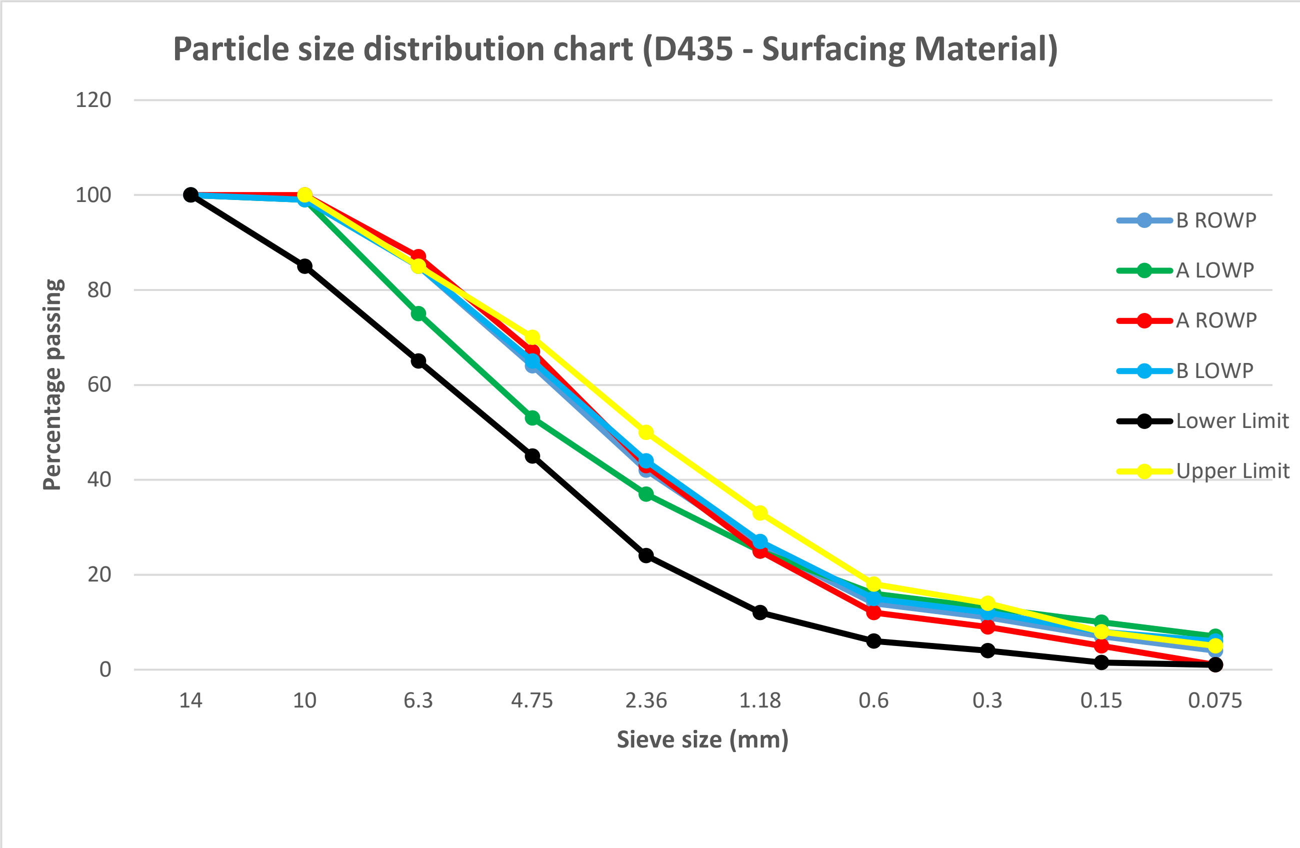


Figure 5-5: Particle size distribution for base material (D435)

5.8.5 *Mass of Aggregate and Bitumen per Unit Area*

Table 5-8 shows the mass of aggregates and bitumen per unit area. Bitumen content by mass of the total mix is also represented in percentage.

Table 5-8: Mass of aggregate and bitumen per unit area (D435)

Core Location	Panel A		Panel B		Unit
	L OWP	R OWP	L OWP	R OWP	
Residual Binder Content	4.9	5.0	5.0	5.2	%
Mass of Aggregate per Unit Area	28.3	23.6	30.8	29.9	Kg/m^2
Mass of Bitumen per Unit Area	2.0	1.8	2.0	2.1	Kg/m^2

As can be seen, the residual binder content is low for this road. This may have been caused due to heavy rainfall experienced in the area during the construction of the pavement. The rain must have washed away the bitumen emulsion before it the elapse of curing. Potholes may become an issue as the surface gets exposed overtime. This could lead to poor performance. However, future monitoring is required to be certain about it.

5.8.6 *Atterberg Limits*

This does not form part of the schedule of activities for the first monitoring round.

5.8.7 *Laboratory CBR*

This does not form part of the schedule of activities for the first monitoring round.

5.9 Visual Condition Assessment

5.9.1 Pavement Defects Assessment

The main surface defects on this road section are raveling and a few potholes as shown in Table 5-9.

Table 5-9: Visual condition assessment of D435

Fig No	Location (Km)	Defect assessment and description	Photos illustrating the pavement distress & defect
Fig 1	Km 0+000 – 0+050	-Rough texture because of rainfall during the pavement's construction	
Fig 2	Km 0+015	-Pothole and ravelling	
Fig 3	Km 0+015	-Pothole and ravelling	

Fig 4	Km 0+100 – 0+150	-Ravelling at LHS	
Fig 5	Km 0+150LHS	-Rough Texture due to because of rainfall during the pavement's construction	
Fig 6	Km 0+225 RHS	-Potholes in section A of the LTPP	

Fig 7	Km 0+270 RHS	-Partially blocked access culvert	
Fig 8	Km 0+273 – 0+300 RHS	- Rough Texture because of rainfall during the construction of the road	
Fig 9	Km 0+315 – 0+350RHS	- Rough Texture due to Ravelling	

Fig 10	Km 0+403 RHS	-Pothole developing on the carriage way	
Fig 11	Km 0+445 – 0+520	-No visible defect	
Fig 12	Km 0+525	- Edge breaking at inner curve	

Fig 13	Km 0+550	-No visible defect on the carriage way -Slight vegetation on the road shoulder	

5.9.2 Present Serviceability Rating

The value of the PSR computed in Table 5-10 is 3.99, which is still regarded as "Good" even with a slight drop in PSR from baseline survey.

Table 5-10: Present Serviceability Rating D435

Road:	Muthuaini - Munugaini Road (D435)												
Section:	Km 0+000 - Km 0+550 main carriage way												
Pavement Structure:	**Date of Survey:**									28/6/2017			
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	4.2	1.5	4.0	5.0	4.5	27.9	3.99	69.75	**Good**	**3.99**
Average PSR		**4.2**	**4.5**	**4.2**	**1.5**	**4.0**	**5.0**	**4.5**	**27.9**	**3.99**	**69.75**	**Good**	**3.99**

5.10 Rainfall Data

The rainfall measured during the first monitoring round period is shown in Table 5-11. Long rains were experienced in May whereas short rains were experienced between the months of October and November.

Table 5-11: Precipitation at D435

Precipitation (mm) at Muthuaini – Munugaini Road (D435)										
2017										
JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER
43.0	46.4	57.8	55.4	361.5	10.6	66	65.7	51.6	115	130.5

6 Kangari-Kinyona Road E511

6.1 Site Description

Road E511 is in Murang'a County. It is starts some 4 km from Kangari town center, at some place called Mairi. It is 900 m in length.Figure 6-1 shows the location map of the road.

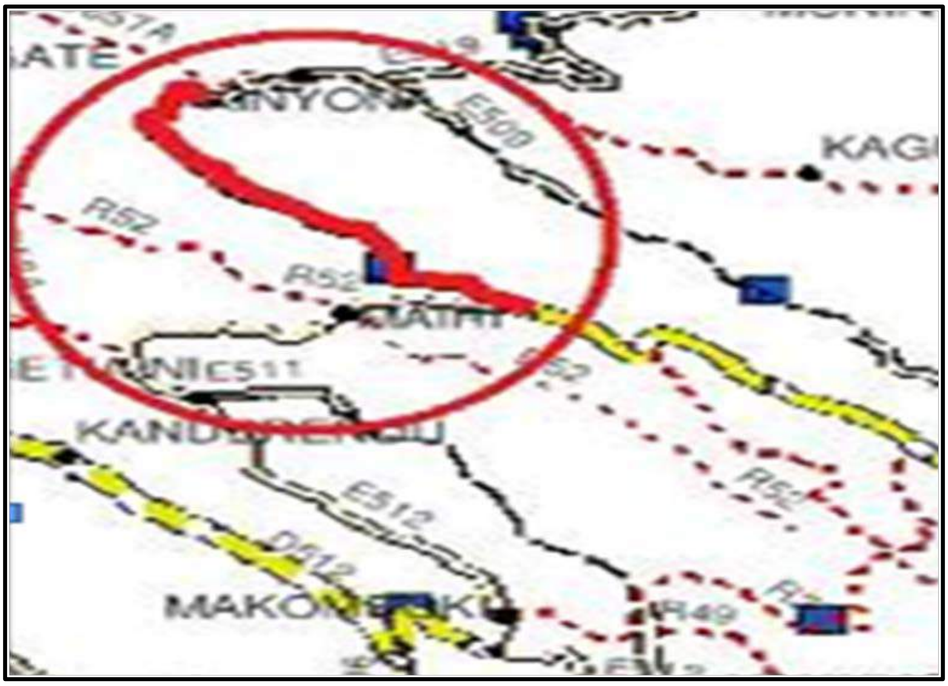


Figure 6-1: Location of Kangari – Kinyona Road (E511), marked in Red

6.2 Pavement Description

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

20 mm Cold Mix Asphalt	
150 mm Neat laterite base	
250 mm Granular sub-base	
Subgrade	

Figure 6-2: Designed pavement structure (E511)

6.3 Traffic Survey

6.3.1 Classified Traffic Counts

Table 6-1 shows the summary of the traffic count. Motorcycles are again the largest users of this road. More recently, the road has been subjected to construction traffic or the pipeline project where heavy tunnelling is taking place thereby impacting negatively on the performance of the road.

Table 6-1: Traffic volume summary (E511)

Vehicle Type	Daily Volume (vpd)	Baseline Survey Results
Motorcycles	315	334

Cars	57	93
Minibus	34	62
Bus	1	0
Light Goods Vehicle	73	69
Medium Goods Vehicle	12	16
Heavy Goods Vehicle	3	13
ADT	**495**	**587**

The numbers recorded for light, medium and heavy goods vehicles are the highest for all the four roads under study.

There was a decrease in the volume of vehicles per day between the two survey periods. The ADT for baseline survey was 587. Notable enough is the decrease in the number of heavy goods vehicles. Comparatively, light goods vehicles increased between the two survey periods.

6.3.2 Axle Load Survey

Table 6-2shows the summary of ESA by vehicle type, and computed ESA/day

Table 6-2: Traffic ESA (E511)

Vehicle Type	ESA/day	Baseline ESA/day
Bus	0.03	0.00
Medium Goods Vehicles	4.2	8.32
Heavy Goods Vehicles	7.38	3.76
Articulated Heavy Goods Vehicles[2]	3.5	XXX
Total ESA/day	**15.11**	**12.08**

Note 1: XXX shows that the vehicle type was not present during the time of the survey.

The ESA/day increased from the value of 12.08 during the baseline survey. This can be attributed to the presence of articulated heavy goods vehicle, which were absent during the baseline survey.

6.4 Rutting

Table 6-3shows the maximum rut depth left and right of each chainage point. The average rut for outer wheel path of 16mm is critical for LVSRs. The average rut for the inner wheel path of 3mm is good. There was a slight change in the average rut for the left-hand side. However, the average rut was the same from that of the baseline survey. No ponding was observed in the ruts.

Table 6-3: Maximum rut depth (E511)

Chainage	LHS Rut in mm Outer Wheel Path	LHS Rut in mm Inner Wheel Path	RHS Rut in mm Inner Wheel Path	RHS Rut in mm Outer Wheel Path
0+000	4	2	2	17
0+025	3	2	3	3
0+040	18	3	10	7
0+055	17	4	2	8
0+070	16	2	0	15
0+085	25	0	4	28
0+100	19	0	1	16

0+115	20	1	1	35
0+130	13	2	0	16
0+145	16	2	1	13
0+160	12	4	3	6
0+175	17	4	4	4
0+200	16	4	4	4
0+250	19	3	1	23
0+300	18	2	2	17
0+350	30	5	3	8
0+400	14	0	4	10
0+450	20	20	3	10
0+500	18	10	4	10
0+550	20	3	0	25
0+600	18	1	3	17
0+650	27	1	2	12
0+700	25	8	2	17
0+750	17	1	8	13
0+800	23	0	8	10
0+850	22	1	4	10
Average	**18**	**3**	**3**	**14**

6.5 Deflection/Stiffness

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

Table 6-4: Deflection and stiffness (E511)

Chainage (m)	Lane No.	Stiffness			Normalized Deflections at Geophone Locations (µm) D_0
		EBase (MPa)	ESubbase (MPa)	ESubgrade (MPa)	
0+008	1	88	123	23	2199
0+025	1	108	127	27	1834
0+034	1	91	129	25	1963
0+065	1	97	128	25	1981
0+094	1	132	141	22	2286
0+100	1	117	136	29	1604
0+109	1	119	135	28	1670
0+125	1	158	150	26	1567
0+139	1	174	152	34	1529
0+160	1	238	178	43	1211
0+170	1	176	148	34	1511
0+186	1	190	160	37	1438
0+196	1	113	122	27	1784
0+246	1	1672	281	49	1240
0+296	1	173	128	59	1084
0+347	1	1191	210	131	751

0+398	1	219	153	107	769
0+448	1	203	151	51	1043
0+499	1	133	131	30	1542
0+549	1	584	33	74	1108
0+599	1	98	120	25	1866
0+650	1	1875	300	35	1919
0+701	1	143	127	42	1308
0+751	1	173	134	54	1169
0+807	1	2000	300	34	1530
0+861	1	225	157	65	933
0+004	2	119	139	29	1772
0+008	2	1912	303	30	2016
0+055	2	300	200	52	1059
0+085	2	80	129	22	2168
0+145	2	206	169	41	1241
0+155	2	177	145	36	1337
0+186	2	112	127	25	2068
0+553	2	300	200	51	976
0+603	2	1879	332	26	2352
0+008	3	103	142	25	1913
0+026	3	77	128	22	2175
0+040	3	106	129	26	1895
0+70	3	67	116	21	2424
0+095	3	132	134	29	1696
0+101	3	154	153	23	1723
0+110	3	139	134	29	1663
0+130	3	141	151	27	1638
0+140	3	1640	296	45	1339
0+161	3	300	200	52	992
0+175	3	212	167	40	1313
0+186	3	225	171	41	1320
0+197	3	121	140	27	1756
0+248	3	1642	284	45	1264
0+298	3	303	45	95	1193
0+348	3	1287	221	153	687
0+402	3	1091	188	124	991
0+449	3	178	134	52	1092
0+500	3	1684	288	43	1248
0+550	3	609	62	81	883
0+600	3	1937	300	32	1752
0+651	3	1944	312	34	1738
0+703	3	1928	323	68	1367
0+752	3	237	171	58	1002
0+809	3	1640	282	32	1579
0+862	3	961	174	97	794

0+008	4	122	135	29	1921
0+049	4	168	159	36	1431
0+080	4	111	130	27	1770
0+115	4	150	144	33	1477
0+186	4	97	118	24	2192
0+201	4	155	150	30	1574
0+252	4	1617	288	34	1689
0+302	4	1131	206	108	940
0+352	4	1265	224	108	986
0+452	4	229	161	71	868
0+502	4	182	154	36	1475
0+552	4	255	173	69	804
0+602	4	150	154	28	1539
0+653	4	1937	312	45	1602
0+753	4	172	134	50	1188

The entire deflection outputs from the FWD for all the sensors (D_0 up toD_6) for all the test locations are presented in the Appendix section of the report as Annex 1-5.Figure 6-3 shows the central deflection for each wheel path along the road section. The values are highly variable. The deflection behaves in almost a similar manner as noted from the values which were obtained in the baseline survey.

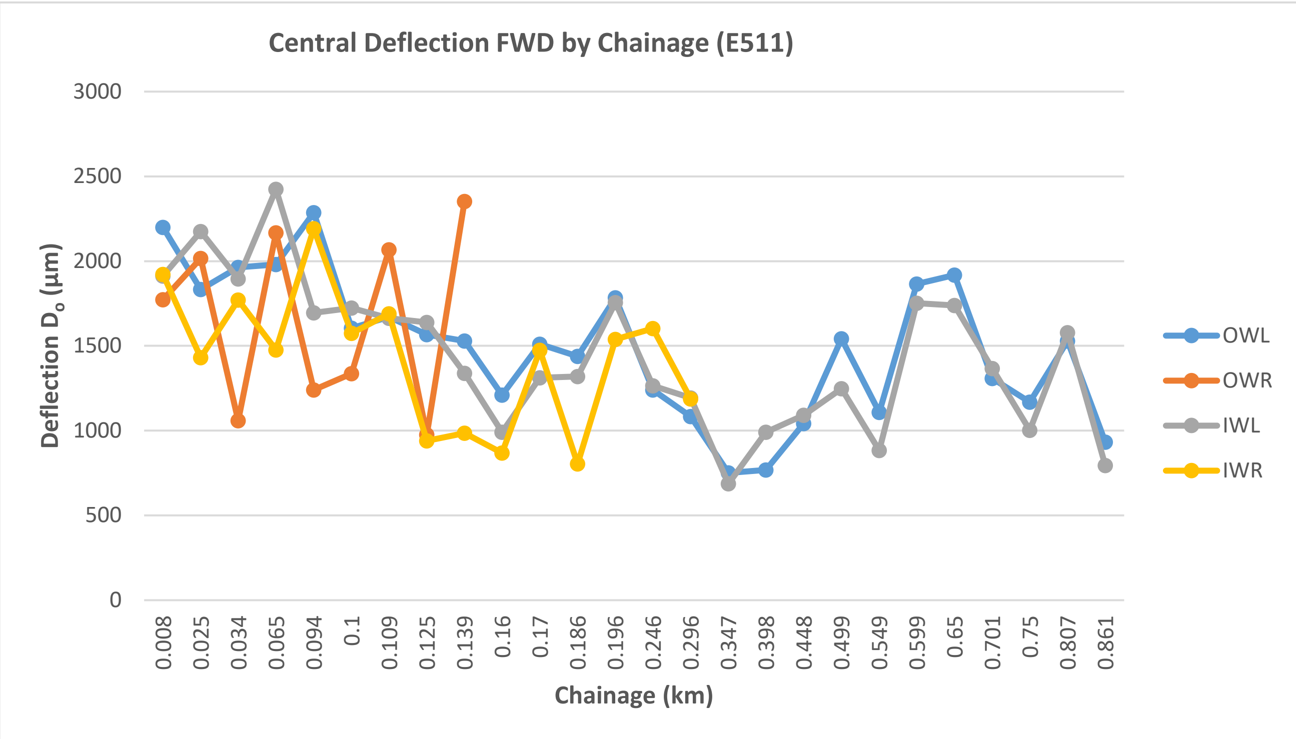


Figure 6-3: Central deflection by chainage (E511)

6.6 DCP Measurements

Table 6-5shows the DN values by layer for each test point and DSN values for 800mm depth. The values are generally within the specification limit except for a few points.

Table 6-5: DN and DSN values (E511)

Chainage (m)	Specifications	≤4.0	≤9.0	≤19	≤25	≤39	DSN800
	Position	0-150	150-300	300-450	450-600	600-800	≥73
0+000	OWL	4.8	4.8	21.1	27.5	27.5	83
0+008	OWL	1.9	1.9	12.1	26.6	26.6	184
0+008	IWL	2.7	5.1	17.1	21.7	27.2	108
0+008	OWR	2.0	7.0	15.0	29.1	29.1	119
0+008	CL	3.8	6.7	31.7	31.7	31.7	78
0+185	IWL	2.3	5.2	19.5	19.5	19.5	120
0+185	CL	3.7	3.7	10.4	19.5	19.5	114
0+185	IWR	1.8	1.8	14.7	18.1	18.1	197
0+185	OWR	2.6	2.6	12.5	21.6	21.6	144
0+186	OWL	1.9	3.0	23.4	23.4	23.4	150
0+200	RHS	3.1	8.8	25.5	25.5	25.5	86
0+250	LHS	2.8	2.8	14.0	18.2	18.2	138
0+300	OWL	4.7	15.2	24.9	24.9	24.9	62

6.7 Roughness Measurements

This does not form part of the schedule of activities for the first monitoring round.

6.8 Test Pits

6.8.1 DN Values

Table 6-6 shows the DN of each layer in the structure measured before excavation of the test pits. The values are well within the recommended specifications.

Table 6-6: DN values at test pits (E511)

Depth (mm)	Specifications	DN values (mm/blow)	
		Pit A @ 0+008	Pit B @ 0+186
0 – 150	≤4.0	1.9	1.9
150 – 300	≤9.0	1.9	3.0
300 – 450	≤19.0	12.1	23.4
450 – 600	≤25.0	26.6	23.4
600 – 800	≤39.0	26.6	23.4
DSN800	≥73.0	184	150

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

6.8.2 Layer Thicknesses

Figure 6-4 is an illustration of the measured pavement layer thickness as measured and description of the materials used.

Test Pit A, km 0+008		Test Pit B, km 0+186
25 mm Cold Mix Asphalt		25mm Cold Mix Asphalt
165 mm Neat laterite base		150 mm Neat laterite base
150 mm Granular sub-base		150 mm Granular sub-base
Subgrade		Subgrade

Figure 6-4: Layer thicknesses at test pit (E511)

6.8.3 *Moisture Content*

Table 6-7 shows the in-situ moisture content for base and sub-base, and subgrade for each layer. For the IWP, only the base sample was taken for testing. However, the other missing values were due to their absence as we observed during the sampling process. Samples were not taken from the layers that have been indicated in the colour coded cells.

Table 6-7: Moisture content at test pit (E511)

Panel	Wheel path	Layer	In-situ Moisture Content (%) LHS	Optimum Moisture Content (%)	Relative Moisture Content (FMC/OMC)	Baseline RMC (FMC/OMC)
Panel A	OWP	Base	13.5	13.2	1.02	-
		Sub-base	XXX	XXX	XXX	-
		Subgrade	28.0	30.0	0.93	0.84
	IWP	Base	11.9	17.8	0.67	0.94
		Sub-base				-
		Subgrade				0.69
Panel B	OWP	Base	9.8	15.3	0.64	-
		Sub-base	14.3	17.2	0.83	-
		Subgrade	30.1	34.6	0.87	0.62
	IWP	Base	9.7	16.2	0.6	-
		Sub-base				0.74
		Subgrade				0.65

Note 1: XXX denotes missing layer.

6.8.4 *Particle Size Distribution*

The plots in Figure 6-5 show the particle size distribution for the surface layer. The surfacing materials fit within specification envelope. The specification is obtained from LVSR Pavement Design Guidelines.

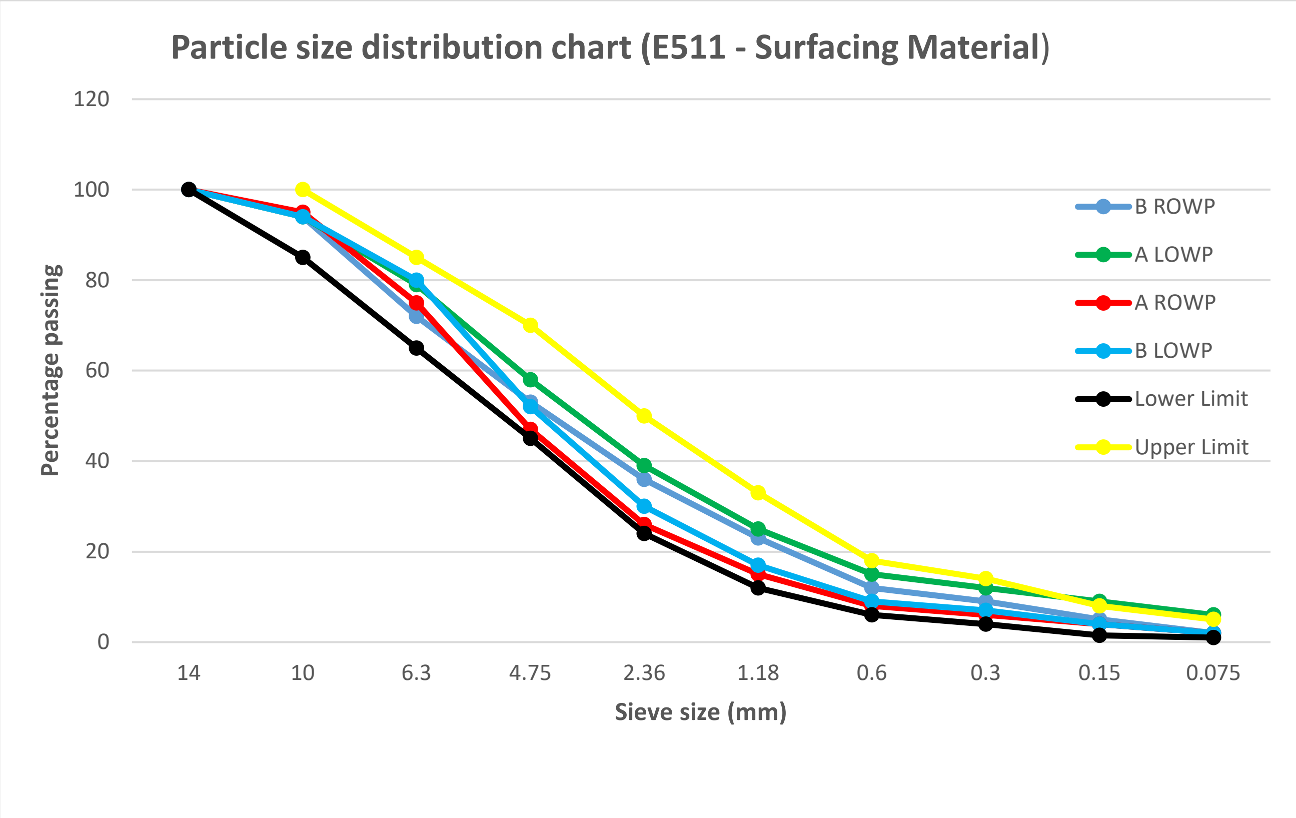


Figure 6-5: Particle size distribution for base material (E511)

6.8.5 *Mass of Aggregate and Bitumen per Unit Area*

Table 6-8 shows the mass of aggregates and bitumen per unit area. Bitumen content by mass of the total mix is also represented in percentage.

Table 6-8: Mass of aggregate and bitumen per unit area(E511)

Core Location	Panel A		Panel B		Unit
	L OWP	R OWP	L OWP	R OWP	
Residual Binder Content	7.5	7.5	9.7	7.1	%
Mass of Aggregate per Unit Area	26.9	23.1	16.4	30.7	Kg/m^2
Mass of Bitumen per Unit Area	2.1	1.9	1.8	2.3	Kg/m^2

6.8.6 *Atterberg Limits*

This does not form part of the schedule of activities for the first monitoring round.

6.8.7 *Laboratory CBR*

This does not form part of the schedule of activities for the first monitoring round.

6.9 Visual Condition Assessment

6.9.1 *Pavement Defects Assessment*

The main defects on this road section are slight bleeding and limited alligator cracks as shown in Table 6-9. The surfacing is mostly good.

Table 6-9: 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+300	-Light vegetation at side drains	
Fig 2	Km 0+020– 0+025 RHS	-Eroded shoulders and edge breaking	
Fig 3	Km 0+145	-Blocked culvert	

Fig 4	Km 0+000 – 0+200 LHS	- Fatigue and hair cracks	
Fig 5	Km 0+300 – 0+350	- Alligator cracks	
Fig 6	Km 0+200 – 0+450	-Blocked side drain with deposits of soil	

Fig 7	Km 0+350 LHS	-Edge subsidence due to poor drainage	
Fig 8	Km 0+350 - 0+400 LHS	-Silted side drain hindering free flow of water along the drain and enhancing accumulation of deposits	
Fig 9	Km 0+450 LHS	-Blocked side drain and Vegetation causing obstruction	

Fig 10	Km 0+450 – 0+800	-No visible defect on the carriage way - light vegetation at shoulders and side drains	
Fig 11	Km 0+650 LHS	-Edge deformation and subsidence	
Fig 12	Km 0+750 LHS	- Vegetation on the shoulder and side drain	

Fig 13	Km 0+753 RHS	-Edge breaking	
Fig 14	Km 0+775 LHS	-Potholes, cracks, Vegetation and soil deposits at the side drain	
Fig 15	Km 0+850 LHS	-Edge breaking at corner and light vegetation at the side drain	

Fig 16	Km 0+800 – 0+850	-Deposits blocking the LHS side drain -Light vegetation at the RHS and thus no drainage structure -No visible defects on the carriage way.	

6.9.2 Present Serviceability Rating

The computed PSR for this section is about 4.7 as shown in Table 6-10, which is regarded as "Very Good". As compared with the baseline PSR, a decrease was noted though slightly.

Table 6-10: Present Serviceability Rating (E511)

Road:	Kangari - Kinyona Road (E511)												
Section:	Km 0+000 - Km 1+ 000 main carriage way												
Pavement Structure:	**Date of Survey:**								30/6/2017				
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	4.0	33.5	4.8	83.75	**V.Good**	**4.8**
2. Km 0+500- 1+000	0.500	5.0	4.5	4.0	4.5	5.0	5.0	4.0	32	4.6	82.0	**V.Good**	**4.6**
Average PSR		**5**	**4.5**	**4.5**	**4.8**	**5**	**5**	**4.0**	**32.8**	**4.7**	**82.88**	**V.Good**	**4.7**

6.10 Rainfall Data

The rainfall data collected during the first monitoring round period is shown in Table 6-11. Long rains were experienced between April and May. Short rains were experienced between October and November.

Table 6-11: Precipitation at E511

Precipitation (mm) at Kangari – Kinyona Road (E511)										
2017										
JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER
30.1	45	103	257.8	208	53	27.1	54.1	55.8	117.6	140

7 Future Monitoring

7.1 Roads

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

- Wamwangi – Karatu Road D379 – Kiambu County
- Kangari – Kinyona Road E511 – Murang'a County
- Lord – Kona Bahati Road D382 – Nyandarua County
- Muthuaini – Munungaini Road D435 – Nyeri County

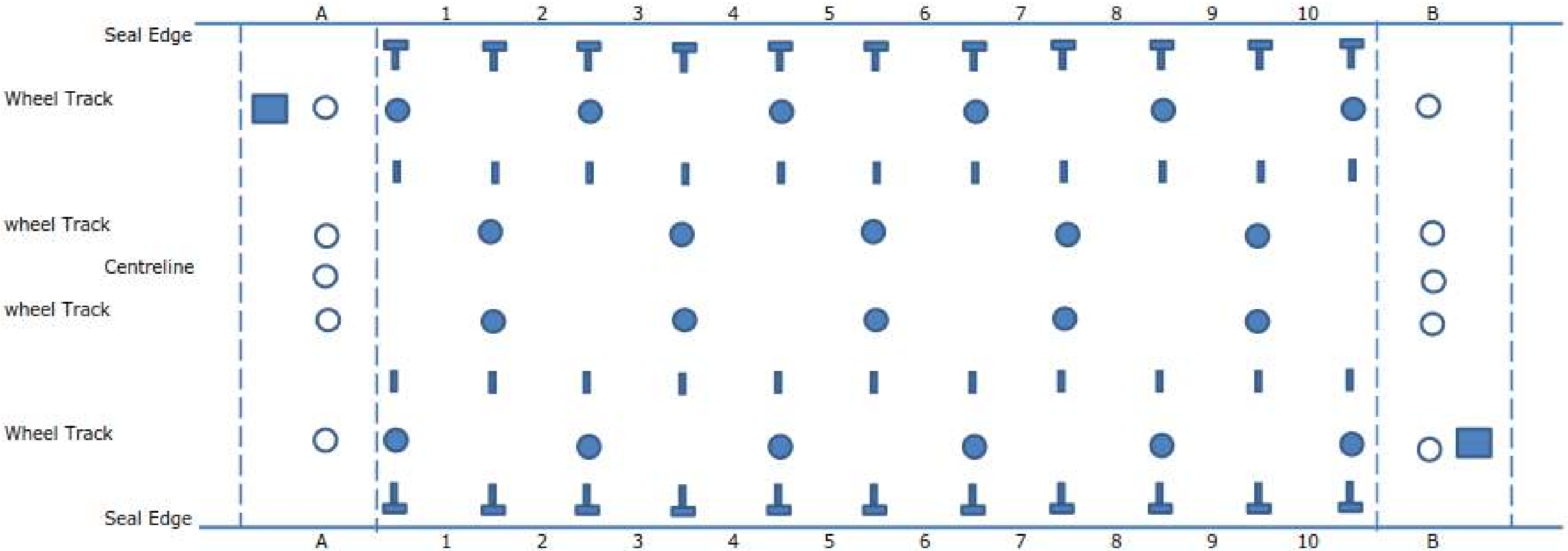
7.2 Tests

The tests to be carried out include:

- Classified traffic counts
- Roughness measurements
- Visual Condition survey
- Rut depth measurement
- DCP tests
- Drainage assessment

8 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

T 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)**