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A Comprehensive Study on Pavement and Geometric Design of Dispensary-Kerio-Gate B (University of Eldoret, Kenya) Road and Upande-Kimumu-Peris Road

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***Abstract*: This study examines the pavement and geometric design of the Dispensary-Kerio-Gate B (University of Eldoret, Kenya) Road and the Upande-Kimumu-Peris Road. The purpose of the study was to evaluate the current pavement conditions and geometric design of the road links, identify the existing problems, and recommend suitable solutions by developing an economical and practicable design that satisfies the standards. The study included field investigations, topographic data collection, traffic count, pavement design, geometric design, materials computation and analysis. The results demonstrated that the pavement conditions and geometric designs of the two-road links were deficient, resulting in frequent accidents, traffic congestion, and vehicle damage. The study recommended a number of measures to enhance the pavement and geometric designs of the roads, such as upgrading to bitumen standards, widening the roads, enhancing drainage systems, and adopting suitable design standards. The study's findings will assist road designers, engineers, and policymakers in enhancing road conditions and safety, as well as the overall transportation system.**

Keywords: Pavement design, Geometric design, topographic data, traffic count, bitumen standards, road safety.

1. INTRODUCTION

The Kenya vision 2030 [1] is a national long-term development blue-print that aims to transform Kenya into a newly industrialized country, the three pillars are anchored on the foundation of infrastructural development through construction of Roads and Affordable housing among others.

Economic studies have shown that with good operating road infrastructure, a country can generate up to 5% of the Gross Domestic Product (GDP) in conjunction with this, The Road Sector Investment Plan (RSIP 2011) articulated that for every shilling invested in highway, the return is two shillings and fifty cents and therefore serving as a vital economic tool. Majority of Kenyan rural roads are in poor condition and mostly during the rainy season which leads to high operating costs and increased road use charges as a result of increased vehicle operating costs.

The geometric design of roads [2] is concerned with positioning the roadway's physical elements according to standards and constraints with objectives to optimize efficiency and safety while minimizing cost and environmental damage. Geometric roadway design is divided into three major components; Alignment, Profile, and Cross-section. On the other hand, pavement design involves determining the number, material composition, and thickness of the different layers within a pavement structure required to accommodate a given applied load.

Ease of accessing university premises and facilities with the least cost and minimal time taken is the desire of every student, staff and visitors. Construction and opening of Gate B whose closure could have emanated from poor road surface conditions along the route road would decentralize traffic from the main gate, elsewhere, poor drainage system along Upande-Kimumu-Peris Road which makes the road impassable during the rainy season is the main reason for desire to improve the road conditions.

2. METHODOLOGY

2.1 Study area

The research areas taken into account in this paper are located in Uasin Gishu county, Ziwa location.

The Upande-Kimumu-Peris Road link is a murram stretch of road link that branches from Eldoret Ziwa road immediately before the University of Eldoret boundary. This road connects the Upande, Kimumu and Peris shopping centers and serves as a key transportation route for the residents. The road link is approximately 1.9 km long and has two lanes with a width of around 7m. The terrain is generally flat, with several junctions along the road. Figure 1 below shows an aerial view of Upande -Kimumu-Peris Road while figure 2 shows the current road condition as of April 2023.

Figure 1. Upande-Kimumu-Peris Road link (1.9km) (Source; Google earth)

Figure 2. Upande-Kimumu-Peris Road link road condition (April 2023).

The Dispensary-Kerio-Gate B Road link is roughly 1.6 kilometers long and is located within the University of Eldoret. This road provides vital transportation link for students and faculty members. The road section from the Dispensary to Kerio is an earth road with a road width of about 6m. The road stretch from Kerio to Gate B is a deteriorating tarmac road with no side drains. The route's general topography is flat, with poor geometry at intersections. Figure 3 below shows an aerial view of Dispensary-Kerio-Gate B Road while figure 4 shows the current road condition as of April 2023.

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Figure 3. Dispensary-Kerio-Gate B (University of Eldoret, Kenya) road link (Source; Google earth)

Figure 4. Dispensary-Kerio Hall- Gate B Road link current road condition (April 2023).

2.2 Pavement design using Kenya Road Design Manual (KRDM)

The Kenyan Road Design Manual Part III, 1987 [3] provides the criteria in terms of traffic classes for selection of the design traffic based on the calculated Cumulative Number Equivalent Standard Axles. Once the cumulative standard axle has been calculated and traffic class determined, the soil bearing capacity (CBR) is used to determine the soil class. The surfacing materials are then determined and from the three data KRDM part III [3]gives the pavement layer thicknesses.

The growth forecasts have been made for the medium scenario (most probable) and from the traffic projection, design traffic in year Fifteen (15) and the corresponding pavement loading and assigned traffic loading classes were estimated.

2.2.1 Data Collection

To meet the project's goal, raw survey data was obtained by conducting a topographic survey with the Real Time Kinematic (RTK) machine, which is the most precise and time-saving survey technology currently available in the country [4]. The topo data

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retrieved from RTK was loaded into Civil 3D software, allowing for the design of horizontal and vertical alignment of the two-road links.

2.2.2 Survey Procedure

Traffic survey methodology followed the provisions of Road Design Manual Part III Manual traffic counts were conducted over a period of 7 consecutive days. The day counts were carried out between 6am to 10pm (16 hours) for five of the seven traffic volume count days. Further two-16-hour counts were conducted for two days, during a typical week day and one typical weekend-day. Results of the counts were analyzed to generate Daily Average Traffic flow data.

2.2.3 Traffic Count Analysis

The ADT from the 7-day counts were derived from averaging the 7-day daily traffic data after applying the 24/12-hour ratios for each vehicle type. The 24-hour counts were used to convert the partial–day counts over 16 hours to a full–24-hour traffic flows (normally, the count is grossed up using a 24-hour traffic count and taking the ratio of traffic in the same counting period and direction to the full 24-hour count.

Finally, two-way traffic flows were deduced from the collected data to show the directional distribution of traffic along all the two project road segments. The ADT for Upande-Kimumu-Peris Road was 165 vehicles while Dispensary-Kerio Hall-Gate B was 225 vehicles.

2.2.4 Projected Traffic

The baseline traffic was projected, considering low, medium and high traffic growth scenarios. The low and high growth scenarios were taken percent of medium economic growth as presented in Table 1, taking the calculated average growth from micro-economic indicators and historical traffic growth trend, the growth rate was taken as 6.48%. The calculated traffic growth rates are as presented in the table 1 below.

Table 1: Traffic Growth Rates for Low, Medium and High Scenarios.

Growth rates (%)	Motorcycles	Small Cars	Large Cars	Matatus & Mini Bus	Small `Bus	Bus	Pick -ups and vans	Light Goods Vehicles	MGVs-Trucks	3 Axle Heavy Goods Vehicles	4-5 Axle Heavy Goods Vehicles	6-7 Axle Heavy Goods Vehicles	Others
Low Growth %	2.78	4.90	4.90	4.78	4.78	4.78	4.50	4.63	4.67	5.39	5.35	5.35	4.90
Medium Growth %	3.20	5.63	5.63	5.49	5.49%	5.49	5.17	5.32	5.37%	6.19	6.14	6.14	5.64
High Growth %	3.68	6.47	6.47	6.32	6.32	6.32	5.95	6.12	6.18	7.12	7.07	7.07	6.48

2.2.5 Projection of Cumulative Number of Standard Axles.

The Kenya Road Design Manual Part III page 2.8 provides that the CNSA denoted as T over a chosen design period N years can be obtained from the equation below.

$$T = 365t_1\left(\frac{(1+i)^N - 1}{i}\right)$$

Where:

t_1 is the average number of standard axles in the first year of opening, and;

i is the annual growth rate expressed as a decimal fraction

From the above equation, the CNSA shown in table 2 below was obtained for the two-road links using a growth rate of 6.48% for the two-road links and an initial traffic of 165 vehicles and 225 vehicles respectively.

Table 2: Summary of Projected Cumulative Number of Standard Axles in Year 1, 10, 15 and 20

Summary	Year 1 CENSAs	Year 5 CENSAs	Year 10 CENSAs	Year 15 CENSAs	Year 20 CENSAs
Link 1	60,225	342,763	811,936	1,454,142	2,333,193
Link 2	82,125	467,404	1,107,045	1,982,921	3,182,627

2.2.6 Pavement Design Traffic Class

The Kenya Road Design Manual Part III, 1987, [3] provides a framework for the selection of traffic classes. The traffic classifications are determined by the use of total number of cumulative Number Equivalent Standard Axles (CENSAs), and based on a CENSAs of 15 years, the traffic class for the two-road linkages is T4. Table 3 below shows traffic classes based on Cumulative Number of Standard Axles.

Table 3: Design Traffic Classes provided by the KRDM [3]

Traffic Loading Class	Cumulative Number of Standard Axles
T1	25 - 60 million
T2	10 - 25 million
T3	3 - 10 million
T4	1 - 3 million
T5	0.25 - 1 million

2.2.7 Soils and Materials Investigations

Alignment soil samples were taken from trial pits dug at 500m intervals on both sides of the two-lane road to an average depth of 1.0m. Eldoret Regional Materials Laboratory evaluated the samples. Atterberg Limits, Linear Shrinkage, Particle Size Distribution, Standard Compaction Test (AASHTO T99), and Standard CBR Test (4-day soak) [5] were among the experiments performed.

3. RESULTS AND DISCUSSION

3.1 Pavement Design

Alignment Test Results

The alignment soils range from reddish "clayey" soil to darkish brown "clayey" soil and are largely S5 quality; hence, modification of the sub-grade is not required [3] [6]. So far, just one gravel borrow pit source has been studied as a potential borrow area for fill, sub base, base, and shoulder material. To evaluate the characteristics of the material, neat materials from the borrow pit were sampled and tested. The test findings for the alignment soils are shown in table 4 and 5 below.

Table:4 Upande-Kimumu-Peris Alignment test results

PROJECT:UPANDE-PERIS ALIGNMENT TESTS RESULTS

CHAINAGE SECTION	ATTERBERG LIMITS					PARTICLE SIZE DISTRIBUTION (%) %PASSING- BS SIEVES (mm)						GRADING MODULUS GM	Compaction T 180		CBR (%)	Swell (%)	EXIXTING GRAVEL LAYER (mm)
	LL (%)	PL (%)	PI (%)	LS (%)	PM (%)	20mm	10mm	5mm	2mm	0.425mm	0.075mm		MDD (Kg/m^3)	OMC (%)	4 Days soak (neat)		
0+000	48	29	19	8	469	95.8	69.4	49.7	35.8	24.7	20.9	2.19	1924	14.2	20	0.6	130
0+500	43	25	18	10	718	94.9	76.1	53.8	35.6	21.2	18.0	2.25	1948	13.4	21	0.6	145
1+000	46	27	19	11	609	96.0	72.1	52.6	31.8	22.0	19.2	2.27	1966	13.8	19	0.6	120
1+500	52	34	18	9	774	92.1	66.8	54.8	34.1	21.0	18.4	2.27	1932	14.4	23	0.6	175
2+000	44	27	17	12	876	97.2	70.7	50.8	36.8	24.7	20.8	2.18	1956	13.1	18	0.6	160

Table:5 Gate B-Kerio-Dispensary Alignment test results

PROJECT:GATE B-KERIO-DISPENSARY ALIGNMENT TESTS RESULTS

CHAINAGE SECTION	ATTERBERG LIMITS					PARTICLE SIZE DISTRIBUTION (%) %PASSING- BS SIEVES (mm)						GRADING MODULUS GM	Compaction T 180		CBR (%)	Swell (%)	EXIXTING GRAVEL LAYER (mm)
	LL (%)	PL (%)	PI (%)	LS (%)	PM (%)	20mm	10mm	5mm	2mm	0.425mm	0.075mm		MDD (Kg/m^3)	OMC (%)	4 Days soak (neat)		
0+000	55	38	17	9	352	91.8	65.4	45.7	31.8	20.7	16.9	2.31	1888	14.2	19	0.6	125
0+500	52	36	16	13	718	94.9	68.5	48.8	34.9	23.8	20.0	2.21	1842	13.4	18	0.6	150
1+000	56	37	19	12	609	96.5	70.1	50.4	36.5	25.4	21.6	2.17	1902	13.8	21	0.6	115
1+500	52	32	20	10	774	93.6	67.2	47.5	33.6	22.5	18.7	2.25	1854	14.4	24	0.6	155
1+600	48	31	30	14	876	96.1	69.7	50.0	36.1	25	21.2	2.18	1912	13.1	19	0.6	145

Based on Kenya Road Design Manual part III [3], soils are classified based on their CBR range. The two-road links mainly consists of lateritic soils with an average CBR of 19.6 and according to table 6 shown below provided by the manual the sub-grade class is S5.

Table:6 Sub-Grade Soil Class

SUBGRADE CLASS	CBR RANGE	MEDIAN
S1	2-5	3.5
S2	5-10	7.5
S3	7-13	10
S4	10-18	14
S5	15-30	22.5
S6	>30	

Source : Kenya Road Design Manual (KRDM), Part III, 1987

Table 7: Summary of the pavement structure

TRAFFIC CLASS	SUBGRADE CLASS	CROSS SECTION TYPE
T4 (CENSAs 1-3million)	S5 (CBR of 15-30)	IV

Based on the three parameters mentioned in table 7 above and with reference to Kenya Road Design Manual (KRDM), Part III, 1987 a Standard Pavement Structure type 2 was taken as an appropriate **pavement structure**:

- Sub base: 150 mm Natural gravel
- Base Course: 125 mm Cement / lime improved Gravel
- Surfacing: A 50mm thick Asphalt Concrete type II surfacing, with 14/20 as first seal chippings and 6/10 chippings as the second seal on top (Double surface dressing).

3.2 Pavement design using Overseas Road Note 31 [7]

Design data considered:

The design should have a two-lane carriage way

The comparative maximum initial traffic in the year of completion of construction =225 cvpd (sum of both direction).
Traffic growth rate =6.48%

Design life=15years
Vehicle damage factor based on axle load survey=2.5 standard axle per commercial vehicle

Design CBR of sub-grade=19.6

Cumulative number of standard axle (8160kg) $N=[365*(1+r)^{n})-1/r\} *A*D*F$

Where A=initial traffic

D=lane distribution factor =0.75 for two lane carriage way

F=vehicle damage factor=2.5

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n=Design life =15years

r=Annual growth rate =6.48%

N=3,717,976=3.72*10^{6}esa=3.72msa

For a Cumulative number of standard axles of 3.72msa the traffic class is T5 as shown in the table 8 below.

Table 8: Traffic classes

Traffic classes	Range (10^6esa)
T1	<0.3
T2	0.3-0.7
T3	0.7-1.5
T4	1.5-3.0
T5	3.0-6.0
T6	6.0-10
T7	10-17

Source: Overseas Road Note 31, 4th ed., Table 2.2 **[7]**

The CBR of sub grade soils was determined as 19.6, and based on the subgrade strength table 9 below the alignment soils was classified as class S5**.**

Table 9: Subgrade soil class

Class	CBR Range in %
S1	2
S2	3-4
S3	5-7
S4	8-14
S5	**15-29**
S6	30

Source: (Overseas Road Note 31, 4th ed., Table 3.1)

The **pavement structure summary** based on Overseas Road Note 31 is as follows;

- Double Surface dressing=50mm

- Cement or lime stabilized road base=200mm
- Cement or lime stabilized Sub-base=175mm

Based on KRDM [3] and Overseas Road Note 31 [7] and depending on factors such as material availability [8] and economic factors of constructing the two-road links, The final pavement structure was taken as.

- **Cement or lime stabilized Sub-base=175mm**
- **Base Course: 150 mm Cement / lime improved Gravel**
- **Surfacing: A 50mm thick Asphalt Concrete type II surfacing, with 14/20 as first seal chippings and 6/10 chippings as the second seal on top (Double surface dressing).**

3.3 GEOMETRIC DESIGN

The design procedure and the standards adopted were in accordance to the Road Design Manual, Part 1 [9]: Table 10 shows the applicable standards adopted.

Table 10: Geometric design standards adopted

Terrain	Flat	Hilly and rolling
Design speed (km/hr)	80	50 – 80
Lane width (m)	3.0	3.0
Shoulder width (m)	1.	1.
Minimum horizontal radius (m)	350	100 – 350
Cross fall	2.5%	2.5%
Cross fall on shoulders	4.0%	4.0%
Maximum super elevation	6.0%	6.0%
Maximum grade	4%	7%
Minimum grade in cuttings	0.5%	0.5%
Maximum length of straights (km)	1.6	1.6
Sight distance (overtaking) (m)	325 – 475	325 – 475
Sight distance (stopping) (m)	100 – 155	100 – 155
Minimum crest curve length (m)	200	200
Minimum sag curve length (m)	200	200

3.3.1 Right of Way (Road Reserve)

Road design manual part 1 section 2.4 specifies that the road reserve width for class E road should be 20m. Registry Index Maps indicated an average existing road reserve width of 18m. In order to minimize land acquisition and maximize on the existing alignment, the horizontal alignment was designed to follow the existing road as much as possible.

3.3.2 Horizontal alignment

The design of a road's horizontal alignment involves several key elements, including tangent, circular curves, transition curves, and superelevation. According to the Kenya Road Design Manual [9], there are several recommendations for road design in terms of horizontal alignment. The manual suggests that straight sections of roads should not exceed 20 times the design speed ($20V_D$) in kilometers. Additionally, straight lengths should be greater than 6VD between curves turning in the same direction. Circular curves should have a minimum length of 150 meters to avoid kink appearance. Furthermore, the maximum rate of superelevation for bituminous roads is suggested to be 8% for flat, rolling, and hilly terrain, while mountainous terrain should not exceed 6%. These design elements are critical to ensuring that a road is safe and comfortable for drivers, and were carefully considered and optimized in the during the design process.

$$e = V_D^2/260R$$

Where:

e = super elevation rate (decimals)

V_D = design speed (km/h)

R = radius of curve (m)

Minimum Curve Radii

The minimum radius for design of Kenyan roads is obtained from the formula which relates design speed and superelevation rate as shown below.

$$R_{min} = V_D^2/127(e+ fk)$$

Where:

Rmin = Minimum Radius for Road Curves (m)

V_D = Design Speed (km/h)

e = Cross fall of road or the maximum superelevation (%/100). (e = positive for cross slopes sloping down towards the inside of the curve and otherwise, negative).

f = Coefficient of side friction force developed between the vehicle’s tires and road pavement.

Minimum curve radii is summarized in table 11 extracted from KRDM Part I,

Table 11: Minimum radii for horizontal curves [9]

Design Speed V_D (km/h)	40	50	60	70	80	90	100	110	120	140
Min. hor. radius, R min (m)	60	100	160	250	350	450	600	750	1000	1400

3.3.3 Vertical alignment

The main design criterion considered was ensuring the fulfilment of the minimum sight distances as stipulated in the Road Design Manual. The Tanzania Road Design Manual (TRDM) [2] summarizes the applicable sight distances for a given design speed as shown in table 12.

Table 12: Sight distances

Design Speed (km/h)	**Coefficient of Friction (f)**	**Stopping sight distances (m)**	**Passing sight distances from formulae (m)**	**Reduced passing sight distances for design (m)**
30	0.40	30	217	75
40	0.38	45	285	125
50	0.35	63	345	175
60	0.33	85	407	225
70	0.31	110	482	275
80	0.30	130	540	315

90	0.30	169	573	340
100	0.29	205	670	375
110	0.28	247	728	399
120	0.28	285	792	425

Geometric Design Manual: 2011 Edition [2]. Table 6-1: Sight Distances on Level Ground (G=0).

3.3.4 Road Geometric Design using Civil 3D

The Upande-Kimumu-Peris road was used to illustrate the steps essential in road geometric design while using civil 3d software.The procedure used in Civil 3d geometric design is as follows.

Importation of topo data

Topo data with eastings, northings, elevations, and point descriptions were imported into civil 3d software. Table 13 below shows a sample topo data that was used to design the Upande-Kimumu-Peris Road [10].

Table 13: Topograpgic survey data

POINT	NORTHINGS	EASTINGS	ELEVATION	DESCRIPTION
1	64181.45	756618.942	2017.241	cl
2	64183.743	756617.161	2017.168	edge
3	64184.405	756616.349	2017.101	edge
4	64184.836	756615.61	2016.513	DR
5	64179.428	756620.893	2017.287	edge
6	64178.178	756622.223	2017.384	fence
7	64171.475	756615.762	2017.276	fence

Surface creation

After points were imported a surface was created as depicted in figure 5 below.

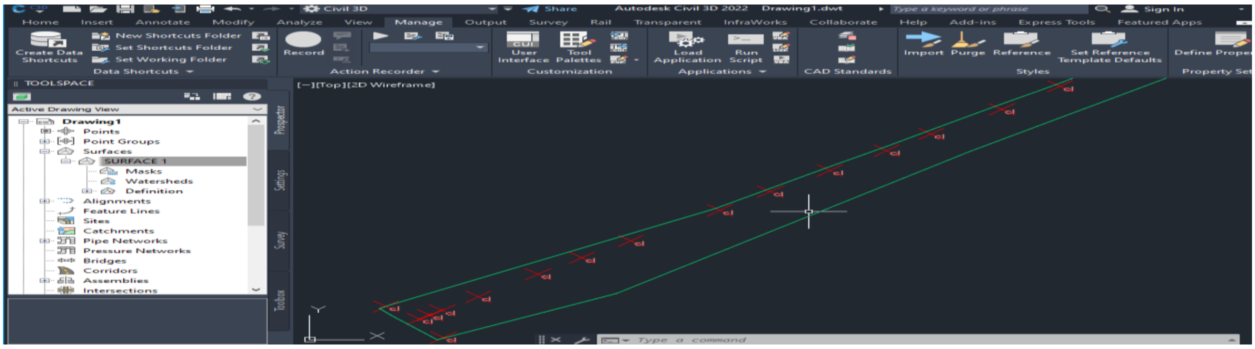

Figure 5: Upande-Kimumu-Peris surface

Horizontal alignment

The design of both the horizontal alignment and the vertical alignment for the Upande-Kimumu-Peris Road and Dispensary Gate B Road was based on design criteria parameters adopted from the Kenya Road Manual [9]. The design speed for the Upande-Kimumu-Peris Road was set at 80km/hr, while the design speed for Dispensary Gate B Road was set at 30km/hr. The superelevation rate was set at 6%, and the friction factor was set at 0.14. For safety reasons, the minimum stopping sight distance adopted was 130m, and the minimum passing sight distance was 540m. The minimum rate of vertical curvature (K) for sag curves was set at 30, while the minimum K for crest curves was set at 26. The roadway width was set at 3m, and shoulder width of 1m. Finally, themaximum grade was set at 4%. Horizontal alignment designed was as close as possible to the existing alignment to alleviate land acquisition costs as shown Figure 6 below.

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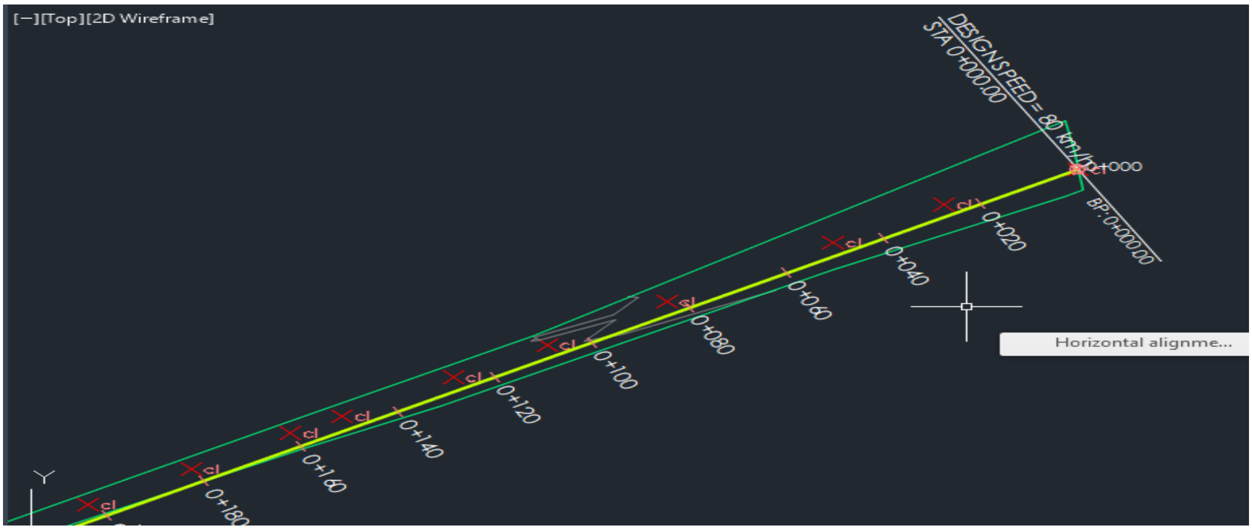

Figure 6: Upande-Kimumu-Peris Horizontal alignment.

Vertical alignment

Figure 7 below shows the vertical alignment profile created. It consists of existing alignment (OGL), stations, vertical curves i.e., crest and sag curves, Profile bands sets and the Design profile [11].

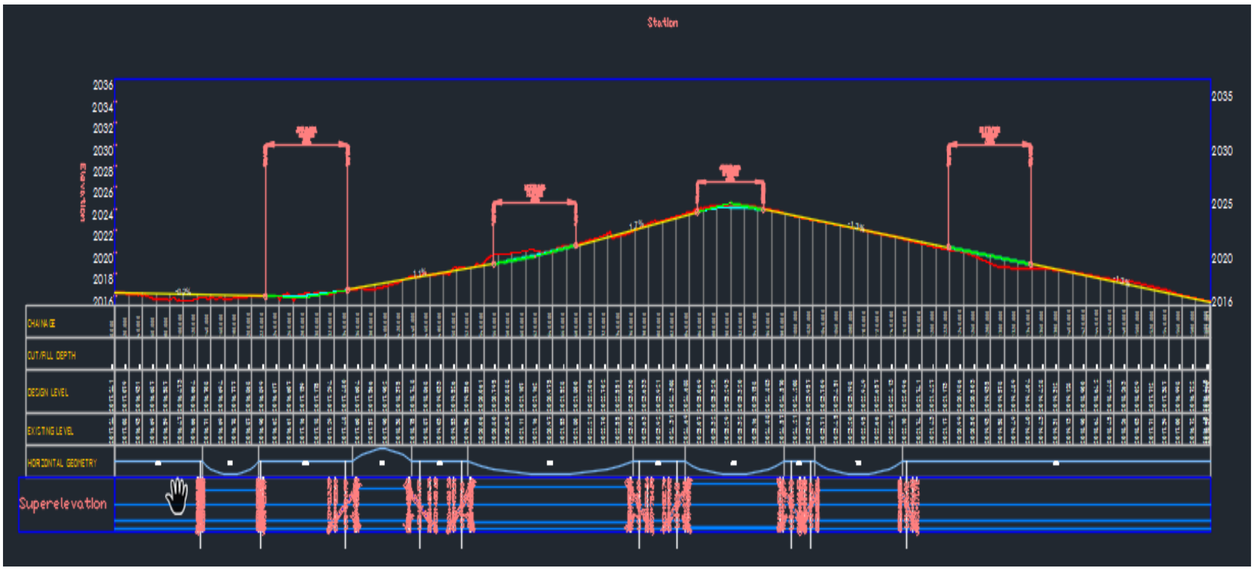

Figure 7: Vertical alignment

Assembly Creation

Pavement structure initially designed was used to create the road cross section [12]. Figure 8 below shows the pavement structure created with normal crossfalls adopted.

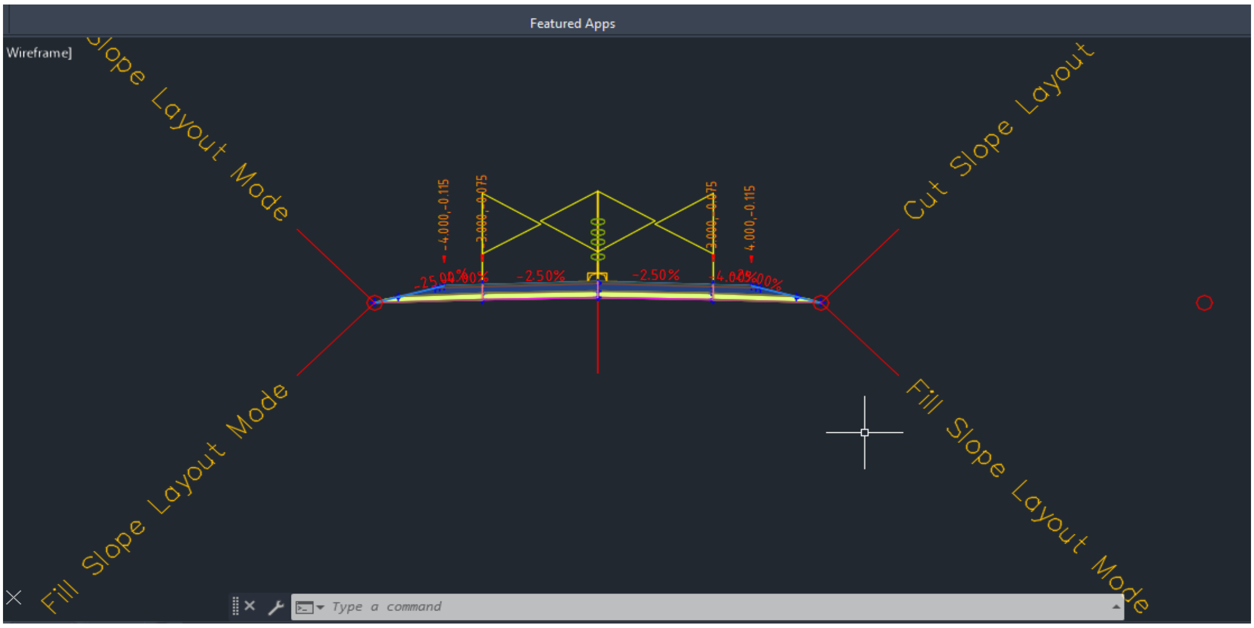

Figure 8: Pavement structure

Corridor creation

Corridor is the resulting dynamic 3D model representation built from the combination of horizontal, vertical and cross section design elements [13]. The Corridor created as shown in figure 9 below was used to compute earthworks, to perform sight and visual analysis, to generate surfaces and to extract information for construction purposes.

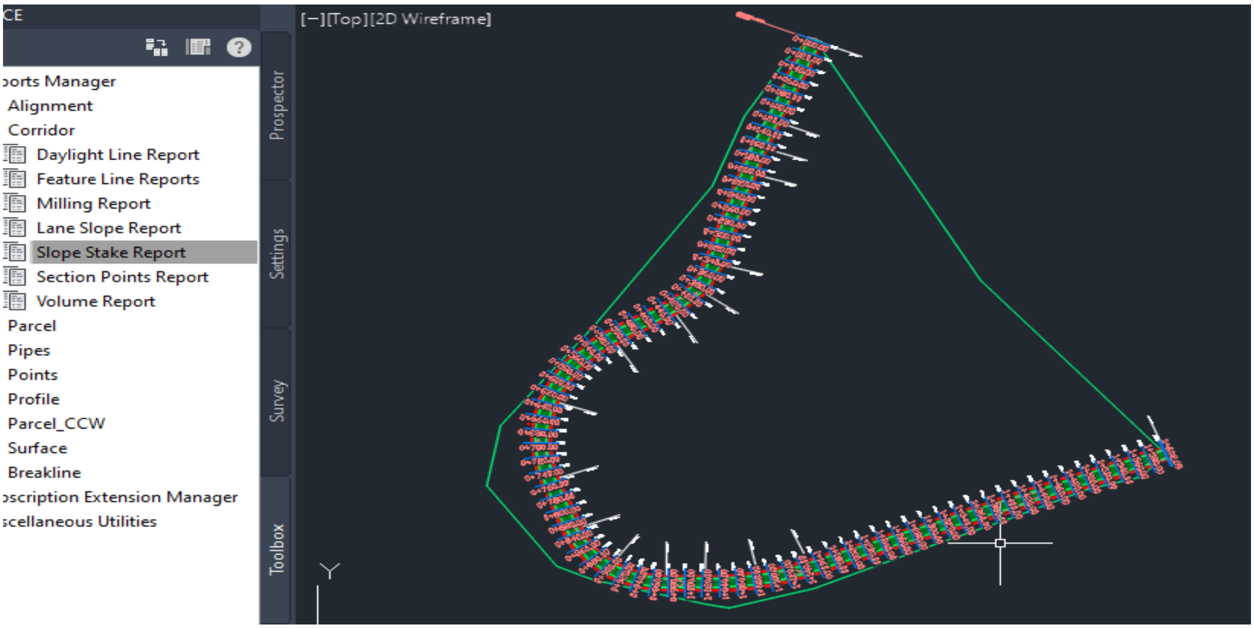

Figure 9: Dispensary-Kerio-Gate B surface and corridor

3.4 QUANTITIES

The design software was used to generate material volume reports that were then utilized to calculate the quantities for both road projects. The project cost determined will be then used in the tendering and bidding process. A sample of generated cut and fill volume is as shown in table 14 below.

Table 14: Upande-Kimumu-Peris Cut and Fill Volume

Station	Cut Area (Sq.m.)	Cut Volume (Cu.m.)	Reusable Volume (Cu.m.)	Fill Area (Sq.m.)	Fill Volume (Cu.m.)	Cum. Cut Vol. (Cu.m.)	Cum. Reusable Vol. (Cu.m.)	Cum. Fill Vol. (Cu.m.)	Cum. Net Vol. (Cu.m.)
0+000.000	0.26	0.00	0.00	0.18	0.00	0.00	0.00	0.00	0.00
0+020.000	1.53	17.89	17.89	0.00	1.87	17.89	17.89	1.87	16.03
0+040.000	0.67	21.98	21.98	0.28	2.84	39.87	39.87	4.71	35.16
0+060.000	1.07	17.41	17.41	0.06	3.39	57.28	57.28	8.10	49.18
0+080.000	1.42	24.95	24.95	0.05	1.09	82.24	82.24	9.19	73.05
0+100.000	2.44	38.60	38.60	0.00	0.50	120.83	120.83	9.68	111.15

A sample of traverse points generated from civil 3D that is essential in setting out of the alignment is as follows in table 15.

Table 15: Upande-Kimumu-Peris alignment incremental traverse points

STATION	Northing	Easting	Tangential Direction
0+000.00	63,103.3930m	757,138.2760m	S60° 55' 57"W
0+020.00	63,093.6762m	757,120.7951m	S60° 55' 57"W
0+040.00	63,083.9593m	757,103.3141m	S60° 55' 57"W
0+060.00	63,074.2425m	757,085.8332m	S60° 55' 57"W
0+080.00	63,064.5257m	757,068.3523m	S60° 55' 57"W
0+100.00	63,054.8088m	757,050.8713m	S60° 55' 57"W

Superelevation data and centerline design levels generated from civil 3d were then imported into excel spreadsheets and used to create Finished Road Levels (FRL). Table 16 below shows an extract of the Finished Road Levels [14].

Table 16: Upande-Kimumu- Peris Finished Road Levels (FRL)

CHAINAGE	SHOULDER (LHS)			CARRIAGEWAY (LHS)			C.L.	CARRIAGEWAY (RHS)			SHOULDER (RHS)		
	EDGE OFFSET	XFALL %	OFFSET	EDGE LEVEL	EDGE OFFSET	XFALL %		XFALL %	OFFSET	LEVEL	OFFSET	X FALL %	LEVEL
0+000	2016.893	-4.00%	-4.50	2016.933	-3.50	2.50%	2017.020	2.50%	3.25	2016.939	4.25	-4.00%	2016.899
0+010	2016.995	-4.00%	-4.50	2017.035	-3.50	2.50%	2017.122	2.50%	3.25	2017.041	4.25	-4.00%	2017.001
0+020	2017.096	-4.00%	-4.50	2017.136	-3.50	2.50%	2017.223	2.50%	3.25	2017.142	4.25	-4.00%	2017.102
0+030	2017.198	-4.00%	-4.50	2017.238	-3.50	2.50%	2017.325	2.50%	3.25	2017.244	4.25	-4.00%	2017.204
0+040	2017.305	-4.00%	-4.50	2017.345	-3.50	2.50%	2017.432	2.50%	3.25	2017.351	4.25	-4.00%	2017.311
0+050	2017.428	-4.00%	-4.00	2017.468	-3.00	2.50%	2017.543	2.50%	3.00	2017.468	4.00	-4.00%	2017.428
0+060	2017.544	-4.00%	-4.00	2017.584	-3.00	2.50%	2017.659	2.50%	3.00	2017.584	4.00	-4.00%	2017.544
0+070	2017.665	-4.00%	-4.00	2017.705	-3.00	2.50%	2017.780	2.50%	3.00	2017.705	4.00	-4.00%	2017.665
0+080	2017.792	-4.00%	-4.00	2017.832	-3.00	2.50%	2017.907	2.50%	3.00	2017.832	4.00	-4.00%	2017.792
0+090	2017.923	-4.00%	-4.00	2017.963	-3.00	2.50%	2018.038	2.50%	3.00	2017.963	4.00	-4.00%	2017.923
0+100	2018.059	-4.00%	-4.00	2018.099	-3.00	2.50%	2018.174	2.50%	3.00	2018.099	4.00	-4.00%	2018.059

Quantities generated were used in collaboration with the cost estimation manual 2022-2023 for road construction and maintenance works. The major bill items quantified in the BOQ based from the Standard Specification for Road and Bridges Construction included bill 1,4,5,7,8,9,12,14,15,20, and 25. The following were the project cost estimates.

- The Upande-Kimumu-Peris project was estimated to cost **105,599,162.66.**
- Dispensary-Kerio-Gate B was estimated to cost **87,006,307.39**.

4. CONCLUSION AND RECOMMENDATIONS

The paper demonstrates that with proper pavement design, suitable and most economical roads can be constructed.

The previous administration in the country as of 30th June 2021 had constructed a total length of road of 8249.2 km at an approximate cost of Kshs.368.7 billion which is about 45 million per every km of road length. The estimated cost of the two-road links considered amounts to about 55million for every km constructed which is slightly above the cost of 1km of a low volume sealed road.

This can be attributed to;

- This project involved a comparative design between Kenya road manual and overseas road note 31to obtain pavement structure. In that case the two pavement structures designed were compared and an optimum pavement structure was chosen in which pavement thickness of different layers were slightly higher than Kenya road design manual.
- Presence of swampy areas along the stretch of the alignments, which calls for rockfill which is costly than filling in soft.

The Kenya Road Design Manual [9] [3] does not cover all aspects of road design and may not be applicable in all road design contexts, such as rural areas, urban areas, and diverse terrain types. The manual contains out-of-date information, standards, and regulations that contradict current best practices and technological advancements. The Kenya Road Manual should be revised to reflect current practices and include all design elements, including friction factors among others.

While carrying out pavement design, it is necessary to evaluate several applicable design manuals in order to come up with the most suitable and cost - effective pavement structure that will last for the design life.

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