Pavement Deterioration Predictive Models for a Section of Ijokodo-Apete Road Ibadan, Nigeria.

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ABSTRACT: A road pavement is a structure composed of structural elements, whose function is to protect the natural subgrade and to carry the traffic safely and economically. When the roads are open to traffic, the pavements deteriorate with time due to the combined influence of the traffic, construction material and the environment. Due to the great complexity of the road deterioration process, performance models are the best approximate predictors of expected conditions. Hence, the aim of this research work is to develop a predictive model for the rate of potholes deterioration for a section of the Ijokodo –Apete road in Ido Local Government Area of Ibadan. In actualizing the above aim, a reconnaissance survey and inventory were conducted on the selected road section and potholes were discovered as the predominant pavement distresses, chainages were established for easy identification of the potholes positions, some selected potholes were measured and their volume change was monitored. The pavement structural evaluation and traffic volume data were collected. Regression models were developed for the potholes deterioration rate using SPSS (Statistical package for social sciences) package. Conclusively, the model with the highest coefficient of determinant ($R^2$) and least standard error was selected as the reliable model and was used to determine the deterioration rate of the independent variables (traffic volume and structural number) selected at random.

KEYWORDS: Pavement, Deterioration, Potholes, Predictive Models.

I. INTRODUCTION

A road pavement is a structure composed of structural elements, whose function is to protect the natural subgrade and to carry the traffic safely and economically. The outstanding durability, resilience, strength and cost of the flexible pavement, makes it the most widely used pavement for most state and federal road projects. Flexible pavement structure is typically a composition of several layers of material with better quality materials on top where the intensity of stress from traffic loads is high and lower quality materials at the bottom where the stress intensity is low. The pavement structure also provides a surface of acceptable riding quality, adequate skid resistance, favourable light reflecting characteristics and low noise pollution.

Due to the great complexity of the road deterioration process, the measurement and prediction of the pavement performance is a critical element of any pavement management system, hence, pavement deterioration models form an integral part of the systems. They provide a pavement management system with the predictive capability to forecast future maintenance needs and consequential road conditions (Agardh, 2005).

II. METHODOLOGY

The methodology adopted for the project work is as follows:

- **Location of the proposed area of study**

The location of the Ijokodo-Apete road was determined with the aid of the map of Ibadan. It was discovered to be the road linking Ijokodo to Apete and located in the Ido Local Government area of Ibadan.

- **Reconnaissance Survey and Road Inventory**

This was carried out by visiting the road to access the condition of the road pavement, determine the categories of defects dominant on the pavement and also observe the different types of vehicles plying the road. The road pavement inventory, pavement distress assessment, waterway inventories and social economic features inventory were conducted sequel to the reconnaissance survey of the road.

- **Establishment of chainages for pothole position determination**

The road was divided into chainages to provide easy access to selected potholes location and to simplify computation.

- **Measurement of Potholes**

The ten potholes that were selected for the purpose of this study were measured in terms of the length which along the longest part, the width and the depth of the potholes. The progression in length, width and depth was monitored for 24hrs span within seven days.

- **Pothole Monitoring and Pavement Structural Evaluation**

This process was carried out by close examination of the potholes under study, the extent of the deterioration and defects seen were noted and the thickness of the...
asphalt layer for various potholes (the ten selected for this project) were measured with the aid of measuring tape and recorded. The thicknesses alongside with the thickness of the base course layer, were used to determine the strength of the pavement which is in terms of Structural Number.

- **Traffic Count and Data Computation**
  A traffic volume count along the road was taken for 12 hours for seven consecutive days. The traffic streams (vehicles) in both directions were counted, tallied and classified into five categories which are: 4 axles, 3 axles, 2 axle-6 tyres, and 2 axle-4 tyres and passenger cars. The numbers of vehicles on hourly basis for each day in a week, plying the route, were observed. The Average Daily Traffic (ADT) was computed from the vehicular count.

- **Field Data Modelling with Statistical Package for Social Science**
  The deterioration rate of the potholes was modelled using the in-situ pavement strength (using structural number approach) and the traffic volume data. They model was calibrated and validated with Statistical Package for Social Science (SPSS).

### III. RESULTS AND DISCUSSION

Apete-Ijokodo Road is eighty-four kilometres (84 km) in length spanning between Ijokodo and Apete suburb of Ido Local Government Area in Ibadan, Oyo State. The asphalt paved road serves as a collector road for Ijokodo, Apete, Ajibode, Arula, Awotan, Olomo and other neighbouring communities along the road span. The project work was limited to the road section between Apete Market and Lifeforte International High School along of the Ijokodo-Awotan-Apete Road.

Sequel to the reconnaissance survey carried out at the commencement of the project work, the following inventories were performed on the road:
- Road Pavement Inventory
  - Geometric features
  - Pavement condition assessment
- Waterway Inventory: Bridges, Culverts and Drainages.
- Socio-economic features

- **Pavement Condition Assessments**
  The pavement condition was assessed by conducting a walking survey along the road section under study to visually inspect and evaluate the pavement surface state or “health”. The different defects types, their severities and pavement surface conditions observed during the survey were estimated and recorded as shown below using Asphalt PASER(Pavement Surface Evaluation and Rating) Manual(2002)
Table 3.1: Pavement Condition Assessment Result

| S/N | Chainages            | Dominant Surface Distress | Degree of Severity | Affected Area (%) (Estimation) | Pavement Surface Condition |
|-----|----------------------|---------------------------|--------------------|--------------------------------|---------------------------|
| i.  | 0+000 - 0+050        | Alligator Cracks Potholes| Low, Medium        | 30, 65                         | Fair                      |
| ii. | 0+050 - 0+100        | Pothole                   | High               | 80                             | Poor                      |
| iii.| 0+100 - 0+150        | Pothole Block cracks      | Medium, Low        | 60, 25                         | Fair                      |
| iv. | 0+150 - 0+200        | Pothole                   | High               | 80                             | Poor                      |
| v.  | 0+200 - 0+250        | Pothole                   | High               | 80                             | Poor                      |
| vi. | 0+250 - 0+300        | Pothole                   | High               | 75                             | Poor                      |
| vii.| 0+300 - 0+350        | Pothole Depressions       | Medium, Low        | 70, 15                         | Fair                      |
| viii.| 0+350 - 0+400       | Pothole                   | High               | 85                             | Poor                      |
| ix. | 0+400 - 0+450        | Pothole                   | Medium             | 80                             | Poor                      |
| x.  | 0+450 - 0+500        | Pothole                   | Medium             | 60                             | Fair                      |
| xi. | 0+500 - 0+550        | Pothole                   | Medium             | 70                             | Fair                      |
| xii.| 0+550 - 0+600        | Pothole                   | Low                | 65                             | Fair                      |
| xiii.| 0+600 - 0+650       | Ravelling Edge Drop-off   | Medium, Low        | 70, 15                         | Fair                      |
| xiv.| 0+650 - 0+700        | Ravelling Delamination    | Low, Low           | 80, 20                         | Good                      |
| xv. | 0+700 - 0+750        | Ravelling                 | Low                | 80                             | Good                      |
| xvi.| 0+750 - 0+800        | Ravelling                 | Low                | 80                             | Good                      |
| xvii.| 0+800 - 0+850       | Ravelling                 | Low                | 80                             | Good                      |
| xviii.| 0+850 - 0+900      | Ravelling Longitudinal cracks | Low, Low          | 75, 20                         | Fair                      |

### 3.2 TRAFFIC STUDY

The traffic study was conducted for seven consecutive days along the Ijokodo-Apete Road stationing at Awotan Junction. The traffic streams (vehicles) in both directions plying the route between 7a.m - 7p.m for each day of the week were counted, tallied and classified into five categories which are: 4axles, 3axles, 2axle-6tyres, Buses (2axle-4tyres) and passenger cars.
Table 3.1: Total Traffic volume count for a week along the Road
(27th Oct. - 2nd Nov. 2014)

| DAYS | CARS  | BUSES | 2AXLES | 2-axles, 6tyres | 3AXLES | 4AXLES | TOTAL |
|------|-------|-------|--------|----------------|--------|--------|-------|
| No.  | Freq.%| No.   | Freq.% | No.            | Freq.% | No.    | Freq.% | No.    | Freq.% | No.    |
| MON. | 1491  | 61.41 | 839    | 34.56         | 87     | 3.58   | 4      | 0.16   | 7      | 0.29   | 2428   |
| TUES.| 1488  | 60.32 | 878    | 35.59         | 92     | 3.73   | 5      | 0.2    | 4      | 0.16   | 2467   |
| WEDN.| 1368  | 62.1  | 769    | 34.91         | 60     | 2.72   | 2      | 0.09   | 4      | 0.18   | 2203   |
| THUR.| 1594  | 62.83 | 841    | 33.15         | 92     | 3.63   | 10     | 0.39   | 0      | 0      | 2537   |
| FRI. | 1397  | 61.43 | 785    | 34.52         | 80     | 3.52   | 10     | 0.44   | 2      | 0.09   | 2274   |
| SAT. | 1298  | 57.89 | 873    | 38.94         | 59     | 2.63   | 12     | 0.54   | 0      | 0      | 2242   |
| SUN. | 637   | 51.12 | 570    | 45.75         | 34     | 2.73   | 5      | 0.4    | 0      | 0      | 1246   |
| TOTAL| 9273  | 60.23 | 5555   | 36.08         | 504    | 3.27   | 48     | 0.31   | 17     | 0.11   | 15397  |

3.3 STRUCTURAL EVALUATION

The values used for this evaluation were obtained from road cross-section study carried out on the pavement structure used for this research. The thickness of the pavement layers at the distress sections were measured and the values were multiplied by each layer coefficient. The summary of the layer thicknesses and the results for the Structural Numbers are presented in table 3.2 below.

Table 3.2: Strength of road pavement sections in terms of Structural Number (SN)

| S/N | \( t_1(\text{mm}) \) | \( a_1 \) | \( t_2(\text{mm}) \) | \( a_2 \) | \( S_N \) |
|-----|---------------------|--------|---------------------|--------|--------|
| 1   | 40                  | 0.44   | 150                 | 0.14   | 38.6   |
| 2   | 56                  | 0.44   | 120                 | 0.14   | 41.44  |
| 3   | 52                  | 0.44   | 125                 | 0.14   | 40.38  |
| 4   | 43                  | 0.44   | 128                 | 0.14   | 36.84  |
| 5   | 36                  | 0.44   | 146                 | 0.14   | 36.28  |
| 6   | 38                  | 0.44   | 148                 | 0.14   | 37.44  |
| 7   | 55                  | 0.44   | 146                 | 0.14   | 44.64  |
| 8   | 50                  | 0.44   | 144                 | 0.14   | 42.16  |
| 9   | 60                  | 0.44   | 110                 | 0.14   | 41.8   |
| 10  | 60                  | 0.44   | 120                 | 0.14   | 43.2   |

3.4 MEASUREMENT AND MONITORING OF SELECTED POTHOLES

The ten potholes (at different section of the road) that were selected for the purpose of this study were measured in terms of the length which was along the longest part, the width and the depth of the potholes. The volume was also calculated as shown:

\[
\text{Volume (m}^3\text{)} = \text{Length (m)} \times \text{Width (m)} \times \text{Depth (m)}
\]

\[
e.g. \quad 0.820 \text{m} \times 0.8 \text{m} \times 0.090 \text{m} = 0.059 \text{m}^3
\]

3.5 CALIBRATION OF POTHOLES MODEL

Parameters used in the calibration of the model were taken over a period of 7 days with mean interval of 24 hours for the deterioration data of the pothole. SPSS employed a numerical ranking system that assigned relative weights to the parameters that caused pavement deterioration at the ten (10) pothole locations and calibrated for 4 stable days. The selected parameters were given range, which was subdivided into discrete intervals, over time, the intervals accumulated were assigned rating reflecting the relative progression.
Table 3.3: Insitu volume deterioration rate of the potholes selected along the road span

| SN | Traffic Count | Structural Number | PH 1 | PH 2 | PH 3 | PH 4 | PH 5 | PH 6 | PH 7 | PH 8 | PH 9 | PH 10 |
|----|---------------|-------------------|------|------|------|------|------|------|------|------|------|-------|
| 1  | 2428          | 38.6              | 0.059| 0.034| 0.038| 0.021| 0.017| 0.038| 0.073| 0.04  | 0.024| 0.051 |
| 2  | 2467          | 41.44             | 0.059| 0.034| 0.038| 0.021| 0.017| 0.039| 0.073| 0.041 | 0.024| 0.051 |
| 3  | 2203          | 40.38             | 0.059| 0.034| 0.038| 0.021| 0.017| 0.039| 0.074| 0.041 | 0.024| 0.051 |
| 4  | 2537          | 36.84             | 0.06 | 0.035| 0.039| 0.021| 0.017| 0.04 | 0.075| 0.042 | 0.024| 0.051 |
| 5  | 2274          | 36.28             | 0.06 | 0.035| 0.039| 0.022| 0.017| 0.041| 0.075| 0.043 | 0.026| 0.053 |
| 6  | 2242          | 37.44             | 0.06 | 0.036| 0.04 | 0.023| 0.019| 0.042| 0.075| 0.046 | 0.027| 0.055 |
| 7  | 1246          | 44.64             | 0.062| 0.037| 0.041| 0.023| 0.019| 0.043| 0.077| 0.048 | 0.028| 0.056 |

NOTE: PH = Pot hole.

Table 3.4(b): Coefficient of predictors for CH.0+020 (Pothole 1)

| Model | Unstandardized Coefficients | Standardized Coefficients | t | Sig. |
|-------|-----------------------------|---------------------------|----|------|
|       | B | Std. Error | Beta |     |     |
| 1     | (Constant) 0.082 | 0.01 | 8.342 | 0.076 |
|       | Traffic Count -4.75E-06 | 0 | -1.653 | -3.566 | 0.174 |
|       | Structural Number 0 | 0 | -0.811 | -1.75 | 0.331 |

a. Dependent Variable: Deterioration Data

Table 3.4(a): Model Summary of the Linear progression for CH.0+020 (Pothole 1)

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate | Change Statistics |
|-------|---|----------|-------------------|---------------------------|-------------------|
|       |   |          |                   |                           | R Square Change   |
|       |   |          |                   |                           | F Change | df1 | df2 | Sig.F Change |
| 1     | .981¹ | 0.962 | 0.885 | 0.000481 | 0.962 | 12.487 | 2 | 1 | 0.196 |
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3.6 VALIDATION OF THE PREDICTIVE MODEL

The results from the calibrated model were used to validate the predictive model. The selected model validation is generated during the regression process, the main purpose for this analysis is to observe the response of the variables while identifying the potential model. From table 3.4(a), it could be seen that the value for the coefficient of determinant (R²) is 96.2% and the adjusted value is 88.5%, the standard error of the estimate is low (0.000481) and the levels of significance (p-values) of the predictors are very low. Hence, from table 3.4(b);

\[ D_{R} = 0.082 - 4.753 \times 10^{-6}(T_{C}) + 0.000 (S_{N}) \]

Where;

Table 4.10 shows the result of validated predictive model for deterioration rate for POTHOLE 1 – 10

Table 3.5: Result of Values for Validated Predictive Deterioration Rate

| S/N | Traffic Count | Structural Number | Pothole 1 | Pothole 2 | Pothole 3 | Pothole 4 | Pothole 5 | Pothole 6 | Pothole 7 | Pothole 8 | Pothole 9 | Pothole 10 |
|-----|---------------|------------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| 1   | 2206          | 38.6             | 0.072     | 0.047     | 0.047     | 0.034     | 0.018     | 0.064     | 0.087     | 0.068     | 0.048     | 0.077     |
| 2   | 2467          | 41.44            | 0.07      | 0.045     | 0.045     | 0.033     | 0.017     | 0.062     | 0.086     | 0.065     | 0.047     | 0.074     |
| 3   | 2206          | 40.38            | 0.072     | 0.047     | 0.047     | 0.034     | 0.017     | 0.064     | 0.088     | 0.068     | 0.048     | 0.077     |
| 4   | 2537          | 36.84            | 0.07      | 0.045     | 0.045     | 0.033     | 0.017     | 0.061     | 0.086     | 0.064     | 0.046     | 0.074     |
| 5   | 2274          | 36.28            | 0.071     | 0.047     | 0.046     | 0.034     | 0.017     | 0.063     | 0.087     | 0.067     | 0.048     | 0.076     |
| 6   | 2242          | 37.44            | 0.071     | 0.047     | 0.046     | 0.034     | 0.017     | 0.063     | 0.087     | 0.067     | 0.048     | 0.076     |
| 7   | 1246          | 44.64            | 0.076     | 0.052     | 0.051     | 0.037     | 0.019     | 0.071     | 0.093     | 0.078     | 0.055     | 0.085     |

IV. CONCLUSION

In this work, predictive pavement was developed for a section of Apete-Ijokodo Road. Many of the models predicted the absolute value of pavement measure, employing the explanatory variables of structural and traffic factors.

Using this prediction, appropriate steps can be taken to schedule maintenance activities, also assisting the pavement managers in budgeting and disseminating limited fund. The proposed model could provide reasonable prediction of pavement performance, thus it could facilitate the decision making of maintenance and rehabilitation in pavement management system.

4.1 RECOMMENDATIONS

From the inventory and results of this project, the following recommendations are made to reduce pavement failure of Apete-Ijokodo Road.

1. The new drainages being provided for the road should be covered-drains to reduce the quantities of debris that are deposited in the drains due to the commercial activities in the area.
2. Government should create effective road rehabilitation programme and this should be implemented speedily before structural cracking deteriorates and eventually lead to pavement failure.

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