Performance Analysis of Candle Wax Modified Asphalt Pavement Wearing Course Submerged in Moisture

Captain Gospel Otto, Scott Bernard Akpila

***Abstract*— Performance analysis of flexible pavement wearing course subjected to submergence was carried out. The goal of this study is to improve the performance of the wearing course in terms of fatigue using candle wax as a waterproofing agent. In Nigeria especially in the Niger Delta area, flooding is common during raining season. Pavements are observed to be underwater continuously causing rapid failure. Founded on this, the recent study was aimed at evaluating the fatigue performance of flexible pavement wearing course using candle wax modified asphalt pavements in soaked conditions. This was accomplished by first modifying the asphalt concrete at 1%, 2%, 3%, 4% and 5% and submerged in water for 0 day to 5 days. The results obtained have shown that fatigue performance can be improved at 4% modification using candle wax. The finding has proven that candle wax is a waterproofing agent.**

***Index Terms*- Candle Wax (CW) and Fatigue Performance**

I. INTRODUCTION

Moisture has been observed to affect the performance of asphalt pavement wearing course. The damages caused by moisture have been studied by [11]. In that study, moisture and traffic frequency were seen to be the major factors affecting the wearing course of pavements. Also, [8] [7] and [6] have shown that moisture contributes seriously towards pavement failure. As long as moisture remains on the pavement after rainfall as a result of lack of functional drainage systems to remove water, the pavement will be submerged for hours, days or weeks as the case may be. This situation, affects pavement performance greatly.

Recently, [12] tried to improve the fatigue performance of asphalt pavement wearing course in submerged condition using shredded tyre chips. The study revealed that shredded tyre chips inclusion enhanced the fatigue performance at 5% and also increased the life span from 20 years to 33years. Also, [4], used shredded tyre chips as filler materials to enhance the dynamic modulus of asphalt concrete. The study exposed the usefulness of the chips as it upsurges the dynamic modulus linearly with a continuous increase shredded tyre chips addition considering the frequencies of 0.1 -25Hz.

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[9] used melted waste polythene bags as modifiers in asphalt concrete pavement. The study exposed the waterproofing behavior of the polythene bags at 3%. The waste polythene bag has been shown to have economic value with a cost savings [10].

[5] have studied the usefulness of candle was as void filler. In the study, candle wax was shown to reduce air voids at 22.7%, 16.7% and 16.7% for light, medium and heavy volume traffic respectively. With this knowledge, the objective of this current study is to improve the performance of pavement wearing course submerged in water using candle wax as waterproofing agent knowing that it can reduce air voids.

II. COLLECTION OF SAMPLES

A. Collection of Samples

Coarse and fine aggregates, asphalt binder (bitumen), modifier (candle wax) were used during this investigation. The coarse aggregates used were gotten from Akamkpa stone crush in Cross River State while the fine aggregates (River Sand) was gotten from Omukwa river in Abua/Odual area of Rivers State. The Bitumen was obtained from Setraco Construction Company, Port Harcourt while the candle wax used as modifier was obtained from Mile 3 market in Diobu, Port Harcourt. Laboratory tests such as specific gravity, grading of asphalt and sieve analysis of the aggregates were carried out after sampling.

B. Sample Preparation

The Bruce Marshal Mix Design Procedure as presented in [2] and [13] for asphalt concrete mixes was used in the preparation of test samples. The sample preparation was done on the bases of 0.5% addition at the preliminary stage to determine the asphalt content. To ensure that the results are consistent, the test samples were prepared in triplicate for each set of asphalt content. In the preparation of the control samples, the aggregates were heated first and stirred appropriately for approximately five minutes before the asphalt were added to allow for homogeneousness and proper absorption of the asphalt into the aggregates. Subsequently the sample was then put into a mould and compacted on the bottom and faces with 75 blows which is a laboratory simulation of the heavy traffic volume using a hammer of 6.5kg in weight falling gravitationally from a height of 450mm. The samples after compaction were subjected to the bulk specific gravity test, stability and flow, density and voids studies at a temperature of 60^0C and at a frequency of

10Hz as specified in [1]. The results gotten were used to obtain the optimum asphalt content of the control sample (unmodified). Candle wax were then added at varying amounts of 1-5% by weight of the total concrete sample of 1200g to the samples at optimum asphalt content and then re-designed using the same Marshal Design Procedures already stated above to produce candle wax modified samples having changing mix design properties.

C. Theory

Determination of the Optimal Binder Content

The optimum binder content (O.B.C.) for the control sample was determined using equation 2.1 as stated by Marshal Mix Design Procedure cited in (Asphalt Institute, 1956; National Asphalt Pavement Association, 1982) as follows:

$$O.B.C = 0.3(A.C._{\text{max. stability}} + A.C._{\text{max. density}} + A.C._{\text{median limits of air void}}) \quad 2.1$$

Determination of Dynamic Modulus

a) Using Asphalt Institute Model (1993)

According to Huang (1993), dynamic modulus can be determined using Asphalt Institute Model (1993). The model equations are as follows:

$$E^* = 100{,}000\,(10^{\beta_1}) \quad 2.2$$

$$\beta_1 = \beta_3 + 0.000005\,\beta_2 - 0.00189\,\beta_2 f^{-1.1} \quad 2.3$$

$$\beta_2 = \beta_4^{\,0.5}\, T^{\beta_5} \quad 2.4$$

$$\beta_3 = 0.553833 + 0.028829\,(P_{200} f^{-0.1703}) - 0.03476\,V_a + 0.07037\,\lambda + 0.931757\, f^{-0.02774} \quad 2.5$$

$$\beta_4 = 0.483\, V_b \quad 2.6$$

$$\beta_5 = 1.3 + 0.49825 \log f \quad 2.7$$

$$\lambda = 29{,}508.2\,(P_{77^\circ F})^{-2.1939} \quad 2.8$$

Where;

E^* = dynamic modulus (psi)

f =loading frequency (1Hz, 5Hz and 10Hz)

T = temperature (°F) (Mixing Temperature)

V_a = volume of air voids (%)

λ = asphalt viscosity at 77°F (10^6 poises)

P_{200} = percentage by weight of aggregates passing No. 200 (%)

V_b = volume of bitumen

$P_{77°F}$ = penetration at 77°F or 25°C

Determination of Fatigue Life Using Asphalt Institute (1982)

According to [3], Fatigue life can be determined using equation 2.9.

$$N_f = 0.0796(\varepsilon_t)^{-3.291}(E)^{-0.845} \quad 2.9$$

where;

N_f = number of load repetitions to failure

E = stiffness modulus

ε_t = horizontal tensile strain at the bottom of the asphalt bound layer

The **tensile strains** were measured directly from all the samples while the **stiffness modulus** was determined using equations 2.2 to 2.8 stated above.

III. Results

Table 3.1: Schedule of Aggregates Used for Mix Proportion in Accordance with ASTM 1951: C136

Sieve Size (mm)	Specification limit	Aggregates (A) Gravel	Aggregates (B) Sand	Mix Proportion (0.58A + 0.42B)
19	100	100	100	100
12.5	86-100	97	100	98
9.5	70-90	62	100	78
6.3	45-70	26	100	57
4.75	40-60	10	99	47
2.36	30-52	0	96	40
1.18	22-40	0	90	38
0.6	16-30	0	73	31
0.3	9-19	0	23	10
0.15	3-7	0	3	1.26
0.075	-	-	-	-

The results obtained from this study are shown in the tables and figures below.

Table 3.2: Laboratory test results showing the properties of all the materials used

Materials	Candle Wax	Asphalt Binder	Coarse Aggregates (A)	Fine Aggregates (B)
Specific Gravity	0.85	1.05	2.80	2.56
Grade of Binder		50/6 0		
Mix Proportion			58%	42%
Viscosity of binder		14.5		
Soften Point		50°C		
Penetration Value		53		

Table 3.3 Mix Properties Unmodified Asphalt Concrete

Asphalt Content (%)	Stability (N)	Flow(mm) (0.25mm)	Density (Kg/m³)	Air Voids (%)	VMA (%)
4.0	4590.621	8.56	2252	5.14	14.52
4.5	5006.316	9.94	2279	4.84	12.69
5.0	7098.273	10.44	2311	3.68	10.5
5.5	5817.483	11.63	2278	3.6	10.79
6.0	5786.025	12.94	2249	3.5	11.04

Table 3.4 Fatigue Results

	Days					
CW %	0	1	2	3	4	5
0	21989696	20995680	20451581	19913658	18774733	18489204
1	24002371	21781490	20384874	19263846	18259100	18029972
2	26519536	23561249	21580628	20236926	19432602	19303193
3	29189276	25762047	23438790	22023224	21530534	21535035
4	31362385	27770654	25355893	23947704	23733878	23863389
5	30245902	26640785	24429064	23003232	22613734	22634488

From the analysis done using equation 2.1, the OBC is 4.95%

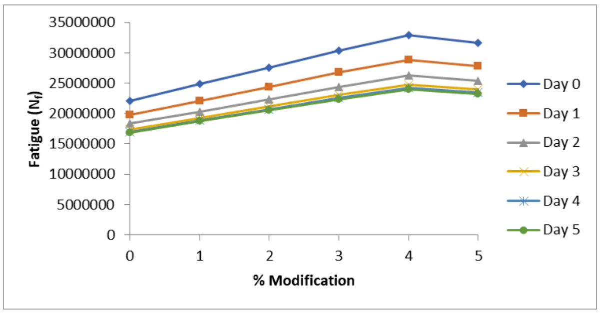

Figure 3.1 Variation of Fatigue with against % Candle Wax Modification

IV. DISCUSSION

The result presented in Table 3.4 and Figure 3.1 showed that the fatigue life was increasing in a linear form up to 4% of the modifier content thereafter the addition of the candle wax caused a reduction in the fatigue life. This was observed in all the number of days the samples were soaked.

V. CONCLUSIONS

Based on the study objective, the following conclusions are made:

1) That the inclusion of candle wax as modifier in hot mix asphalt, enhances the fatigue life at 4% modification for submerged conditions of moisture.
2) That the inclusion candle wax increases the waterproofing behavior of the asphalt pavement wearing course thereby increasing its fatigue life.

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