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INTERNATIONAL JOURNAL OF CURRENT RESEARCH

International Journal of Current Research
Vol. 14, Issue, 01, pp.20518-20520, January, 2022

DOI: https://doi.org/10.24941/ijcr.42939.01.2022

ISSN: 0975-833X

RESEARCH ARTICLE

PREDICTION OF FLEXIBLE PAVEMENT MAINTENANCE WORKS BASED ON RAINFALL DATA AND IMPACT

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ARTICLE INFO

Article History:
Received 18th October, 2021
Received in revised form
19th November, 2021
Accepted 12th December, 2021
Published online 31st January, 2022

Keywords:

Pavement Service, Design life, Rainfall Impact, loss of Strength, Duration of Exposure 'age', Pavement Maintenance.

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ABSTRACT

Moisture due to rainfall is required to be properly managed to avoid its destructive impact on flexible Pavement surface of Asphaltic Concrete. In spite of this consideration, Pavement continues to be exposed to rainfall all through the service life. Flexible pavements, tested and verified, show that during the service years of the Pavement, rainfall contributes to the deterioration and loss of strength, with duration of exposure. The statistical analysis of the results, employing empirical models, show that a linear correlation existed between loss of strength and duration of exposure to moisture (water) due to rainfall. This result was utilized to predict pavement maintenance programmes.

Citation: Goc Amuchi, Prof. J.C Agunwamba. "Prediction of flexible pavement maintenance works based on rainfall data and impact", *2022. International Journal of Current Research, 14, (01), 20518-20520.*

INTRODUCTION

Airport runways, highways and roads are usually provided with Asphaltic concrete surfaces – binding and wearing courses. These infrastructures are designed with specified service life span. Usually, they range from 25years to 40years and beyond, depending on the proposed function, traffic volume, economic considerations among others. On completion and during service, the pavement is exposed to traffic loading and annual rainfall. These, in addition to other conditions, affect aging and pavement surface durability. The continuous exposure of pavement to annual rainfall, impacts on the serviceability of pavement surfaces. This becomes more challenging along many areas, where it rains regularly during the year, keeping the pavement surface generally in moist (wet) condition. A number of studies have been conducted on the behavior of flexible pavement layers to rainfall and its impact. Studies have also shown that moisture is capable of weakening the bearing capacity of the granular layers of the pavement – subbase and base courses (Oguara, 2013). It is therefore recommended that these layers be effectively compacted at (OMC) optimum moisture content, to bring the layer as near as possible to the naturally occurring state, for stability (FMW, 2013). Other research works emphasized the need to protect the flexible pavement layers and foundation (subgrade), from the deteriorative consequences of long contact with water (Asphalt). They recommended the use of adequate provision of suiTable hydraulic structures to mitigate these impacts (Garber, 2007).Available studies also recommend the use of geotextile layers, subsoil filters, side drains and culverts, stone pitching and chutes as well as gabions to manage moisture and stabilize high slopes, that could lead to embankment collapse (Tighe, 2011). A few researchers treated the direct impact of annual precipitation on the pavement, Many of such studies concluded that the impact of rainfall on pavement was a highly complicated process (National Cooperative highway research program (NCHRP), 2006). This challenge was addressed in this study. An existing Pavement surface of 60mm and 40mm thickness of binder and wearing courses respectively, was investigated for rainfall effect, and to understand the pavement performance with respect to water effect and model findings to application to road maintenance works.

MATERIALS AND METHODS

The dual carriage way, from Ontisha - Owerri, within the rain forest belt of high annual rainfall records, was considered for this study (7). Using the steel coring cylinders, the coring machine, brushes, pans and diggers, samples were obtained from the flexible pavement surface, staggered left, centre and right hand sides (LHS, CL, RHS) respectively. They were cleaned weighed and crushed in groups to keep record of the average dry crushing strength. This provided a guide to the mode of failure due to rainfall values. The specimens were immersed in water basin outside, throughout the test duration. The group new crushing strength, new weights, and moisture absorption were noted at intervals of seven days, for a total of 154 days (see Table 1). The exposure to moisture (water) in a basin was considered similar to the surface exposure to moisture due to rainfall durations. The closest to field condition, was immersion in water, similar to the experience during precipitation. Water will be on the pavement surface all through the rainfall duration, sometimes ponding, stagnant or running off. The duration (minutes/hours) of rainfall was obtained from the rain gauge records from Owerri/Onitsha basin, for the purpose of this study. The observed impacts were used to predict, plan and programme preventive maintenance works for flexible pavements, to protect and prolong the service life and cost effectively, manage the pavement in service.

RESULTS AND DISCUSSION

The summary of the results, showing the impact of moisture on the pavement specimens are as shown on Table 1 – Summary of effect of water, below. The results obtained show that the value of crushing strength of the groups, reduced steadily, following days (duration) of exposure to moisture. It shows that water has a direct strength reduction effect on the surface of flexible pavement.

Table 1. Summary of Effect of Waters

GROUP SAMPLE NO.	GROUP AVERAGE DRY STRENGHT 'KN' Y	DAYS IN WATER X	GROUP AVERAGE NEW STRENGHT Y
001	5.0	0	5.0KN
002	5.1	14	3.0
003	5.0	28	2.8
004	5.12	42	2.0
005	5.1	56	2.0
006	4.98	70	1.98
007	5.07	84	2.0
008	5.1	98	0.7
009	4.99	112	0.6
010	5.1	126	0.5
011	5.0	140	0.4
012	5.11	154	0.43

The asphaltic concrete surface, serves as the vital protection to the entire pavement structure. The weakening and eventual failure of the surface, exposes the granular layers to excess moisture permeation, loss of bearing strength and eventual disintegration. With the result of crushing strength following duration in moisture, gradual steady strength reduction occurred with age of contact. This implies a reduction of the pavement ability to support axle load, as it.

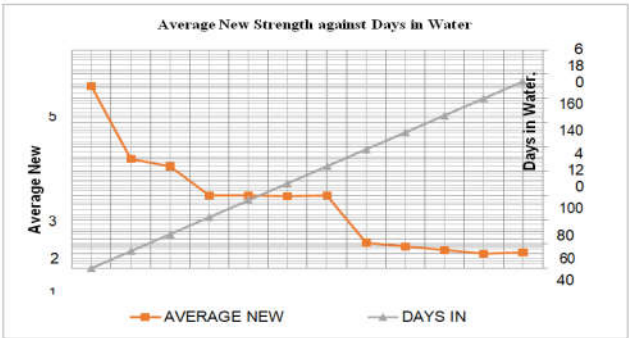

Figure 1. Variation of the average strength with days 1 water

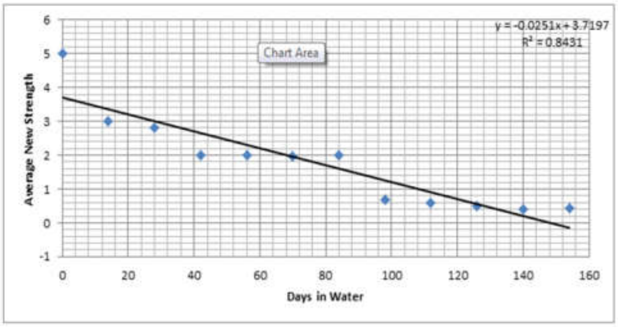

Figure 2. Strength - days in water linear relationship

Gets steadily weakened. The dry sample average due to moisture strength test result was 5KN, after 14 days of constant contact with moisture, strength was 4KN, and 3.3KN after 84days. On the 154th day of exposure to moisture, the strength value reduced to 1.3KN. This deterioration rate was analyzed statistically and the relationship plotted as shown in Figure.1, - Variation of average strength with days in water and Figure. 2 - The strength Vs days in water. They reflected a linear relationship from these plots. From the above trend, the cumulative impact of rainfall, within a geographical region was considered, to arrive at an applicable pavement maintenance programme. With other hydraulic structures in place, effective Pavement surface protection and management, is vital to the serviceability and durability of the pavement.

FINDINGS AND APPLICATION

Considering the results from this experiment, the maintenance of flexible pavement surface (asphaltic concrete) can be predicted. The total annual amount of rainfall (moisture) on the pavement surface, was considered to determine the rate of deteriorative impact on the pavement surface. See the rainfall Table within the basin considered (Owerri-Onitsha), Table 2.

Table 2. Typical annual record of monthly rainfall duration (min) from the above results and curve

S/N	MONTH	DAYS IT RAINED	TOTAL DURATION
1	Jan	1 day	30 min.
2	Feb	No rain	-
3	March	2 days	40 min.
4	April	4 days	100min.
5	May	6 days	180min.
6	June	10 days	300min.
7	July	25 days	750min.
8	Aug	20 days	600min.
9	Sep	25 days	750min.
10	Oct	20 days	600min.
11	Nov	10 days	300min.
12	Dec	-	-
	12 Months	122 days	3,650Min. (60.83 Hrs.)

- Cumulative duration of rainfall (moisture on Pavement) – 60.83hrs (61hrs)
- 61hrs under rainfall gives = $\frac{16}{24}$ = 2.54 days Pa
- Original
- to moisture – 3.7KN (154days)
- Loss of strength per strength of (dry) Pavement specimen – 5KN
- Strength 'Y' after 154 days in water – 1.3KN
- Loss of strength due day due to moisture $\frac{3.7}{154}$ = 0.024KN
- Loss of strength per hour due to moisture = 0.001KN
- Loss of strength for 1year 2.54days of rain = 2.54 x 0.024 = 0.61KN/Pa

Considering a pavement design life of 25yrs.

Table 3. Years of service and current strength

	Years in use	Loss in strength (KN)	Remaining strength
A	After 25Yrs of use	1.53KN	3.47
B	After 30Yrs of use	1.83KN	3.17
C	After 50Yrs of use	3.05	1.95

With the above table, the pavement studied, given the prevailing hydrological information of a geographical terrain (rainfall data), the prediction for due maintenance and pavement strengthening requirements, are specified and recommended as follows:

Table 4. Pavement maintenance programme prediction Table – (PMP-Prediction)

	Service years	Current Capacity CC = OC - LC	Required maintenance type
A	0-10	4.39	Routine maintenance work viz:- Cleaning, repair of turn outs, vegetation control
B	10-15	4.09	Routine: Pavement surface repairs, drainage repairs, vegetation control, repair of road signs and lave markings
C	15-25	3.47	Recurrent: Selective surface treatment, crack sealing locational overlays.
D	25-30	3.17	Recurrent: Additional resurfacing of pavement milling and inlay where required conduct further pavement strength tests.
E	30-40	2.56	Recurrent/Rehabilitation: Based on current strength test above, and original design service life, additional surface overlay, milling and inlay, or total surface rehabilitation might be required.
F	4-50	1.95	Recurrent/Reconstruction: Further tests on pavement current strength and integrity will be conducted and analyzed. Comprehensive rehabilitation, expansion and partial reconstruction.
G	Above 50	<1.95	Recurrent/Expansion: This will require renewal of traffic census, analysis, abutting settlements needs and reconstruction takes place. Technically, the payment t this stage has become very fragile, less flexibility and sucis Table to quick disintegration.

OC – Original capacity: LC – Loss in capacity: CC – Current Capacity. The rainfall intensity and total duration within any given route alignment, can be utilized at design stage, to predict future rate of deterioration due to expected precipitation.

CONCLUSIONS AND RECOMMENDATION

The findings and results from this experiment, show that flexible pavement protective surface strength, is highly correlated with duration of exposure to rainfall per annum. The unavoidable exposure of pavement to annual precipitation steadily leads to consistent loss of bearing strength with age. This is with respect to moisture related deterioration of the pavement surface. The outcome of this investigation (experiment) can be used to predict relevant pavement deterioration rate and predict related appropriate measures to prolong pavement life, delay total collapse and save huge cost. This model can be adapted to various geographical terrains, as long as the appropriate values of rainfall durations are available. This is a guide for engineers to predict failure mechanism and schedule preventive measures appropriately.

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