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Rutting Failure on Pavement Layers along Timboroa to Eldoret Road Section in Kenya

Waweru S.G.,
Senior Lecturer, Masinde Muliro University of Science and Technology

Onchiri R.O.
Associate Professor, Technical University of Mombasa

Masibayi E.N.
Lecturer, Masinde Muliro University of Science and Technology

ABSTRACT

The Timboroa to Eldoret Road (A104) in Kenya forms part of the Northern corridor which is lifeline for several countries in the greater East African region. Traffic studies along the Timboroa to Eldoret highway indicate that the traffic mainly consist of transit traffic carrying import and export goods to and from the port of Mombasa in Kenya to the countries of Uganda, Rwanda, Burundi, Democratic Republic of Congo and part of Southern Sudan. Axle loading measurements show cases of overloading of the trucks which may have contributed to severe rutting failure of the flexible pavement in some sections. Current design standards and construction methods were reviewed in order to verify their impact on the pavement deterioration. Regression method of analysis was applied on the data obtained to correlate the results with pavement failure. Research findings from this study indicate that the major contributors to pavement distresses are the weak subbase layer and unstable subgrade used which has resulted to permanent deformation. Overloading factor associated with the heavy goods vehicles also plays a significant role. Other factors observed as contributing to rutting are the material characteristics of the base and subbase layers.

Keywords: traffic, axle loading, rutting failure, flexible pavement

INTRODUCTION

Timboroa - Eldoret road section (A104) is part of the Northern Corridor International Trunk Road which serves as a major transit route linking the port of Mombasa through

Nairobi to other countries like Uganda, Rwanda, Burundi, Democratic Republic of Congo and Republic of South Sudan. This road section is approximately 73km long within Uasin Gishu County, and starts at Timboroa through several trading centres of Nabkoi, Kondoo, Burnt Forest, Cheptiret and ends at Eldoret municipality. Figure 1 shows the location of the study area and existing drainage conditions.

As part of the international trunk road linking landlocked countries to the port of Mombasa, the road section exhibits heavy traffic emanating majorly from the port of Mombasa and the capital city of Nairobi. Thus the traffic on the Eldoret bound (Northern bound) lane or Left Hand Side lane is characterized by overloaded heavy goods vehicles heading to Malaba border and beyond, while the Timboroa bound (Southern bound) lane or Right Hand Side has light traffic comprising mostly of empty trucks returning back to the port of Mombasa after delivering their goods.

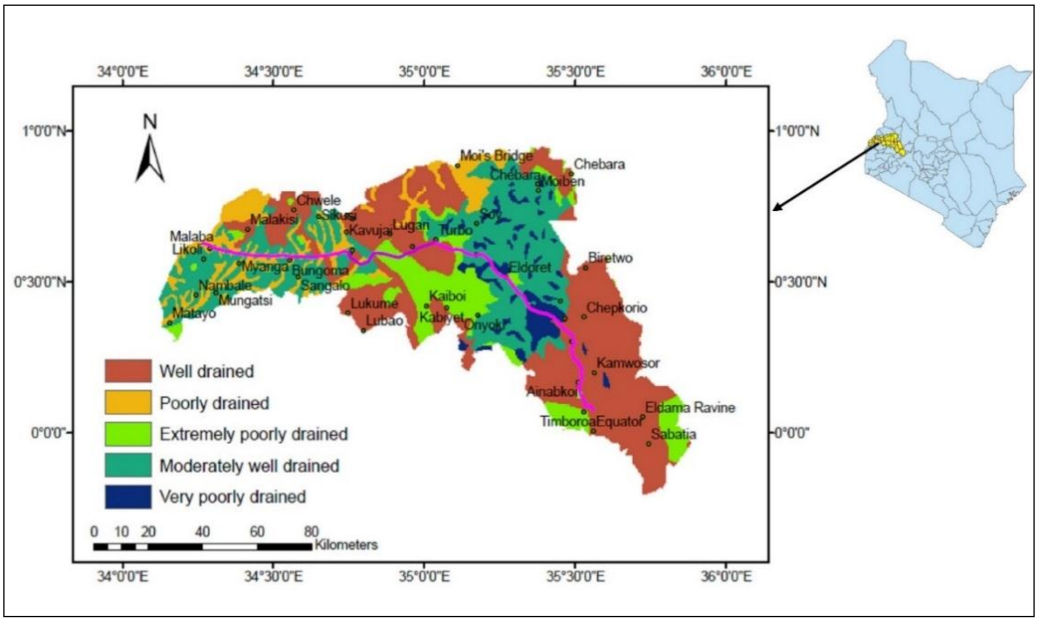

Figure 1: Location of the study area in Western Kenya

The stability of the pavement layers and more so the subgrade layer relies immensely on the drainage conditions of an area (Salama 2005). A poorly drained soil will cause the water table to raise and therefore affect the subgrade layer which is the foundation. It is observed that rutting was prevalent in the well-drained sections as well as those that are moderately well drained. This means that the drainage condition did not play a significant role on the development of rutting on the road section. Apart from a few swampy areas observed around Timboroa and toward Eldoret town, it is imperative that the ground water table was apparently deep and therefore not significantly affecting the road pavement. The rutting failure as shown in Plate 1 was so severe in some sections not necessarily with drainage problems but dictated by other factors (Waweru et.al 2016).

Plate 1: Severe rutting observed along the road section

RESULTS AND DISCUSSIONS

Pavement and Subgrade Moduli

The deflection data obtained from the Falling Weight Deflectometer (FWD) was analysed using the Rosy Design Software to obtain layer moduli and overlay for the homogeneous sections identified. The Moduli of Elasticity for the pavement layers (surfacing, base, subbase and subgrade) are shown in Table 1.

Table 1: Pavement Layers Elastic Moduli for Homogeneous Sections

	Elastic Modulus, E_M (MPa)			
Homogenous section	**Surfacing**	**Base**	**Sub base**	**Sub-grade**
Km 0+000 - Km 4+000	9800	10924	1667	223
Km 4+000 - Km 14+700	8466	8067	1544	174
Km 14+700 - Km 28+950	6625	6012	1023	154
Km 28+950 - Km 33+800	6621	5725	1157	138
Km 33+800 - Km 42+400	6920	7092	1175	160
Km 42+400 - Km 66+600	8493	9523	3750	218
Km 66+600 - Km 73+600	8053	7371	1443	207
Average E_m(MPa)	**7854**	**7816**	**1680**	**182**

Graphical figures of the Elastic moduli for the subgrade, subbase, base and surfacing layers are presented in Figure 2 to Figure 5.

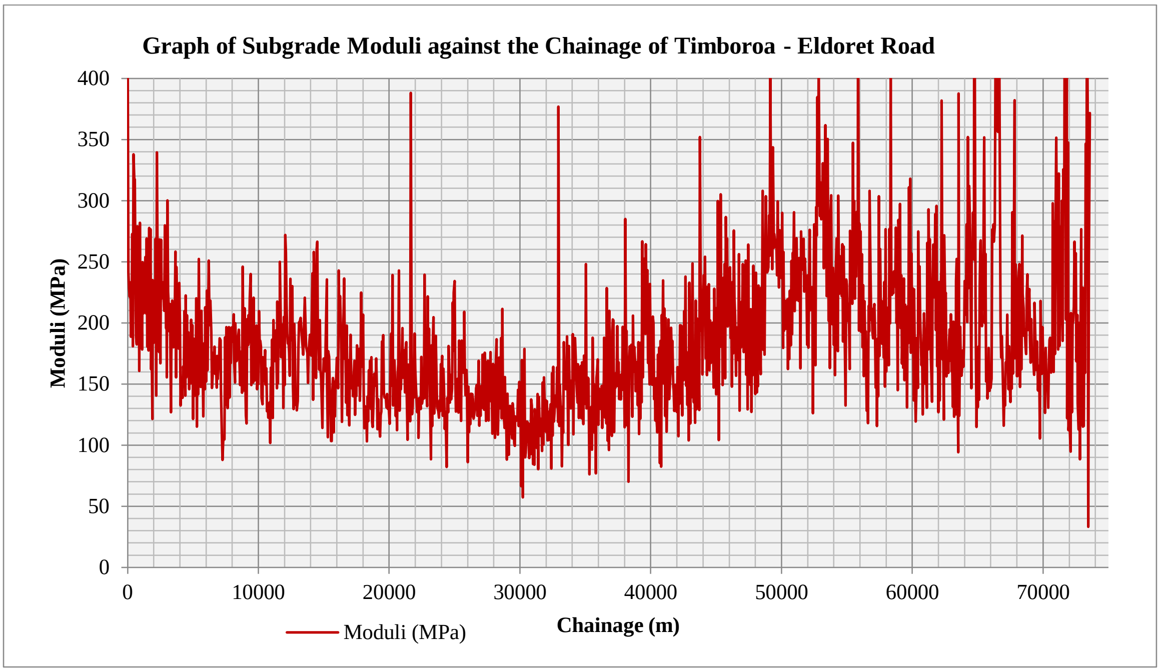

Figure 2: Moduli of subgrade layer along Timboroa – Eldoret section

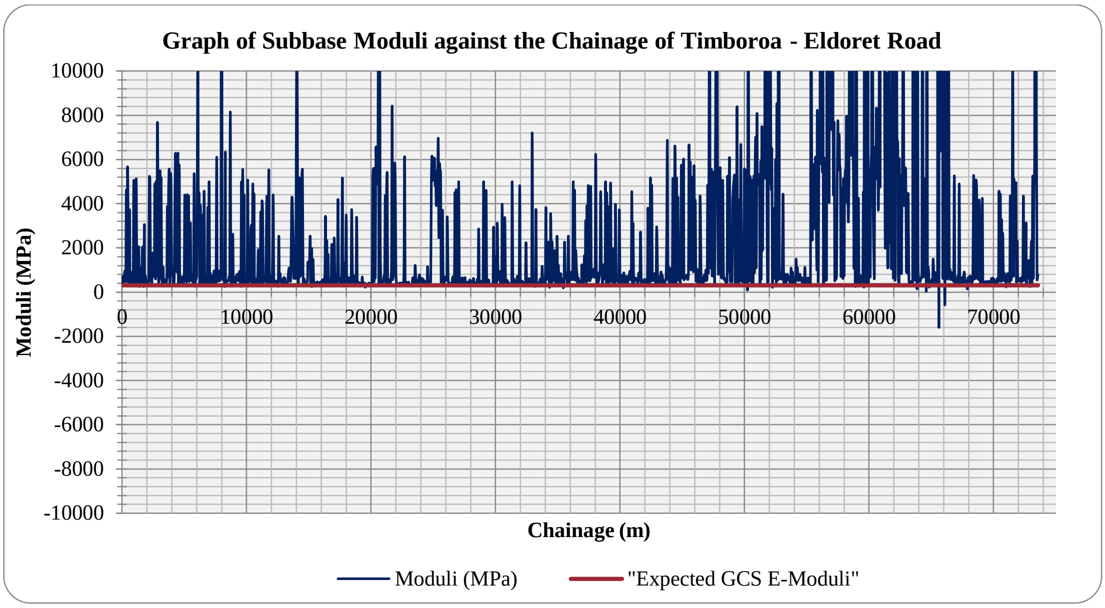

Figure 3: Moduli of subbase layer along Timboroa – Eldoret section

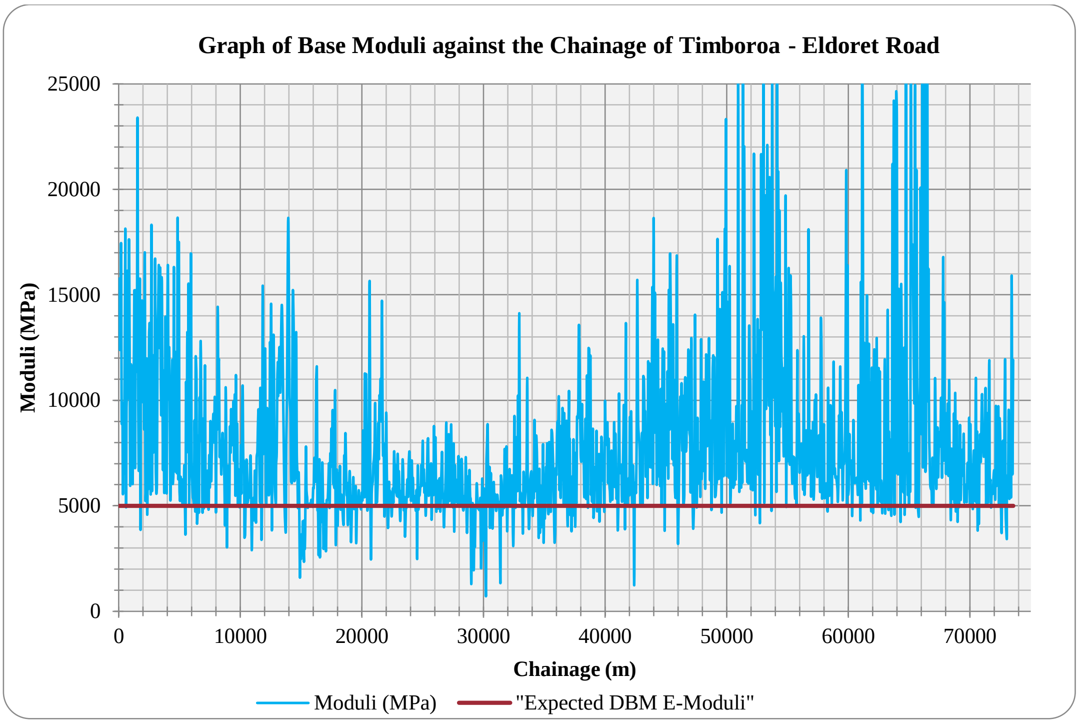

Figure 4: Moduli of base layer along Timboroa – Eldoret section

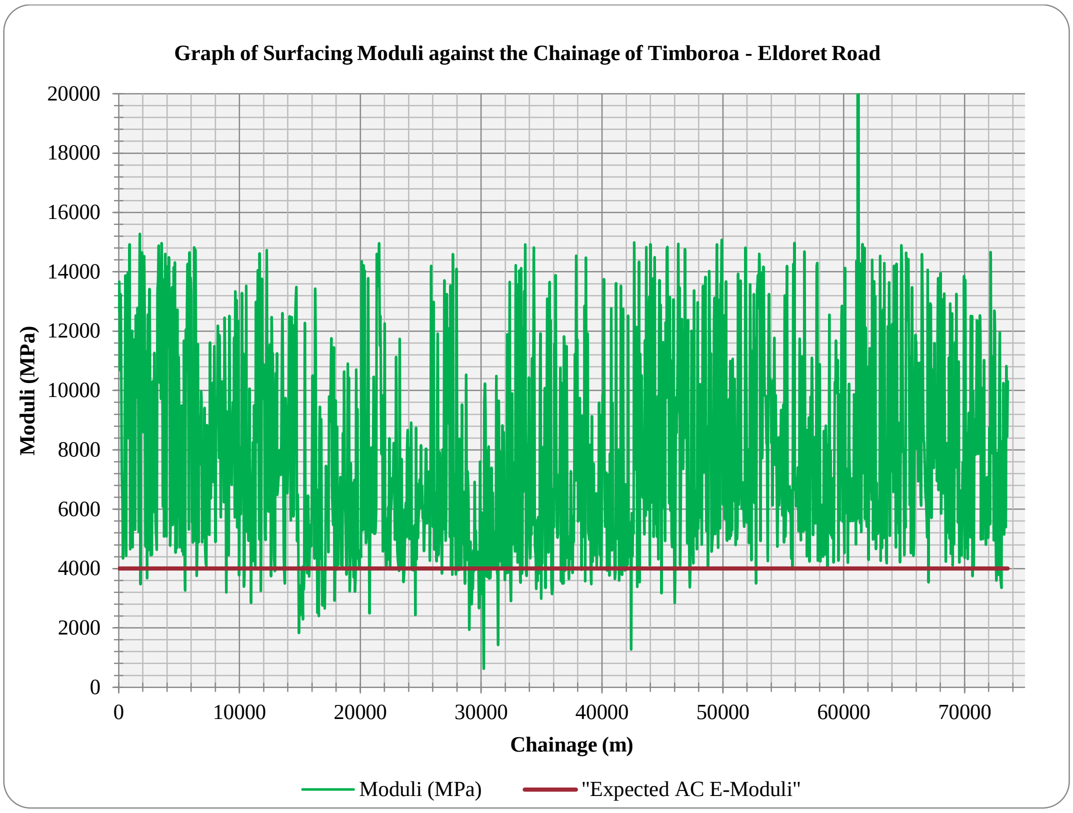

Figure 5: Moduli of Surfacing along Timboroa – Eldoret

From the plots in Figures 2 to 5, the following can be deduced after the analysis of moduli of elasticity values for the different layers at a pavement temperature of 25^0C which is equivalent to air temperature of 20°C given in Kenya Road Design Manual part IV:

(i) **Sub-grade:** The average elastic moduli values indicate sub-grade Classes S5 at in-situ moisture condition;

(ii) **Sub-base:** The average elastic moduli values for most sections are above the moduli values attributed to neat GCS of 400 MPa therefore the sub-base layer is considered to be stable due to consolidation;

(iii) **Base:** The average elastic moduli values are above the value of 5000 MPa attributed to dense bitumen macadam.

(iv) **Surfacing:** The average elastic moduli values are above the value of 4000 MPa attributed to Asphalt Concrete.

Correlation between Soil texture and Rutting

In this study the soil texture was used to compare the rutting distress to the soil profile type along the Timboroa to Eldoret road section. From Figure 6 it is observed that severe rutting was taking place in the road sections with clayey soils as the subgrade material.

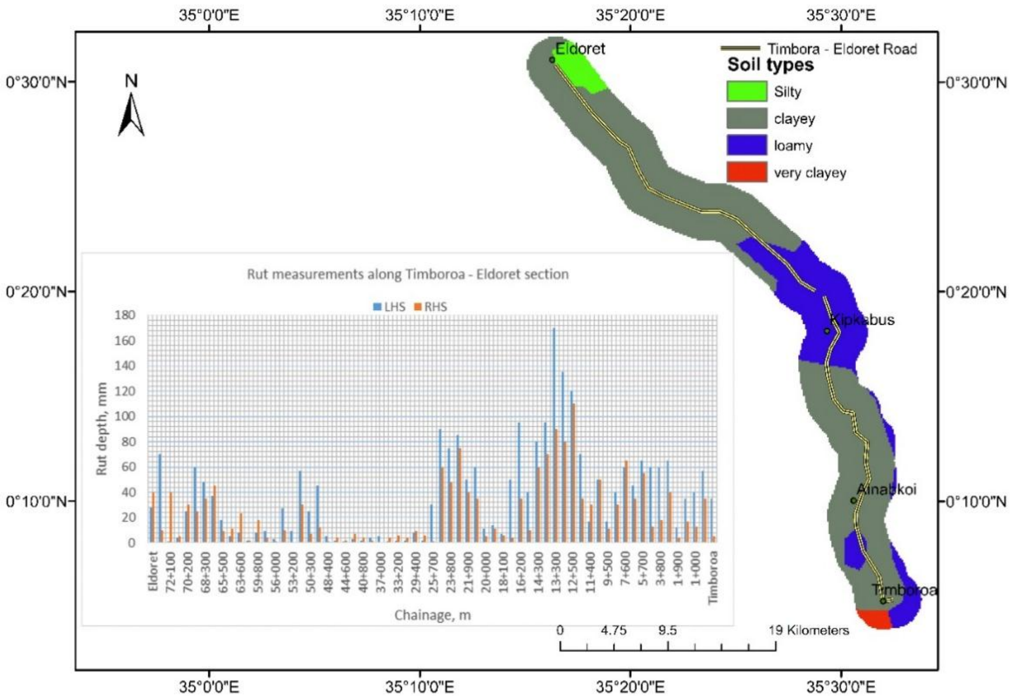

Figure 6: Correlation between Rut depth and the Soil type

Most sections of the road were dominated by the red clay soil and in some instances the expansive clay soil locally referred to as black cotton soil. In sections covered by the loamy soils less rutting was experienced. From these analysis it can established that the subgrade layer is the major contributor to the stability of the pavement against the rutting problem.

Correlation between Geological data and Rutting

Geological data was obtained from the digitized lithology maps using ArcGIS software. The digitized map in Figure 7 shows the presence of three types of igneous rocks (basic igneous, igneous and intermediate igneous). Sections prevalent with basic igneous and the intermediate igneous rocks has the severest rutting cases. This is mainly between Timboroa and Ainabkoi, and the section towards Eldoret town. From the plotting it can be concluded that subgrade soils founded on the basic igneous and the intermediate igneous rocks are quite unstable and unsuitable to support the road pavement.

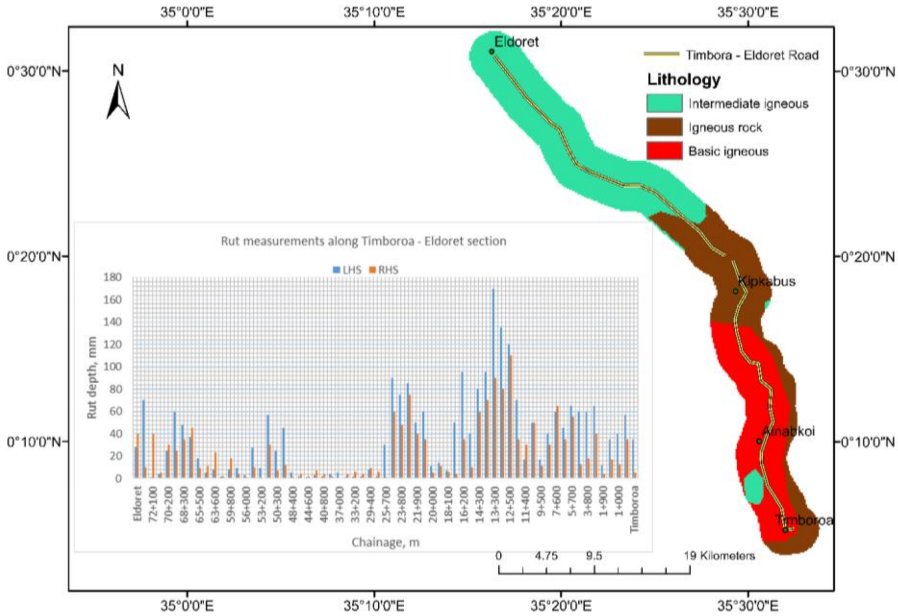

Figure 7: Correlation between Rut depth and Lithology

Correlation between Drainage and Rutting

The stability of the pavement layers and more so the subgrade layer relies immensely on the drainage conditions of an area (Paterson 1987). A poorly drained soil will cause the water table to raise and therefore affect the subgrade layer which is the foundation. Figure 8 compares the rutting depth against the drainage conditions within the study area.

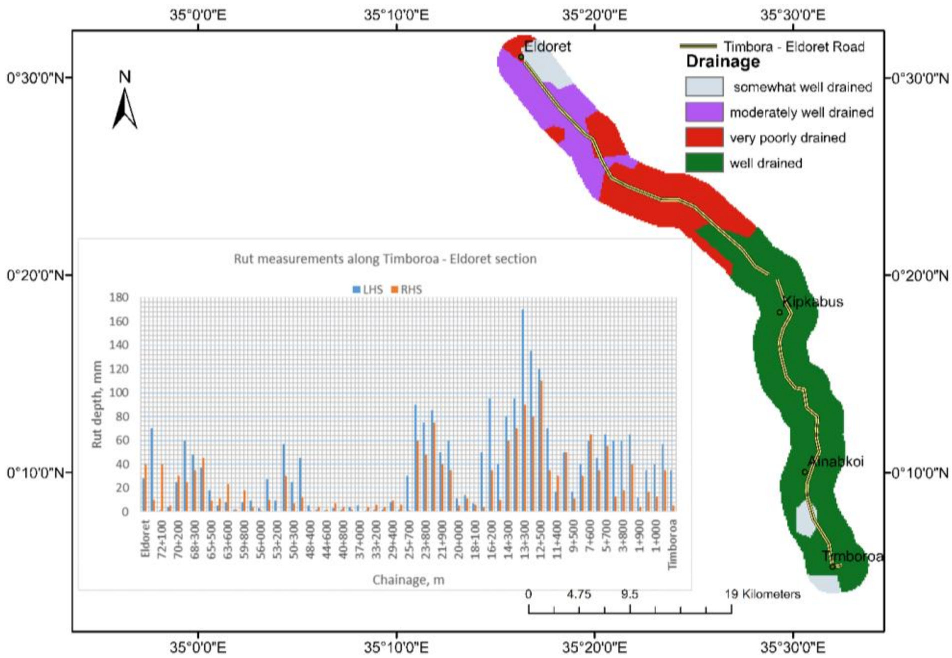

Figure 8: Correlation between Rut depths and Drainage conditions

From the plotting it is observed that rutting was also prevalent in the well-drained sections as well as those that are moderately well drained. This means that the drainage condition did not play a significant role on the development of rutting on the road section. Apart from a few swampy areas observed around Timboroa and toward Eldoret town, it can be concluded that the ground water table was apparently deep and therefore not significantly affecting the road pavement.

Homogenous Sections and Deflection Bowls

Identification of homogeneous sections was achieved using cumulative difference method of the central deflections (Myers et.al 1999). Results for the ccumulative sum of mean normalised central deflections for the homogeneous sections are plotted in Figure 9. The results indicate that the mean normalized central deflection was very high in the first stretch of the Timboroa to Eldoret road section from chainage 0 to 30 Km and chainage 55 to 73 Km indicating a serious problem with the pavement layers.

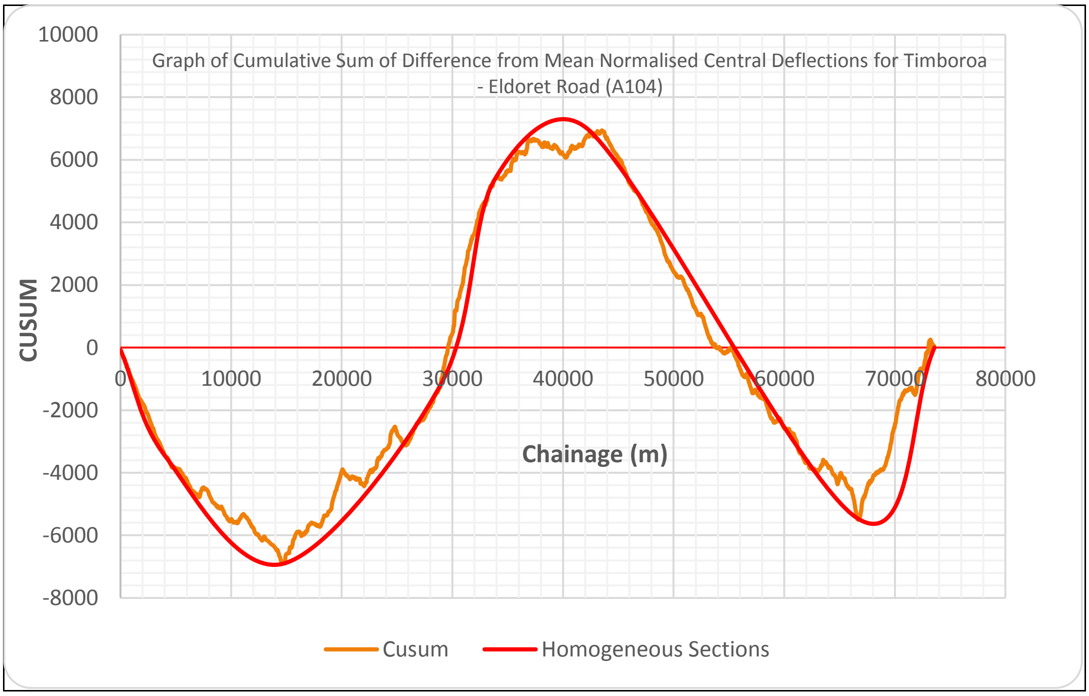

Figure 9: Plot of Cumulative Sum of Mean Normalized Central Deflections

The strength of the sub-grade and variation of strength in pavement layers affect the shape and form of the deflection bowl. The deflection bowls for the selected homogenous sections are as shown in Figure 10.

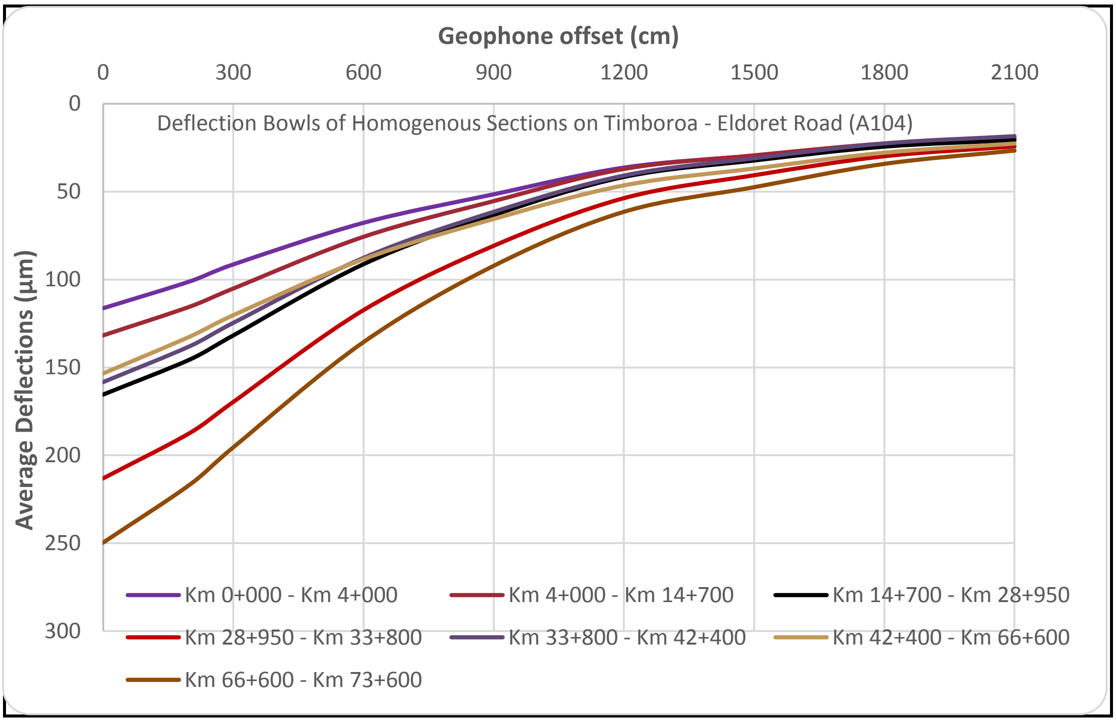

Figure 10: Deflection bowls of Homogenous sections

From the plots of the deflection bowls represented in Figure 10 for the Timboroa to Eldoret road section, the following can be deduced:

(i) The sections from Km 0+000 – Km 4+000 and Km 4+000 – Km 14+700 have stronger pavements compared to the other sections as indicated by the shallow deflection bowl; and,

(ii) The section from Km 66+600 – Km 73+600 has the weakest pavement as shown by the deep deflection bowl.

CONCLUSIONS

The soil properties, hydrogeological conditions and the surface and structural conditions of the pavement along the road section were analysed and the following can concluded:

1. The properties of the subgrade soil along the road section are found to play an insignificant role to the general rutting failure.
2. The hydrological conditions especially the drainage conditions in some sections have contributed immensely to surface and structural distresses including rutting failure.
3. The subgrade layer is the major contributor to the stability of the pavement against the rutting problem and therefore should be well designed and constructed.

4. The average residual life of the subbase was less than the design life. This therefore demands for review of the design standards for the subbase layer of the flexible pavements (HMA) on Kenyan roads
5. Traffic loading is found to have a direct contribution to the rutting failure in most sections. This calls for implementation of stiff regulations against overloading by the transit traffic.

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