Interpretation of the Falling Weight Deflectometer (FWD) testing Data for the Nairobi Eastern By-Pass Road Flexible Pavement

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ABSTRACT

Falling weight Deflectometer (FWD) testing is today the common tool used to assess the structural condition of the pavement. The objective of the study was to analyse the FWD surface deflection test results of flexible pavement for the Nairobi Eastern by-pass to predict the pavement's structural capacity. The study observed that the pavement exhibits varying characteristics from strong pavement to moderate pavement as the deflections values fluctuates along the pavement length with much of the pavement stretch being characterized as reasonably strong. Three locations at around chainages14.4km, 24.2kms and 25.8kms had signs of a moderate pavement that required a thin overlay despite the pavement structure showing characteristics of stability. It was recommended that surface dressing with 10/14 class 1 chippings and 80/100 penetration grade bitumen binder for pavement surface treatment will be suitable for the entire stretch of the study section.

KEYWORDS: *Falling Weight Deflectometer testing, Pavement, Surface Treatment, Penetration grade bitumen*

1. INTRODUCTION

As part of a research at the University of Nairobi on the evaluation of flexible pavements in Kenya, the pavement structure of Nairobi Eastern By-Pass Road was evaluated, by conducting FWD deflection testing of the pavement

The FWD is attached on testing truck and comprises of a mechanical loading system, a falling load, and a measuring system. The mechanical loading system simulates the vertical loading element through the induction of load pulses of a single wheel moving at a road speed. The falling weight, applies the load on a rubber buffer that is attached to a stiff loading plate leading to the discharge of haversine fashioned load pulses. The load pulses cause pavement surface deflections that are registered by a set of geophones at an increasing fixed distance from the centre of the loading plate as shown in Figure 1. Further, analysis based on deflection basin-shape indicators and back calculation of pavement layer moduli (E) is performed with the pavement surface deflection data (Doré & Zubeck, 2009).

The performance a flexible pavement in service under traffic loading influences the surface deflections of a pavement. The accumulation of the permanent strains leads to permanent deformation and subsequent cracking of the road surfacing. High deflections always indicate structural deficiency. However, low deflections do not necessarily denote a satisfactory structural condition (Roads Department, 1988).

Three modes of pavement deterioration mechanisms include; fracture, distortion and disintegration (Roads Department, 1988). The deterioration rate of a pavement is influenced by; nature of subgrade soils and the landscape, pavement materials used for pavements construction and pavement layer thicknesses, surface and subsurface drainage, construction and maintenance workmanship, environmental factors - rain, frost, solar radiation; volume, axle loads and configuration of traffic, and pavement condition (O'Flaherty, 2002).

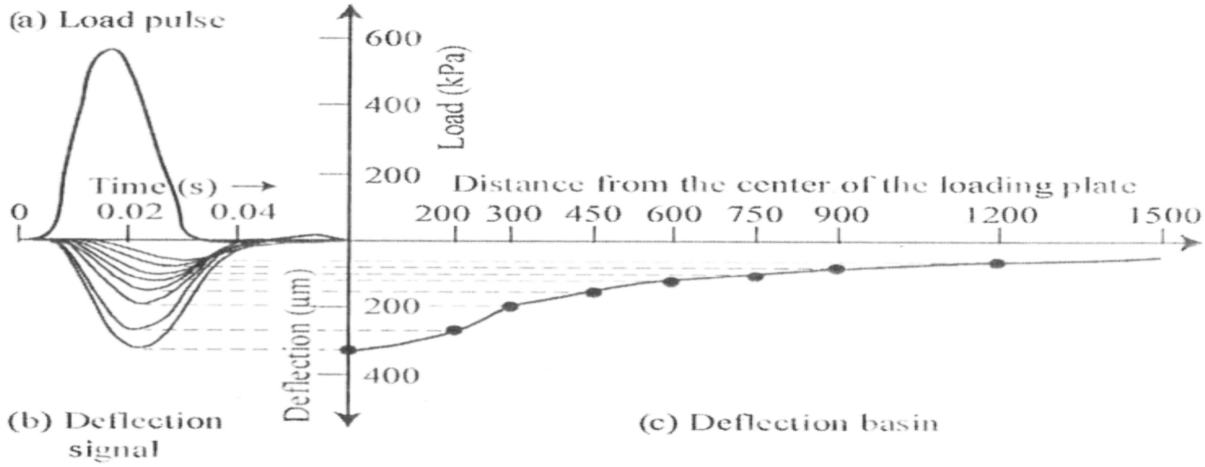

Figure 1: FWD Loading and Pavement Response (Doré & Zubeck, 2009)

2. METHODOLOGY

The test was done in accordance with ASTM D4694 – 09; Standard Test Method for Deflections with a Falling-Weight-Type Impulse Load Device.

2.1 FWD Pavement Deflections' Measurement and Analysis

The Primax Falling Weight Deflectometer (FWD) testing at the Nairobi Eastern by-pass road flexible pavement was carried out on both directions over the entire length at 100m intervals on 15th June 2017. The FWD equipment being towed is shown in plate 1.

Plate 1: Pavement Surface Deflection Measurement Using FWD Equipment

2.1.1 FWD Sensor Spacing

For this research, the spacing of geophones was: 0 mm, 200 mm, 300 mm, 600mm, 900 mm, 1200 mm, 1500 mm 1800 mm and 2100mm (Roads Department, 1988).

2.1.2 Surface Temperature Measurement

The pavement surface temperature was measured and recorded automatically to the FWD file. The monitoring of the surface temperature during testing was used to help the FWD operator in taking decisions to stop testing in case the pavement became very hot.

2.1.3 Variation Characterization of Homogenous Sections

The Cumulative Sum Method (CUSUM) is used on the FWD central deflection measurements (d_o). The CUSUM method involves plotting the cumulative sum of the differences of the FWD deflection (d_o) from the mean FWD value calculated from all the results based on equation 1. The homogenous sections are identified in the CUSUM plot and the design of the overlays or any form of strengthening is based on the characteristics of each homogenous section.

$$S_i = FWD_i - \mathrm{FWD}_{mean} + \mathrm{S}_{i-1} \quad \text{.................................}\textbf{Equation 1}$$

Where:

FWD_{mean} = Mean FWD deflection of the road
FWD_i = FWD deflection at chainage i
S_i = Cumulative sum of the deviations from the mean deflection

(Roads Department, 1988)

2.1.4 Analysis of Pavement FWD Deflection Data

Tables 1 and 2 were used in the interpretation and analysis of FWD deflection values that were obtained from the Nairobi Eastern by-Pass Road.

Table 1: Criteria for FWD Deflection Interpretation for National Roads (TII, 2000)

D1 Criteria	SCI Criteria (D1 – D2)	Comment
<100 µm	<40 µm	Very Strong Pavement
100-200 µm	80-140 µm	Strong Pavement
200-350 µm	140-200 µm	Reasonably Strong May require overlay depending on traffic volume
350-500 µm	200-300 µm	Moderate pavement probably requires overlay depending on traffic volume
500-700 µm	200-300 µm	Moderate to weak pavement requiring overlay (Possibly granular layer required)
>700 µm	>300 µm	Poor Pavement (Granular Layer or Reconstruction required)

Table 2: Use of FWD on National and Regional Roads (TII, 2000)

D_9 Criteria (2100mm Criteria)	Comment
<10 µm	Very Stiff Subgrade
10-20 µm	Stiff Subgrade
20-30 µm	Stiff to Moderate Subgrade
30-40 µm	Moderate to Weak Subgrade
40-50 µm	Weak Subgrade
>50 µm	Very Weak Subgrade

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3. DATA PRESENTATION AND ANALYSIS

3.1 Structural Pavement Conditions of the Nairobi Eastern By-pass Road

3.1.1 Falling Weight Deflectometer (FWD) Data

The pavement deflection data (D_i) measured by the FWD equipment was normalized to standard pressure to obtain the normalized deflections (ND) for all the geophone locations. The analysis and interpretation of the pavement deflection data was based on the normalized deflections (ND). Figure 2 shows that the deflections reduce from the point of load application outwards with ND_1 having higher values of deflections and ND_9 having lower values of deflections.

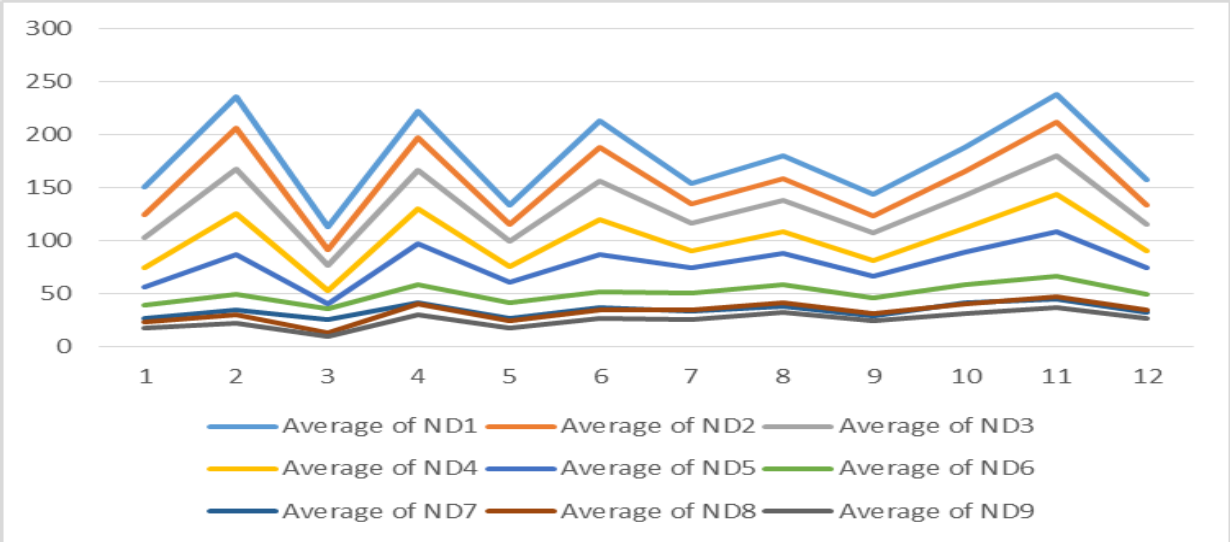

Figure 2: Normalized Pavement Surface Deflection Curves

3.1.2 FWD Central Deflection (ND1) Plot

A plot for the central normalized deflections is provided in Figure 3. There is variation of the central deflections (ND_1) along the pavement with the values ranging from about 90 - 425µm. In reference to table 1, the pavement exhibits varying characteristics from strong pavement to moderate pavement as the deflections values fluctuates along the pavement length. Much of the pavement stretch can therefore be characterized as reasonably strong as the ND_1 are between 200-350µm which may require overlay depending on traffic loading.

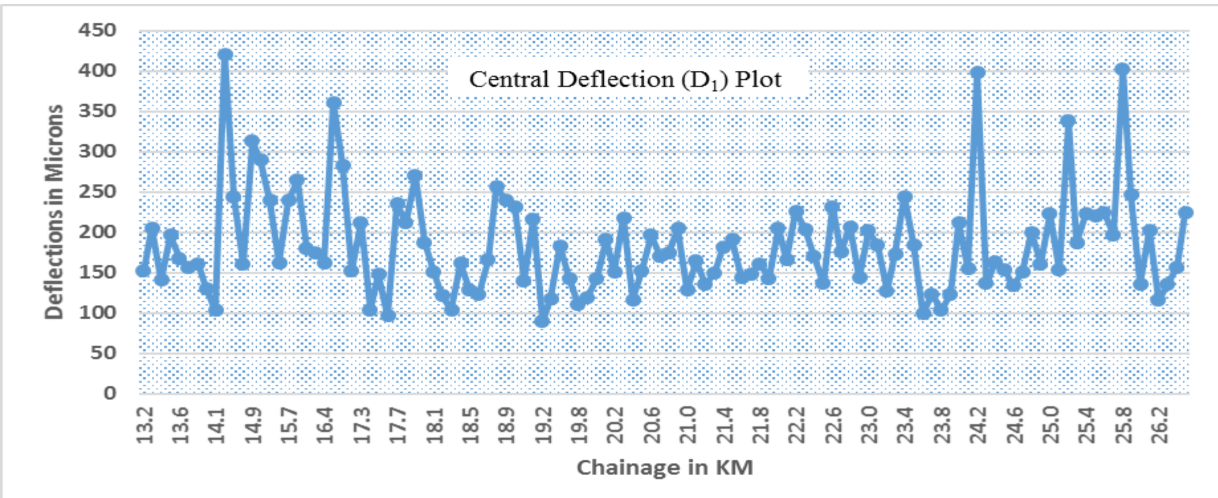

Figure 3: FWD Central Deflection (ND_1) Plot

The results also show that only three locations at around chainage 14.4km, 24.2kms and 25.8kms that have signs of a moderate pavement that may require an overlay depending on the traffic volumes using the road section.

3.1.3 Pavement Surface Curvature Index (SCI)

Surface Curvature Index (SCI) is the difference of deflections measured with geophones in the center of the loading plate (D_1) and 200mm from the center (D_2), and it characterizes the condition of the pavement layers. The pavement surface curvature index curve (D_1 - D_2) range is within 40-80 giving an indication of strong upper layers in the pavement structure in reference to Table 1. Further, it is noted that Figure 4 has the same shape profile like Figure 3 indicating that the upper layers of the pavement have a large influence on the pavement structural condition.

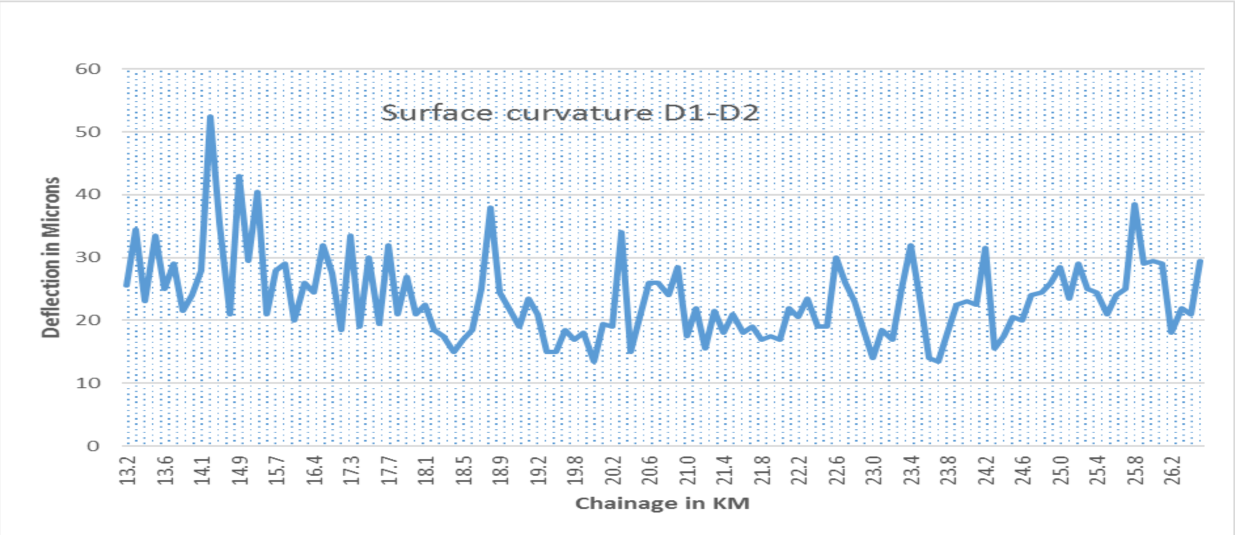

Figure 4: Pavement Surface Curvature Index (SCI)

3.1.4 FWD Outer Deflection (ND_9) Plot

Figure 5 gives a plot for the ND_9 against the chainage along the length of the road. The values of ND_9 are relatively low showing the possibility of a stiff subgrade supporting the pavement structure.

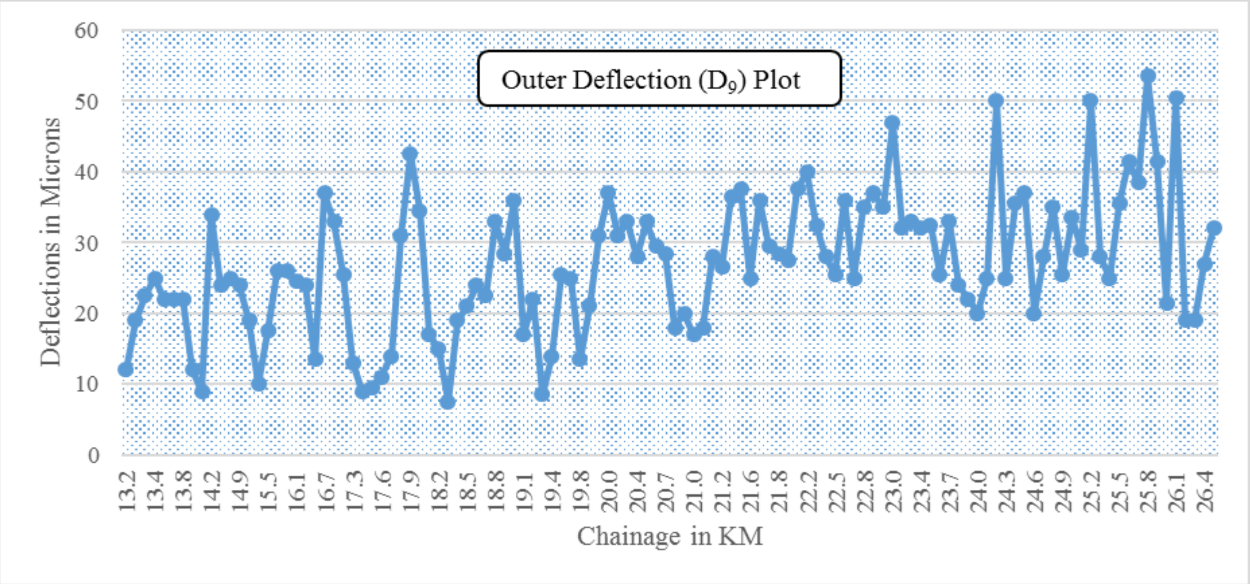

Figure 5: FWD Outer Deflection (ND_9) Plot

4. CONCLUSION

The pavement exhibits varying characteristics from strong pavement to moderate pavement as the deflections values fluctuates along the pavement length. Much of the pavement stretch was characterized as reasonably strong but may require overlay depending on the traffic loading. The pavement surface curvature index gave an indication of strong upper layers in the pavement structure and it was observed that it's the upper layers of the pavement that have a large influence on the pavement structural condition. There is also the possibility of a stiff subgrade supporting the pavement structure.

5. RECOMMENDATION

The results showed that only three locations at around chainage 14.4km, 24.2kms and 25.8kms had signs of a moderate pavement that required a thin overlay despite the pavement structure showing characteristics of stability. Therefore, it is recommended that surface dressing with 10/14 class 1 chippings and 80/100 penetration grade bitumen binder for pavement surface treatment will be suitable for the entire stretch of the study section.

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