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Low Standard Bitumen Surfaced Roads in Kenya: A Case Study on Mackenzie – Kandara (D415) Road

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Abstract

Roads impose logistical, technical and financial burden on most agencies in the sub-sector due to constraints on physical, human, financial and natural resources. Substantial length of un-surfaced, particularly gravel feeder roads in Kenya is increasingly becoming difficult to sustain.

While use of the conventional designs and construction procedures needs to be adhered to, development and application of relaxed specifications in building of LVSRs has better economic and environmental value compared to the traditional gravelling.

The Kenya Road Design Manual, Part III classifies Roads which carry traffic less than 500,000 cumulative equivalent standard axles (ESA) as Low Standard Bitumen Surfaced Roads. These roads are also known as Low Traffic Volume Sealed Roads (LVSRs).

Mackenzie – Kandara (D415) Road was a 6.7km road constructed under the AfD/GoK Roads 2000 Programme in Central Kenya as a trial section to a single layer pavement standard, using labour intensive methods and utilizing different stabilizers and materials under eleven (11) different sections to aid the development of design standards and construction specifications for LVSRs.

The performance of the trial section was studied under the base line evaluation indicated initial success in many aspects of the project. Level controls and construction thickness tolerances were however not uniformly achieved in the project with the subgrade not performing as expected.

Compared to the conventional gravelling of low traffic volume roads, the project objectives were met with the cold mix asphalt surfacing effectively protecting the pavement and subgrade layers from traffic and environmental effects.

The findings from this trials and other research backed by the provisions of Chapter 12 and 13 of the RDM III, culminated in the development of Design Guidelines for Low Volume Sealed Roads in June, 2014 by Materials, Testing and Research Division, under the Ministry of Transport and Infrastructure, which is expected to enhance effectiveness and sustainability in implementing the LVSRs initiatives and have been used to complement the phase II of the Roads 2000 Programme in central Kenya.

The design guideline has proved very useful in the implementation of the Government's Roads 10,000Km Programme. A total of over 3,000Km has been designed using the guidelines and some LVSRs have been tendered.

Key Words:

Low Volume Sealed Roads, Equivalent Standard Axles, Cold Asphalt, Composite Bitumen Emulsion, Hand Packed Stones and Design Guidelines

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Abbreviations and Acronyms

AADT:	Average Annual Daily Traffic
AC:	Asphalt Concrete
ADT:	Average Daily Traffic
AHGV:	Articulated Heavy Goods Vehicle
BS:	British Standards
CBR:	California Bearing Ratio
CESA:	Cumulative Equivalent Standard Axles
CIG:	Cement Improved Gravel
DCP:	Dynamic Core Penetrometer
DESA:	Daily Equivalent Standard Axles
DSD:	Double Surface Dressing
EF:	Equivalence Factor
ESALs:	Equivalent Standard Axles
FDD:	Field Dry Density
FWD:	Falling Weight Deflectometer
HGV:	Heavy Goods Vehicles
KeRRA:	Kenya Rural Roads Authority
LGV:	Light Goods Vehicles
LVSR:	Low Volume Sealed Road
LHS:	Left Hand Side
LIG:	Lime Improved Gravel
MDD:	Maximum Dry Density
MG:	Medium Goods vehicles
mm:	Millimeters
NGR:	Natural Gravel
OMC:	Optimum Moisture Content
PI:	Plasticity Index
RC:	Relative Compaction
RDM:	Road Design Manual
RHS:	Right Hand Side
RMC:	Relative Moisture Content
TRL:	Transport Research Laboratories
VEF:	Vehicle Equivalence Factor.

Section 1: Introduction

1.1 Background

The Kenya Road Design Manual, Part III classifies Sealed Roads which carry traffic less than 500,000 cumulative equivalent standard axles (ESA) as Low Standard Bitumen Surfaced Roads. These roads are also known as Low Traffic Volume Sealed Roads (LVSRs). The two terms are interchangeably used in this paper.

While use of the conventional designs and construction procedures needs to be adhered to, development and application of relaxed specifications in building of LVSRs has better economic and environmental value compared to the traditional gravelling.

Mackenzie – Kandara (D415) Road was constructed under AfD/GoK Roads 2000 Programme in Central Kenya as a trial section to a single layer pavement standard, using labour intensive methods on eleven (11) different trial sections, utilizing different materials and soil treatment agents.

The objectives of the project were as follows:

(i) To construct sealed pavement for low traffic volume instead of the conventional gravel wearing course;

(ii) To implement labour intensive pavements and surfacing construction methods;

(iii) To compare performance of alternative stabilizers with cement and lime;

(iv) To determine performance of low volume sealed pavement constructed by labour;

(v) To develop specifications for surfaced low traffic volume pavements constructed by labour.

Compared to the conventional gravelling of low traffic volume roads, the project objectives were met.

1.2 Study Objectives

The objectives of the case study were as follows:

(i) To carry out design review of the trial section;

(ii) To carry out pavement construction review; and

(iii) To determine the performance of the trial section.

Section 2: Pavement Design Review

2.1 Design Pavement Standard

The design of the project road was based on Chapter 12 & 13 of the RDM Part III and other technical guidelines and adopted the following standards:

i. Subgrade

The adopted design subgrade was Class S3 and achieved by improving the in-situ red clay with 200mm of existing gravel wearing course (S4 quality material).

ii. Pavement Layers

A single layer pavement standard was adopted for the trial section using materials tabulated below for respective cumulative length of the trial sections. The minimum design base thickness was 100mm and constructed to subbase standard with a cold asphalt mix surfacing of 15mm thickness across the entire trial section.

Pavement Material	Design Layer Thickness (mm)	Cumulative Length (Km)
Natural Gravel	200	2.0
Cement Improved Gravel	100	1.0
Composite Bitumen Emulsion Treated Gravel	100	1.0
Consolid System Treated In situ Material	100	1.7
Hand Packed Stones	150	1.0

2.2 Design Sections

The length of each section and the corresponding pavement materials were as shown in the table below.

Trial Section	Chainage		Type of Pavement Structure
	From	To	
1	0+000	0+100	Consolid Improved Gravel (Demonstration)
2	0+100	0+700	Cement Improved Grave (CIG)

3	0+700	0+940	Emulsion Treated Gravel (ETG) (Demonstration)
4	0+940	1+120	Composite - Emulsion Treated Gravel + Cement Improved Gravel (ETG/CIG)
5	1+120	1+560	Cement Improved Gravel (CIG)
6	1+560	2+200	Composite - Emulsion Treated Gravel + Cement Improved Gravel (ETG/CIG)
7	2+200	3+220	Consolid Improved Gravel + Red soil
8	3+220	4+000	Neat Gravel (NG)
9	4+000	5+760	Composite - Emulsion Treated Gravel + Cement Improved Gravel (ETG/CIG)
10	5+760	6+260	Composite - Emulsion Treated Soft Stone + Cement Improved Soft Stone (ETG/CIS)
11	6+260	6+780	Hand packed Stone (HPS)

Section 3: Pavement Construction Review

3.1 General

Construction of the trial section was achieved by both labour and equipment. The subgrade was mechanically stabilized using gravel residue of existing gravel wearing course and constructed by machine while the base and the surfacing were constructed by labour.

3.2 Pavement Materials Properties

The following are the properties of the materials utilized in the construction of each section of the trial section.

Trial Section 1: Consolid System Improved Gravel (0+000-0+100)

Subgrade: Consolid liquid treated red clay (2cc of C444) of 15% 4 days soak CBR and PI of 27%.

Base: Consolid Improved gravel, neat CBR of 50% PI of 18%. The improvement was done using a combination of 2cc Consolid liquid (C444) and 2% Consolid Solidry powder.

Trial Section 2: Cement Improved Gravel (0+100 – 0+700)

Subgrade: 4 days soak CBR ranging between 8% - 15% and maximum PI of 27%.

Base: 2% Portland Pozzolanic Cement (PPC) improved gravel of neat CBR of 50% and PI of 18%.

Trial Section 3: Emulsion Treated Gravel (ETG) (0+700 – 0+940)

Subgrade: 4 days soak CBR ranging between 8% - 15% and maximum PI of 25%.

Base: 1.5% A4-60 emulsion and 1% cement treated gravel, neat CBR of 33% and PI of 18%.

Trial Section 4: Composite - Emulsion Treated Gravel + Cement Improved Gravel (ETG/CIG) (0+940 – 1+120)

Subgrade: 4 days soak CBR ranging between 10% - 17% and maximum PI of 25%.

Base: Composite of 1.5% A4-60 emulsion, 1% lime and 1% cement Emulsion treated gravel, neat gravel CBR of 33% and PI of 18%.

Trial Section 5: **Cement Improved Gravel (1+120 – 1+560)**

Subgrade: 4 days soak CBR between 6% - 17% and maximum PI of 26%.

Base: 2% Pozzolanic Cement treated gravel, neat CBR of 33% and PI of 18%.

Trial Section 6: **Composite - Emulsion Treated Gravel + Cement Improved Gravel (ETG/CIG) (1+560 – 2+200)**

Subgrade: 4 days soak CBR between 9% - 15% and maximum PI of 23%.

Base: Composite of 1.5% A4-60 emulsion, 1% lime and 1% cement treated gravel (33mm) on top of neat gravel (67mm), neat gravel CBR of 40% and PI of 19%.

Trial Section 7: **Consolid System Improved Gravel (2+200– 3+220)**

Subgrade: Insitu red clay of 4 days soak CBR between 9% - 15% and PI of 24% and treated with 2cc of C444 Consolid liquid.

Base: Consolid Improved (2cc Consolid liquid (C444) and 2% Consolid Solidry powder) Insitu gravel wearing course, neat CBR of 21% PI of 23%.

Trial Section 8: **Neat Gravel base section (3+220 – 4+000)**

Subgrade: 4 days soak CBR between 11% - 23% and maximum PI of 27%.

Base: Neat gravel of CBR of 33% - 36% and PI of 17% constructed in two layers of 100mm each.

Trial Section 9: **Cement Improved Gravel (4+000 – 5+760)**

Subgrade: 4 days soak CBR between 15% and maximum PI of 27%.

Base: Cement treated gravel, neat CBR of 40% and PI of 19%. The base was improved with 2% Pozzolanic Cement.

Trial Section 10: **Composite - Emulsion Treated Soft Stone + Cement Improved Soft Stone (ETG/CIS) (5+760 – 6+260)**

Subgrade: CBR (4 days soak) of 16%.

Base: Composite of 1.5% A4-60 emulsion, 1% lime and 1% cement treated gravel (33mm) on top of neat soft stone (67mm), CBR of 39% and PI of 18%.

Trial Section 11: Hand Packed Stone (6+200 – 6+700)

Subgrade: In-situ black clay mechanically stabilized with gravel residue of the existing gravel wearing course.

Base: Hand Packed Stone base with Non plastic fines from LAA constructed to a thickness of 150mm and 50mm Emulsion treated gravel of neat CBR of 40 and PI of 19%.

Surfacing Trial: Cold Asphalt Mix Surfacing

The surfacing was laid to a uniform compacted thickness of 15mm on all the sections. Aggregate gradation of 0/6mm was used with K3-65 emulsion binder.

Coal Prime – E emulsion, manufactured by Colas East Africa was used as the primer instead of conventional MC30.

3.3 Achieved Results

The constructed thickness of each section together with laboratory and field quality control tests achieved on the project were as follows:

Trial Section	Control Parameters Achieved	
	Thickness (mm)	**CBR%**
Consolid Improved Gravel	150	80
Cement Improved Grave (CIG)	85 - 115	110
Emulsion Treated Gravel (ETG)	75 - 90	42
Composite - Emulsion Treated Gravel + Cement Improved Gravel (ETG/CIG)	87 - 105	120
Cement Improved Gravel (CIG)	70 -100	62 - 85
Composite - Emulsion Treated Gravel + Cement Improved Gravel (ETG/CIG)	85 - 110	85 - 89
Consolid Improved Gravel + Red soil	100 – 140	61 - 63
Neat Gravel (NG)	80 – 112 per layer	36 - 37
Composite - Emulsion Treated Gravel + Cement Improved Gravel (ETG/CIG)	90 - 140	67 - 110

Composite - Emulsion Treated Soft Stone + Cement Improved Soft Stone (ETG/CIS)	85 – 130	240
Hand packed Stone (HP)	150	N/A

Section 4: Pavement Condition Study

4.1 Evaluation Criteria

Base line study was carried out in July 2012 and included both structural and functional aspects of the trial section. Data related to the following activities were collected and analyzed.

i. Traffic Studies including Classified Axle load and traffic counts;
ii. Deflection Measurements using Falling Weight Deflectometer;
iii. Surface Condition Survey

4.2 Traffic Studies

4.2.1 Traffic Counts

The traffic counts were carried out on the trial road at Mackenzie between 7th and 12th July, 2012. The computed average daily traffic (ADT) from the data which consisted of a five-day 12 hour count and one-day 24 hour counts is summarized in the table below.

The 12 hour counts were converted to 24 hour counts using a 24/12hour ration determined from the study.

Table 4.1: Average Daily Traffic on Mackenzie – Kandara Road (D415)

Vehicle Type	DAY OF THE WEEK						TOTAL	ADT
	Tue	Wed	Thu	Fri	Sat	Sun		
Non-Motorized traffic (NMT)								
Others	7	1	14	6	10	13	51	**9**
Bicycles	413	462	377	325	326	319	2220	**370**
Motorized traffic								
Motor bikes	597	640	566	465	540	492	3300	**550**
Cars	68	57	48	42	56	36	306	**51**
Vans/Matatus	156	95	127	123	180	146	827	**138**

Small Trucks	0	0	8	6	6	4	24	**4**
Motorized Commercial Vehicles (MCV)								
Buses	8	0	6	3	0	0	17	**3**
MGV	18	11	18	33	27	2	108	**18**
HGV	0	3	3	0	2	32	39	**7**
AHGV	0	0	0	0	1	1	2	**0**
TOTAL	1265	1268	1167	1003	1147	1044	6894	**1149**

Based on the motorized traffic, the ADT on Mackenzie – Kandara trial section was found to be 770 vehicles per day of which 3.6% are commercial vehicles.

4.2.2 Equivalence factor (E.F.) and Daily Equivalent Standard Axles (DESA)

The equivalence factors used in the traffic analysis for Mackenzie – Kandara were derived from the Road Design Manual Part III.

Table 4-2: Daily Equivalent Standard Axles on Mackenzie – Kandara Road (D415)

Vehicle Type	ADT	E.F	DESA
BUS	3	1.0	3
HGV	18	1.0	18
MGV	7	4.0	26
A-HGV	0	4.0	1
TOTAL	28		**48**

Design traffic loading of 38 was adopted for the pavement analysis based on the assumption that the central strip is trafficked by 80% of all commercial vehicles.

4.2.3 Traffic Growth Rate

The annual traffic growth rate for this road was estimated at 5.0% based on Gross Domestic Product from 1961 to 2009 as given in *World Bank, World Development Indicators - Updated in December 22, 2010*

4.2.4 Cumulative Equivalent Standard Axles

It was estimated that the trial section will carry 0.3 million cumulative equivalent standard axles for a 15-year design period at 5.0% annual traffic growth rate. The calculated cumulative equivalent standard axles for different design periods at various traffic growth rates were as tabulated below.

Table 4-3: CESA on Mackenzie – Kandara Road (D415)

DESIGN PERIOD	ANNUAL TRAFFIC GROWTH RATE					
	3.0%	**4.0%**	**5.0%**	**6.0%**	**7.0%**	**8.0%**
5	74,542	76,047	77,582	79,147	80,742	82,369
7	107,584	110,895	114,317	117,852	121,505	125,279
10	160,957	168,570	176,598	185,063	193,988	203,396
15	261,135	281,138	**302,970**	326,802	352,820	381,225
20	377,269	418,094	464,257	516,482	575,590	642,513

4.3 Pavement Deflection measurement

4.3.1 FWD deflection test method and analysis

Pavement deflection measurements were carried out using the Falling Weight Deflectometer (FWD) on the road sections to determine the residual strength of the existing pavement.

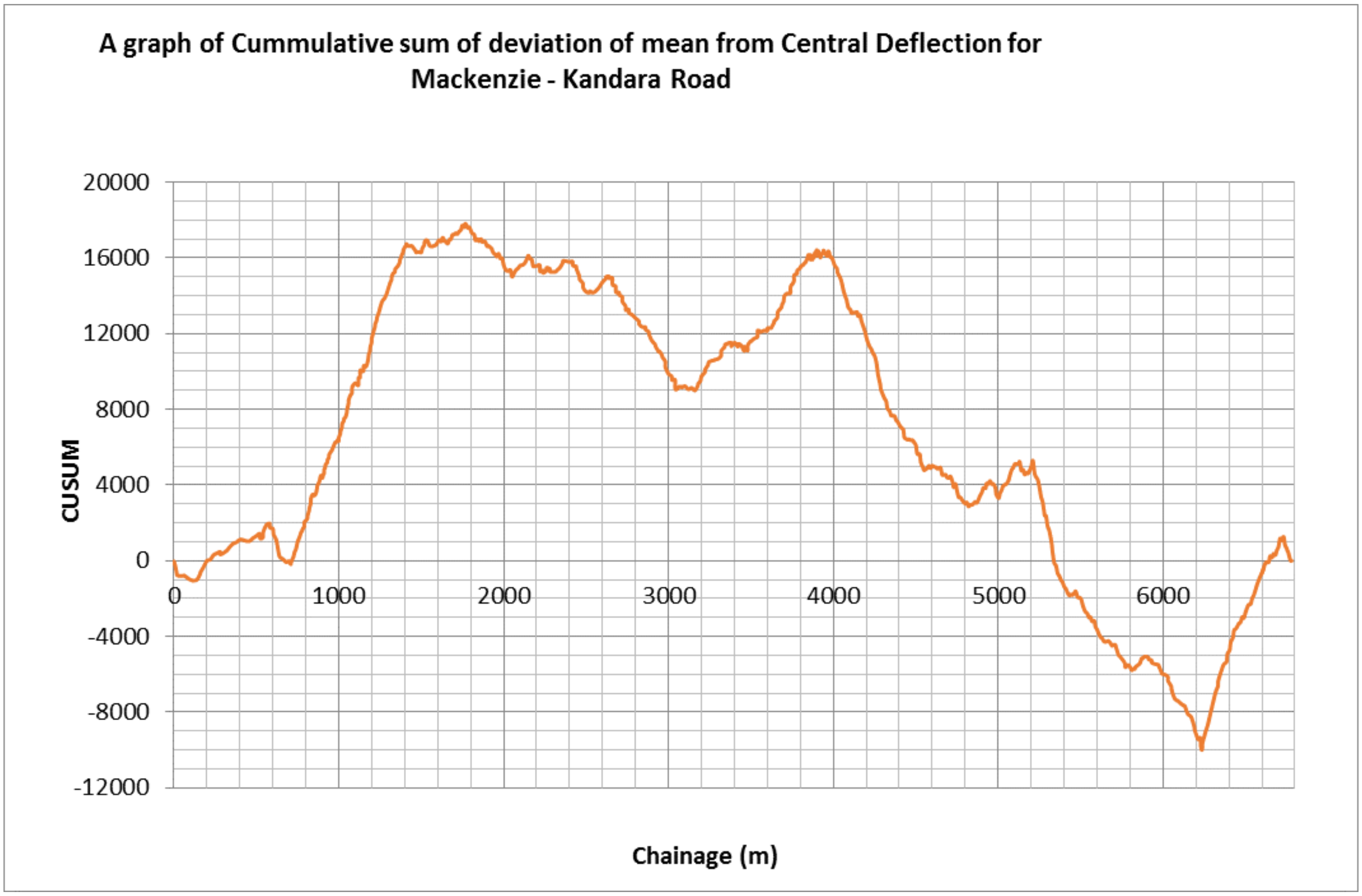
Measurements were taken at intervals of approximately 100 m at an offset of about 0.6 m from the edge of the carriageway, along the outer wheel paths.

The deflection data collected was used to identify homogenous sections along the road section and to derive deflection bowls on each homogenous section. The data was then combined with the existing pavement layer thicknesses, material properties and traffic loading characteristics and analyzed using Rosy Design Software to determine the residual structural life, critical layers and overlay requirements of the pavement.

4.3.2 Determination of Homogenous Sections

Cumulative sum of the difference from the mean of the central deflections, D0, was used to identify the homogeneous sections. The cusum plot was as shown in Figure 4-1 below.

Figure 4-1: Graphs of Homogenous Sections from Cumulative Difference Method



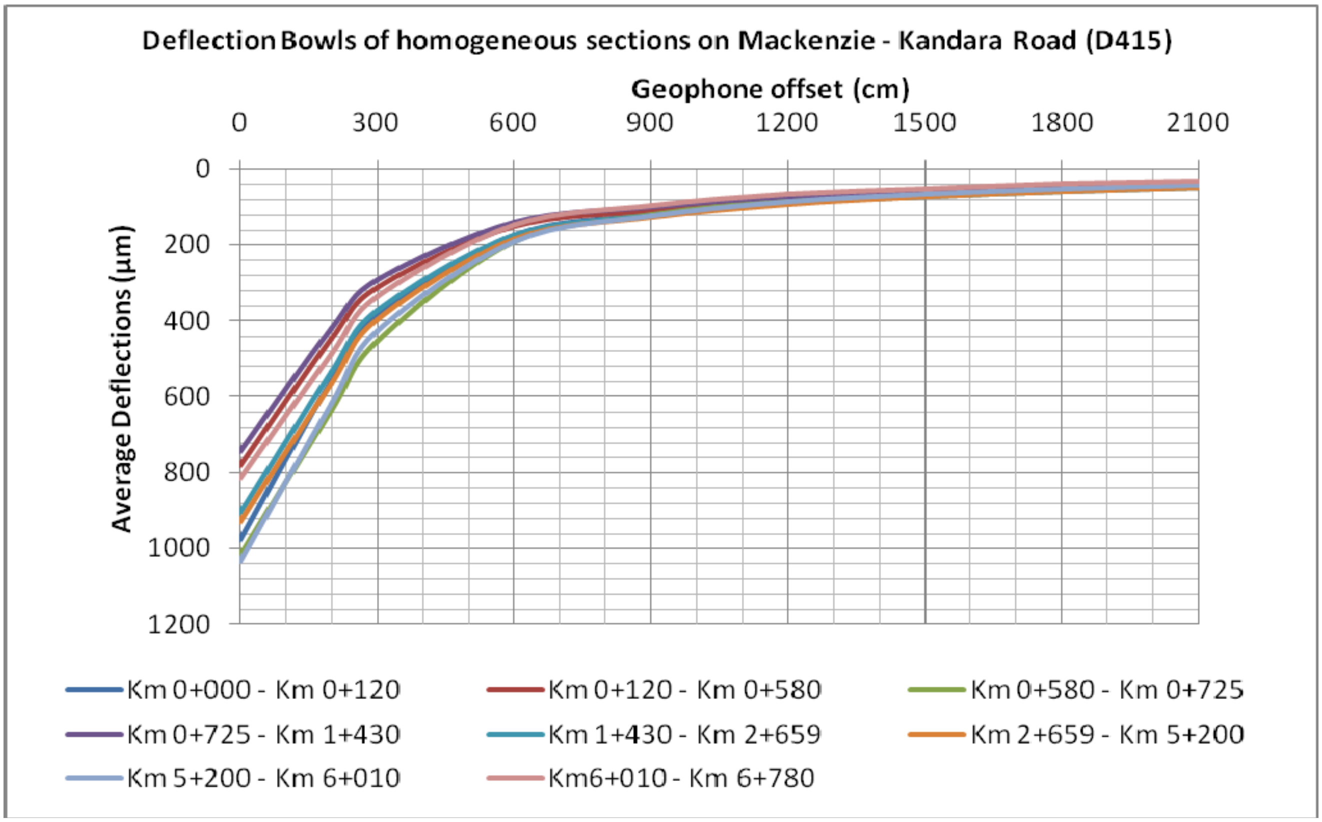
From the graph above, eight homogenous section were identified on Mackenzie – Kandara Road (D415) as Km 0+000 - Km 0+120, Km 0+120 - Km 0+580, Km 0+580 - Km 0+725, Km 0+725 - Km 1+430, Km 1+430 - Km 2+659, Km 2+659 - Km 5+200, Km 5+200 - Km 6+010 and Km6+010 - Km 6+780.

The homogenous sections shows overlap of different sections. This could be attributed to a relatively comparable construction control parameters achieved from the different sections.

4.3.3 Pavement deflection bowl and pavement strength

The shape and form of the deflection bowl provides a comparative strength of the subgrade and variation of strength in pavement layers for homogenous sections. The deflection bowls of various homogenous sections were as shown below:

Figure 4-1: Deflection Bowls of Homogenous sections on D415



The following were deduced from the deflection bowls above:

a. The pavement layers at Km 0+750 - Km 1+430 are strongest as indicated by shallow deflection bowl. This section overlaps both Composite Emulsion Treated gravel Section and Cement Improved Section.

b. The pavement layers at Km 0+580 - Km 0+725 and Km 5+200 – Km 6+010 are weakest as indicated by deepest deflection bowl. These sections covers mostly the Composite Emulsion Treated Gravel + Cement Improved gravel and soft stone (Sections 9 &10).

The corresponding moduli of elasticity of pavement layers for the homogenous sections were as shown in the table below.

Table 4-4: Pavement Layers' Elastic Moduli of Homogenous Sections

Homogenous section	**Elastic Modulus (MPa)**		
	Surfacing	**Base**	**Sub grade**
Km 0+000 - Km 0+120	2076	888	163
Km 0+120 - Km 0+580	2987	1133	197
Km 0+580 - Km 0+725	1561	1057	140
Km 0+725 - Km 1+430	2365	1122	200
Km 1+430 - Km 2+659	1659	1137	162
Km 2+659 - Km 5+200	1758	1148	161
Km 5+200 - Km 6+010	1802	1019	157
Km6+010 - Km 6+780	2088	1175	180
Average (MPa)	**2037**	**1085**	**170**

The following were deduced from the average moduli of elasticity values:

a. Subgrade: The elastic moduli values indicate subgrade Classes S5 for all the sections under in-situ moisture condition. This can be attributed to proper equipment compaction for the subgrade.
b. Subbase: The elastic moduli values were above 300 MPa attributed to cement/lime improved gravel subbase in all the sections under in-situ condition.
c. Surfacing: The cold mix asphalt surfacing achieved elastic moduli values between 1561 – 2987 MPa and were below the 4000MPa for hot mix AC in all the homogeneous sections.

4.3.4 Pavement residual life and strength

Table 4-5: Pavement Residual Life of Homogenous Sections

Homogenous section	**Residual Life (Years)**	**Critical Layer**
Km 0+000 - Km 0+120	2	3
Km 0+120 - Km 0+580	4	3
Km 0+580 - Km 0+725	2	3

Km 0+725 - Km 1+430	4	3
Km 1+430 - Km 2+659	3	3
Km 2+659 - Km 5+200	3	3
Km 5+200 - Km 6+010	3	3
Km6+010 - Km 6+780	3	3
Average (MPa)	3	

The following deductions are made from the above table:

- Parts of the CIG and ETG/CIG sections have the highest residual lives of 4years. The pavements for the trial section have average residual life of 3 years;
- The subgrade is the most critical layer for all the homogeneous sections;

4.3.5 Strengthening Requirements

Overlay requirements (Cement Improved Gravel) as derived from the RoSy software are as follows:

Table 4-6: Strengthening Requirements

Homogenous section	**Strengthening Requirement**			
	15 yr.	**10 yr.**	**5 yr.**	**3 yr.**
Km 0+000 - Km 0+120	110	90	60	45
Km 0+120 - Km 0+580	90	70	45	30
Km 0+580 - Km 0+725	105	85	55	35
Km 0+725 - Km 1+430	95	75	50	35
Km 1+430 - Km 2+659	95	80	50	35
Km 2+659 - Km 5+200	95	80	50	35
Km 5+200 - Km 6+010	100	85	55	40
Km6+010 - Km 6+780	95	80	50	35

4.4 Roughness Measurements

Different Roughness of roads with similar pavement construction is a good measure of the relative pavement condition.

Most pavement defects contribute to increasing the roughness of the road pavement, either directly from a deformed surface or indirectly as a result of repair work e.g. cracks and pot holes. Changes in roughness over time are an indicator of pavement distress taking place.

Roughness measurements were done using MERLIN meter on all the wheel paths of every section and summarized in table 4.6 below:

Table 4-7: Roughness (IRI) on Mackenzie – Kandara Road

Chainage	Outer Section		Inner Section	
	RHS	**LHS**	**RHS**	**LHS**
Km 0+040 - Km -0+060	4.0	4.0		
Km 0+040 - Km 0+600	5.1	4.9	4.8	5.5
Km 0+600 - Km 0+870	4.8	4.6	4.9	4.8
Km 0+790- Km 1+060	4.9	4.8	4.8	4.6
Km 1+060 - Km 1+500	4.6	4.8	4.5	4.8
Km 1+580 - Km 2+070	5.3	5.0	4.5	4.5
Km 2+200 - Km 2+640	5.6	5.1	4.7	4.9
Km 2+700 - Km 3+150	4.8	4.9	5.4	4.7
Km 3+180 - Km 3+650	4.9	4.4	4.4	4.8
Km 3+700 - Km 3+950	5.2	4.9	5.2	4.7
Km 3+990 - Km 4+500	5.0	5.1	4.8	5.4
Km 4+500 - Km 4+940	4.7	5.0	5.3	5.3
Km 5+050 - Km 5+500	5.2	5.4	5.3	5.1
Km 5+500 - Km 6+200	5.4	5.5	5.4	5.4
Km 6+200 - Km 6+700	5.8	6.1	6.1	5.7
Average	**5.0**	**5.0**	**5.0**	**5.0**

The road IRI values achieved for all the sections indicates a fair serviceability rating with the first section on Consolid achieving the lowest IRI. The hand packed stone section had the highest IRI value indicating a poor serviceability rating.

Section 5: Discussion, Conclusion and Recommendations

5.1 Discussion on Study Findings

The performance of the trial section studied under the base line evaluation indicated initial success in many aspects of the project.

Changes in traffic pattern is not anticipated on the trial section with the 15 years post construction traffic projection at below 0.5 million cumulative equivalent standard axles (Traffic Class T5) for the trial section.

The road section construction was achieved through labour intensive methods. The construction control parameters such as compaction and mixing were achieved. There was however difficulties in achieving tolerances due to manual construction level control.

The constructed base layer in all the sections achieved results complying with subbase construction specifications except in the first section of the Emulsion treated gravel which recorded a 42% CBR. The achieved Plasticity Index did not uniformly comply with the requirement of 5 – 12 % and maximum 15% on improved and neat subbase material respectively.

The road IRI values achieved for all the sections indicates a fair serviceability rating with the first section on Consolid achieving the lowest IRI. The hand packed stone section had the highest IRI value indicating a poor serviceability rating. The IRI rating achieved is attributed to irregular surface finish resulting from the manual control of levels.

From the structural survey carried out, the road section with Consolid had the lowest residual life of 2 years while the cement improved gravel section has the highest residual life of 4 years.

The road sections with cement improved gravel subbase have considerable subbase strength as compared to the other sections. The section with Emulsion Treated Gravel has the least strength as indicated by lower elastic moduli.

The subgrade soils had soaked CBR values ranging from 8% - 25% indicating minimum subgrade class S2, while the design subgrade was class S3. In in-situ condition the subgrade materials have average strength of subgrade class S5 as determined from the deflection measurements indicating that proper compaction of the subgrade. However the subgrade, based on analysis is most critical indicating inadequacy in strength to support the pavement layer for the road design life.

5.2 Conclusions

The following are conclusions from the pavement evaluation:

i) Cement treated sections performs better than the rest of the sections. The cement improved gravel yielded better strength qualities than the non-conventional stabilizer sections.

ii) The constructed subgrade did not achieve the design subgrade specification as the pavement analysis indicated that the subgrade was the most critical layer.

iii) The construction pavement thickness tolerances and level controls were not achieved by labour.

5.3 Recommendations

Further monitoring of the section should be carried out at six months, one year, two years and five years and the results compiled to derive conclusive construction specifications for labour intensive low cost bitumen surfaced pavements.

Further research on the construction technique and the cold mix asphalt need to be carried out to complement this research.

Strict quality control at implementation stage for future trial sections.

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