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FACTORS CAUSING STRUCTURAL FAILURE OF THE FLEXIBLE PAVEMENT ALONG TIMBOROA TO MALABA ROAD IN KENYA

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ABSTRACT

Transportation infrastructure plays a vital role in the economic and social development of any country and this role cannot be underestimated. The impact of growth and prosperity achieved in the transportation sector extends to include other sectors, and therefore, there is a strong synergy between the growth in transportation sector and the growth in gross domestic product of the country. In Kenya flexible pavements have been adopted for the construction of major highways. A flexible pavement consists of a matrix of sub-base, base course, and surface course positioned on top of the subgrade to support and distribute the traffic load uniformly. Distresses in the form of rutting, cracking and ageing are a common occurrence on HMA pavements. Rutting is one of the habitually observed permanent distresses on major highways in Kenya and consequently instigated this research. This paper addresses the factors and attributes which leads to structural failure of the flexible pavement along the Timboroa - Malaba (A104) road section and goes ahead to point out the major

Key words: Transportation, Flexible Pavement, Distresses, Rutting

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INTRODUCTION

The transportation system of a country is one of the main investments every modern society must make (World bank, 1994). It is therefore of great importance to base decisions on a well-founded design method and to have a good overview of the maintenance needed during a system's service life in order to minimize both the construction cost and maintenance cost (Claussen, 1977). Pavement structures wear down and deteriorate under heavy loadings and exposure to climatic conditions such as high and low temperatures, freezing, underground water and increased precipitation (Lister, 1981). The pavements must therefore be properly designed to begin with and the service life should be maintained and improved on a regular basis.

The quality and performance of road pavements significantly affects the safety and comfort of road users, the effective management of the road freight task, the load-carrying capacity and hence the life of the road, the type and extent of wear and tear on vehicles, especially heavy vehicles and the impact on amenity of the surrounding natural and built environment (Paterson, 1987).

A study conducted on 85 developing countries found that 25 % of the paved roads outside urban areas have been lost owing to inadequate maintenance. This loss could have been saved with preventive maintenance costing $12 billion. In addition, 40 % of the paved roads were in need of routine maintenance in five years costing $40 billion. However, if no action is taken, the cost will reach $100 billion. The crisis has reached such dimensions, because the rate of deterioration of roads is not immediately evident. New paved roads deteriorate very slowly and almost imperceptibly in the first ten to fifteen years of their life, and then deteriorate much more rapidly unless timely maintenance is undertaken (The World Bank 2002).

Pavement failure is a common distress feature frequently observed on most Kenyan roads. It occurs predominantly on the hot mix asphalt (HMA) layer and includes alligator and longitudinal cracking, rutting, lateral deformations, potholes, corrugations and surface stripping. Rutting is a surface depression which normally appears along the wheel path. It has been well documented that the subgrade soil plays a critical role in the initiation and propagation of permanent deformation of pavement structures and therefore directly influences pavement performance (Huang, 1993).

Pavement uplift (shearing) may occur along the sides of the rut. Ruts are particularly evident after a rain when they are filled with water that often results to hydroplaning or aquaplaning problems. It is a fact that all highway pavements will deteriorate over time which in essence determines the service life of the pavement. The situation in Kenya is not any different as witnessed by the high frequency of pavement failure on our roads.

RUT DEPTH MEASUREMENTS

The rut depth measurements were taken at the edge of the road, at 500mm, 1000mm, 1500mm, 2000mm, 2500mm and 3000mm on each lane. Measurements were carried out at 1km intervals and at closer intervals in the most rutted sections. Plate 1 & 2 indicates the extent of the rutting along the road section.

The data processing was mainly to subtract the height of the upstands and find the deepest measure in each profile. The results of the rut depth measurements along Timboroa – Eldoret road section chainage 0 to chainage 80 are illustrated in figure 1

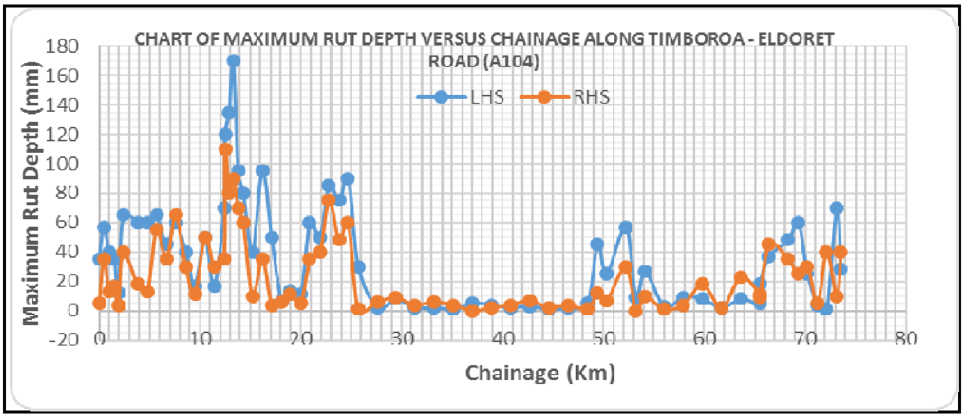

Figure 1 Maximum rut depths along Timboroa – Eldoret Road (A104)

The Figure 1 illustrate the maximum rut depth from chainage o to chainage 80. It was observed that 36% of the road is in a sound condition, 15% of the road will need minor overlay for more than 20% of the road length and 49% of the road will require reconstruction.

RESULTS FROM FIELD AND LABORATORY TESTS

Atterberg Limit tests

The Atterberg tests were carried out on samples collected along the road. Plasticity index (PI) which indicates the degree of plasticity of a soil was determined. The greater the difference between liquid and plastic limits, the greater is the plasticity of the soil. A cohesionless soil has zero plasticity index. Such soils are termed non-plastic. Fat clays are highly plastic and possess a high plasticity index.

Table 1 Atterberg Limit test results along Timboroa – Eldoret road

Chainage	Reference	Atterberg Limits				
		LL (%)	PL (%)	PI (%)	LS (%)	PM
0+399 LHS	Improved subgrade	46	31	15	8	375
12+950 LHS	Improved subgrade	38	23	15	8	555
20+525 LHS	Improved subgrade	38	20	18	9	1242
30+200 RHS	Improved subgrade	44	26	18	9	954
40+000 LHS	Improved subgrade II	43	23	20	10	840
40+000 LHS	Improved subgrade I	48	30	18	9	918
50+253 RHS	Improved subgrade II	44	22	22	11	924
50+253 RHS	Improved subgrade I	44	22	22	11	1628
60+620 LHS	Improved subgrade	46	27	19	10	1026
70+165 RHS	Improved subgrade	45	24	21	11	966

Test results of the Atterberg limits of the subgrade soil along Timboroa to Eldoret road are shown in Table 1. The plasticity index ranged between 15% and 22% with an average value of 19%. The results indicates a subgrade composed of clay of medium to high plasticity.

Grading curves

Soil samples for the subgrade layer were also subjected to sieve analysis. The results from the sieve analysis are shown in Figure 2. The plotted grading curves indicate that they fall within the envelope of the maximum and minimum recommended sizes. This shows that the subgrade soil was well graded in most sections along the Timboroa - Eldoret road. The subgrade soils along the road section ranged between fine silts to coarse gravel.

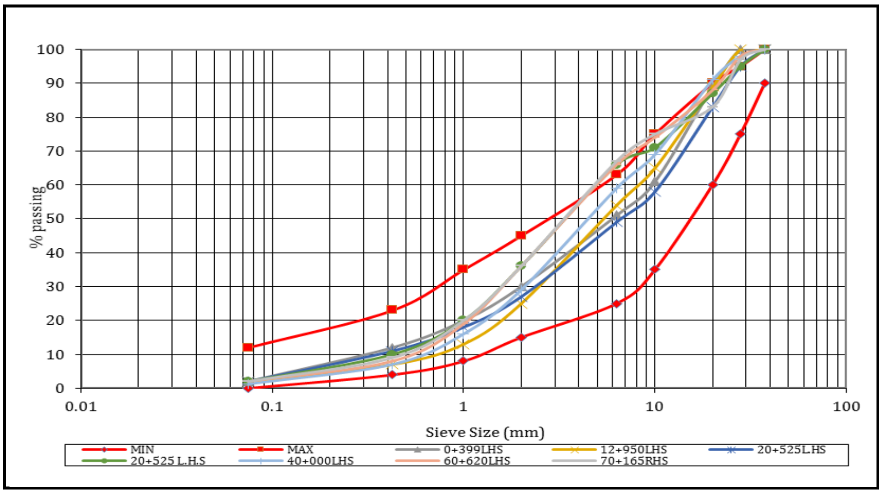

Figure 2 Grading curves for subgrade soil along Timboroa – Eldoret Road

CORING

Coring was done to ascertain layer thickness, depth of cracks and obtain samples for laboratory testing at the various locations on the road section. The cores were obtained in accordance to ASTM D3549 of thickness and density of pavement cores. From the cores, the Asphalt Concrete (AC) bitumen content and core voids were determined.

From Figure 3, the binder content for the Asphalt Concrete cores ranged from 4.7% to 6.3% with an average of 5.8%. The core voids ranged from 1.4% to 4.1% with an average of 2.4%. The voids in 75% of the cores tested are below the specified minimum (3%) for Type I wearing course for this road section (according to Kenya Road Design Manual - KRDM Part IV 1987).

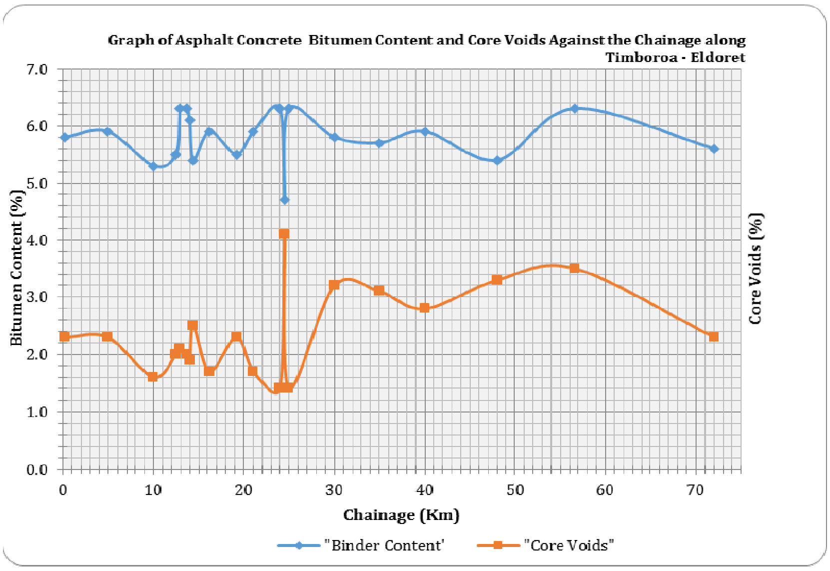

Figure 3 Bitumen content and Core voids for Asphalt Concrete

The binder content from the DBM cores as shown in Figure 4 ranged from 4.0% to 5.9% with an average of 4.5%. The core voids ranged from 3.4% to 6.9% with an average of 4.9%. The core voids in 35% of the cores tested are below the specified minimum (4%) for DBM in the standard specifications (KRDM Part IV 1987).

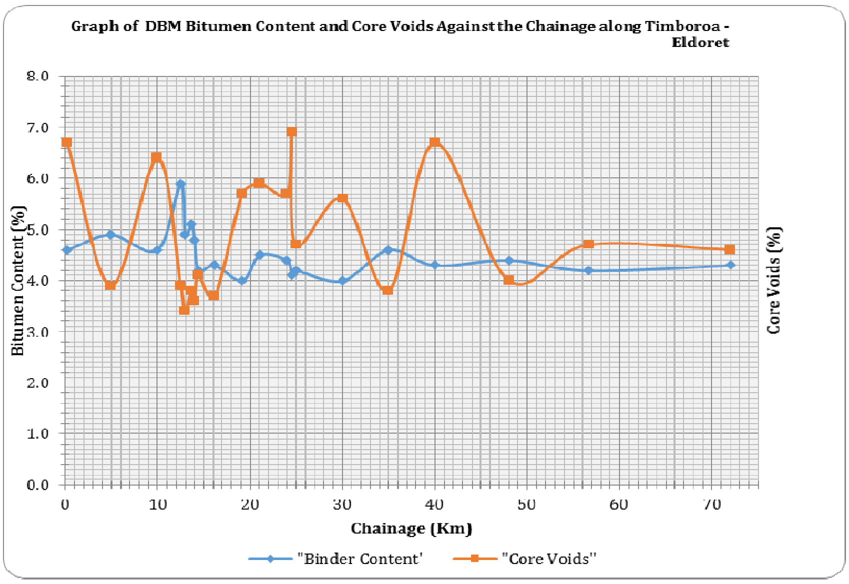

Figure 4 Bitumen content and Core voids for DBM

Grading of the aggregates was carried out to determine the particle distribution of the AC and DBM. Figures 5 and 6 represent the grading of the aggregates obtained from the Asphalt Concrete (AC) and Dense Bitumen Macadam (DBM) cores respectively.

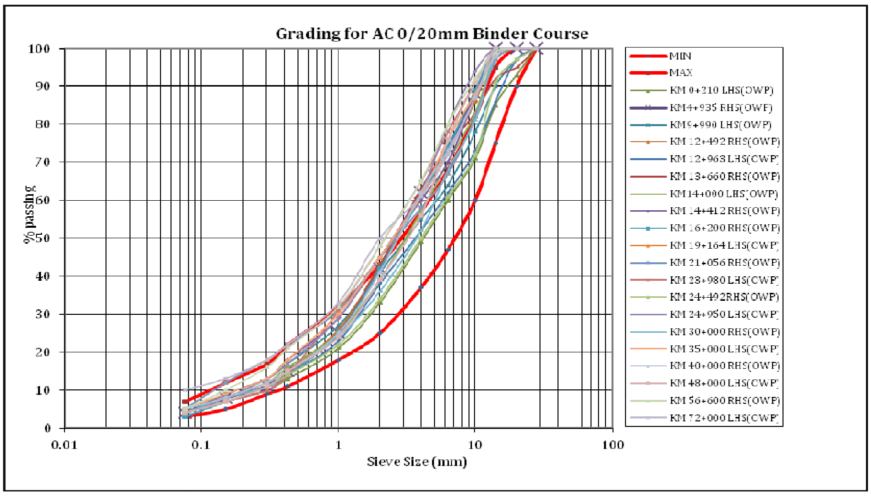

Figure 5 Grading curves of AC core aggregates

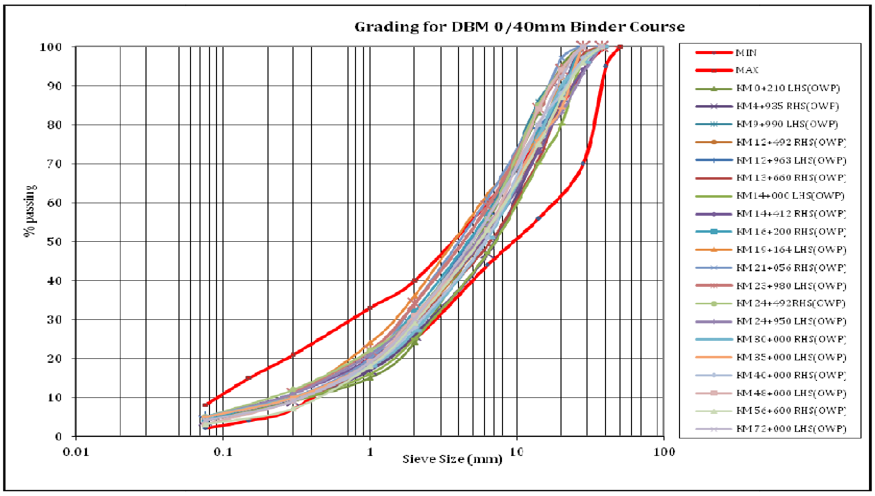

Figure 6 Grading curves for DBM core aggregates

The grading curves taken for the AC core aggregates and the DBM core aggregates indicates that both the asphalt concrete and dense bitumen macadam aggregates are outside their respective recommended envelopes or specifications. Previous research studies have realized the important role, the coarse aggregate plays in the rutting behavior of HMA related aggregate structure stability to coarse aggregate morphologies (Klaus, 2003). Conversely, instead of locking together, smooth, rounded aggregate particles tend to slide past each other. If the aggregate provides a high degree of internal friction (Ø), the shear strength of the asphalt mixture will be increased and, therefore, the resistance to rutting. This is accomplished by selecting an aggregate that is angular, cubical, has a rough surface texture, and is graded in a manner to develop particle to particle contact (McGennis *et al*, 1994)

DISCUSSIONS

Permanent deformation in asphalt (flexible) pavements, commonly referred to rutting, usually consists of longitudinal depressions in the wheel paths, which are an accumulation of small amounts of unrecoverable deformation caused by each load application. From the rut depth measurements it is evident that rutting was more severe on the Left Hand Side (LHS) as compared to the Right Hand Side (RHS) of the road. This can be attributed to overloading of the heavy goods vehicles travelling from the port of Mombasa to the border town of Malaba. The South bound heavy goods vehicles from Malaba towards Timboroa are usually empty having delivered their cargo to their destination therefore explaining the less austere rutting on the RHS. Results from the Atterberg limit tests indicate a subgrade composed of clay of medium to high plasticity. This type of clay is the most possible cause of the heavy rutting in some sections of the highway due to permanent deformation emanating from traffic loading.

From the core samples the core voids for both the asphalt content and the dense bitumen macadam was far below the minimum required as per the standard design specifications in Kenya. The grading curves plotted for the core aggregate samples for the AC and DBM indicate that the materials used during the construction stage for AC and DBM layers were poorly graded for most parts of the road section.

CONCLUSION

The following conclusions can be deduced from this study:

1. The properties of the subgrade soil along the road section are found to play a very insignificant role to the general rutting failure. The hydrological conditions especially the drainage conditions in some sections have contributed immensely to surface and structural distresses including rutting failure.
2. The highly plastic clays encountered in some sections of the road have contributed immensely to severe rutting through the effects of permanent deformation.
3. Grading curves for core aggregates for the asphalt concrete and the dense bitumen macadam layer indicate that there exist a major problem in the mixing of the aggregate materials during construction. This is likely due to lack of close supervision and appropriate quality checks.

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