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Asphaltic Concrete Pavement Strength and the Impact of Rainfall

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ABSTRACT

Studies have shown that moisture impacts on the strength of flexible pavement surface of asphaltic concrete. Several investigations and relevant researches treated the effect of subsurface and surface water sources, on the durability of flexible pavements. This study is focused on the surface water sources, as a result of precipitation (rainfall), on the surface of flexible pavements. To conduct this experiment, the considerations made include (i) the continuous exposure of the pavement surface to annual rainfall (ii) application of pavement exposure to moisture in the field. This study considered the amount of rainfall each day, as the duration (age) of pavement exposure to moisture (being under water during rainfall). For the purpose of this experiment, the Owerri to Onitsha about 90km of dual carriage way in south east of Nigeria, was considered. This is a flexible pavement that traverses through the rain forest belt, characterized with high amount of annual rainfall values. Flexible pavement specimens from this road were obtained, cleaned and immersed in water after weighing, to keep vital records of the necessary parameters, before further tests at 7days intervals. Values of strength obtained after days in water, that approximated to the appropriate field situation of exposure to rainfall, showed a consistent loss of strength, from the crushing strength results.

Keywords-- Flexible Pavement Specimens, Exposure to Water, Drop in Strength

I. INTRODUCTION

Asphaltic concrete flexible pavement surface is a vital component of the entire flexible structure of the pavement, that makes direct contact with wheel axle loads of trucks/vehicles. It consists of two layers, viz: (i) the flexible pavement binder course (ii) the flexible pavement wearing course. Both layers (i) and (ii) above, function as the flexible pavement surface. The asphaltic concrete (bituminous), material used for the provision of the flexible pavement surface, is designed, selected, processed and layed under very high temperature, considered to be substantially water proof (Sharma, 2012). The Asphaltic Concrete, unlike ordinary Portland cement concrete, from studies, becomes weak and less durable, if exposed to moisture over time. This is unlike the Cement concrete, where reasonable strength increase occurs with age of exposure to weather and moisture. Inspite of this condition, the pavement surface remains exposed to surface water from rainfall, all year round, during the service life. So many research findings recommend that the pavement surface should be designed and built to encourage adequate surface runoff and reduced ponding (Ralph H.).

This experiment examines an existing flexible pavement surface in service, sufficiently exposed to rainfall. In line with design and specifications, the pavement surface exhibits due characteristics such as crossfalls, adequate slopes, cambers and drainage structures to receive surface run off water from rainfall, into drains other hydraulic structures and conducted them, to safe disposal locations low lying areas and water bodies.

The action of rainfall on the pavement surface, is an inevitable process. Many literatures on this phenomenon, indicate that it is a highly complicated process that has not been fully understood (Martin, 2016). This is partly because the field and practical experimental requirements are hardly available. To present a near practical field situation of precipitation in the laboratory, with respect to height, droplets size, frequency, duration and volume are not easily achievable.

Thus, this experiment recognizes that during each period of rainfall, the flexible pavement surface remains exposed to moisture as long as the rainfall occurs. In some cases, ponding occurs on the pavement surface, and in many cases only surface wetness throughout the rainfall duration and beyond, takes place. To conduct this experiment in the laboratory, the expected pavement surface wetness, that occurs during rainfall, was considered. The most severe field situation, being ponding on the pavement, during and slightly after rainfall.

The cored pavement samples of 60mm and 40mm (100) respective thicknesses of asphaltic concrete surface was cored and immersed in water to test for parameters including strength, after intervals of 7 days. The outcome of this experiment is expected to improve on the knowledge of the behaviour of pavement surface, due to exposure to annual rainfall. This will also serve as a guide, to design and preventive maintenance planning engineers and procuring entities, from the public and private investors.

II. LITERATURE REVIEW

Flexible pavements are designed to be water repellent, rebound after load impact, support runways, road and provides transportation comfort, while in service. Wear and tear, in due to consistent exposure to rainfall, weather and their effect on the pavement surface, is a complicated process.

From the literature reviewed on this study, various work and findings have been concentrated on the different effects of moisture on pavements generally. They show that the exposure of pavement to water was an inevitable phenomenon. Thus, there are recommendations on adequate protective measures, necessary to ensure that surface runoff, due to rainfall do not pond on the pavement surface. Adequate slopes should be provided for efficient runoff from the pavement surface.

Poor management of rainfall, increases the moisture content of the pavement subgrade, that could to road foundation failures (Enright, 2016). Research works and investigations on the origin of pavement cracks and subsequent failure, were closely related to the presence of moisture on the pavement surface, usually due to annual rainfall.

The Institute of Transportation (UK) in 2016, concluded in their research findings, that surface water could leads to total pavement disintegration. Moisture increase due to rainfall, reduces pavement stability and the bearing capacity most construction materials. Many other related literatures, emphasized that rain water has a very high complex destructive effect on pavement, that leads to aggregate stripping and surface loss. The details on these impacts are yet to be adequately investigated.

Looking at existing studies, on the mode of impact of rainfall on flexible pavement, this work is concentrated on the specific effect of water, due to annual rainfall on flexible pavement surface. The control measures, as well as the process will help to advance relevant knowledge for highway professionals.

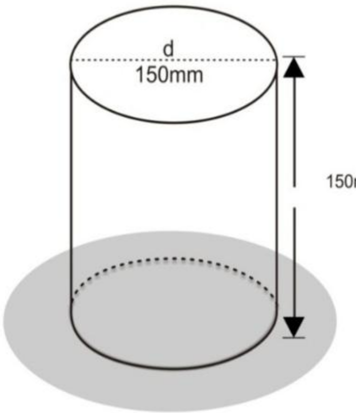

Figure 1: 150 x 150mm steel cutters.

III. AIMS AND OBJECTIVE OF STUDY

The aim of this study is to investigate the behaviour of asphaltic concrete flexible pavement, when exposed to rainfall. To conduct the experiment process, that will suitably expose pavement samples to moisture the way rainfall will lead to wetness in field situation. It is expected that this investigation will serve as a guide to further understand the impact of rainfall (Storm water) on flexible pavement.

The specific objectives are:

- to determine the effect of moisture on asphaltic concrete flexible pavement, considering the exposure of pavement to annual rainfall.
- to verify the relationship between moisture generated from rain water and the strength of the flexible pavement.
- establish effect of age (days) of presence in moisture with the pavement response to strength.
- apply the knowledge to pavement preventive maintenance works and design.

IV. MATERIALS AND METHOD

The materials required for this investigation are grouped into two, the field materials and the laboratory materials. To collect flexible pavement surface samples, a van was arranged to move aids (men) and field equipment, along the road for pavement coring. The equipment used on the field include:-

Cylindrical steel cutters, the mechanical cutting machine, bituminous concrete to refill cut holes, hammers, brushes and pans as well as water containers. See fig 1 below.

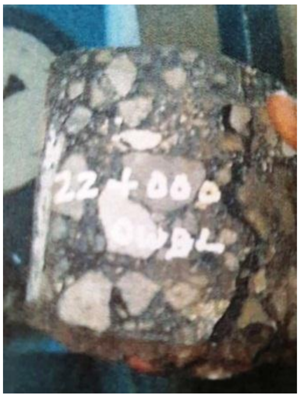

Plate 1: Sample of cut flexible pavement surface

At the laboratory, the weighing devices, the basins containing water, brushes and the compression testing machine, were assembled. To commence the experiment, cleaned pavement specimens were weighed and immersed in clean water.

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Specimens in clean water, represent the field condition, where pavement surface is similarly exposed to water (moisture) all through the rainfall duration each day it rains.

At the end of every seven days (168hrs) the specimens were brought out in groups and crushed to test the new strength. This experiment continued at every seven days intervals and the new strengths obtained were recorded.

V. RESULT

The values obtained for typical area annual rainfall are as shown below.

Table 1: Annual rainfall data for Owerri basin (Owerri – Onitsha stretch)

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.)

Table 2: Parameters obtained from test results

GROUP SAMPLE No.	GROUP AVERAGE DRY STRENGHT 'KN' y	DAYS IN WATER X	GROUP AVERAGE NEW STRENGHT Y	MOISTURE ABSORBTION M
001	5.0	0	5.0KN	+8
002	5.1	14	3.0	+2
003	5.0	28	2.8	+11
004	5.12	42	2.0	+14
005	5.1	56	2.0	+21
006	4.98	70	1.98	+17
007	5.07	84	2.0	+22
008	5.1	98	0.7	+20
009	4.99	112	0.6	+24
010	5.1	126	0.5	+26
011	5.0	140	0.4	+27
012	5.11	154	0.43	+30

Record of the group strength of the pavement specimens were recorded after every seven days of contact (immersion) with water, as shown on table 2 above.

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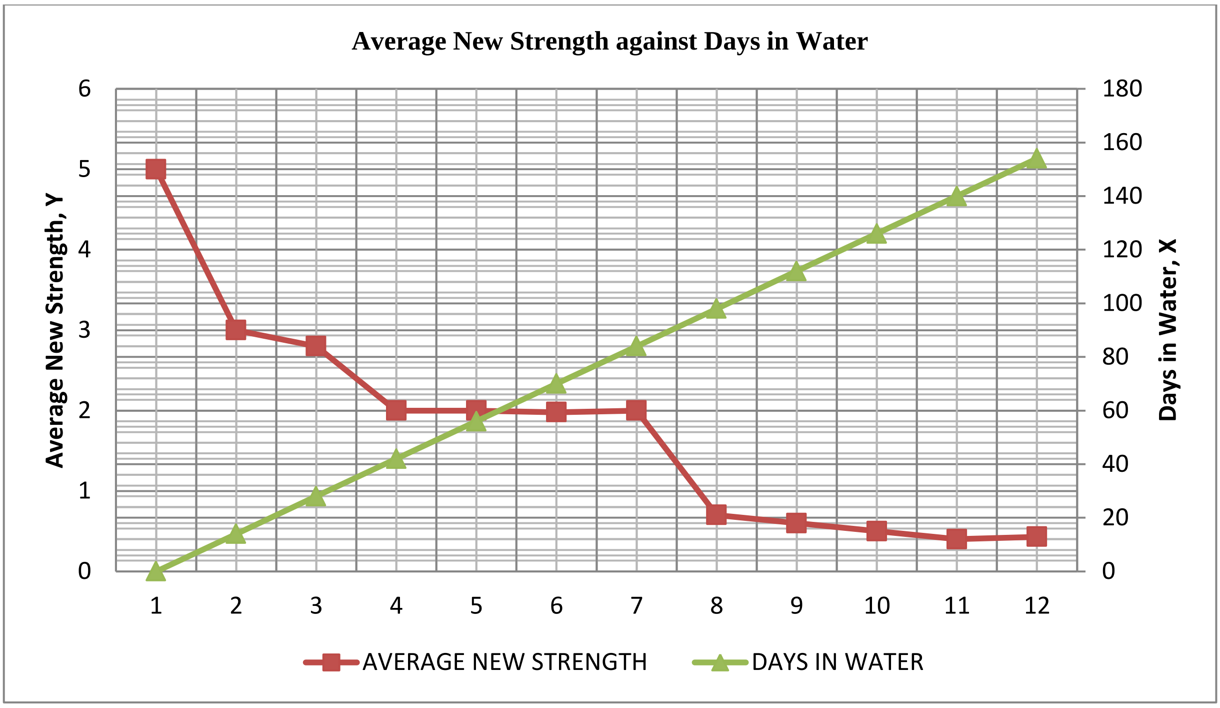

Figure 1: Variation of average New Strength against days in water

Effect of Days in Water on New Strength

Figure 1 above, shows that, with days the sample stayed in water, the strength reduced progressively. The deductions from this observation include:

i. that the existing voids within the pavement sample, after due effective compaction, made it a bit porous, absorbing water by suction and capillarity, overtime.
ii. the absorbed moisture, trapped within the pavement, tends to react and weaken the interlocking properties of the pavement component materials, aggregates, fillers, bonding properties.
iii. the binding qualities of the bituminous mix, in the presence of trapped moisture and temperature, further weakens the pavement, as it loses adhesion with time. This observation agrees with the Asphalt Institute Research finding report of 2018, that the gradual but continuous intake of moisture over time, results in a steady progressive process of weakening, and loss of strength, as the sample stayed in contact with water.
iv. average new strength values reduced from about 5KN while dry, to values less than 1KN with days (age) of contact with water.

VI. DISCUSSON

The table of the annual monthly record of rainfall duration for one year, shows that it rained virtually every month of the year, with varying number of days and duration per month. This was summed up to an average of 3650min (60.83hrs) per annum. This was considered as the pavement surface being in contact with moisture (rainfall duration) for (60.83/24) 2.53days p.a.

With this record of area rainfall amount per annum, the outcome of the strength test was computed to obtain the effect per hour and day. From the curve and table 2 above;-

Original average dry strength of pavement = 5KN
New strength value after 154 days in water 0.43KN
Loss of strength due to water for 154 days is 4.47KN
∴ New strength after 1 day (age) in water is:-

$$\frac{0.43}{154} = 0.003 \text{ KN}$$

And for 2.53 days Pa = 0.003 x 2.53 = 0.008KN

This pavement surface, will be looking appropriately 0.008KN of strength per annum, as a result of rainfall only.

VII. CONCLUSION AND RECOMMENDATION

This experiment shows the impact of rainfall on the aging process of asphaltic concrete flexible pavement surface.

The results and verifications show that the cumulative effect of rainfall on the pavement surface is gradual but leads to consistent loss of strength. The ability to support loading by the pavement surface is lowered with age (duration) of exposure to moisture.

With the rainfall data along this basin, the pavement surface bearing capacity was reduced from 5KN to 0.43KN after 154 days of exposure to moisture

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from rainfall. This implies a rate of 0.003KN per day (24hrs) of rainfall.

This knowledge will be adequately put to use in the planning and execution of pavement preventive maintenance. This will be highly useful in the generation of relevant data for pavement preventive systems (PMS) along studied routes. At about 50% loss of the original design strength of a flexible pavement (due to rainfall only), it will be required to carry out surface strengthening work (asphaltic concrete overlay). This will increase the pavement strength and bearing capacity, and save the huge cost of total rehabilitation, due to complete pavement weakness, that could lead to disintegration. This in turn, impacts positively on the cost of goods and services, check inflationary trends and promote overall economic growth of nations that are exposed to high annual rainfall values.

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