International Journal of Research in Engineering and Science (IJRES)
ISSN (Online): 2320-9364, ISSN (Print): 2320-9356
www.ijres.org Volume 10 Issue 10 ǁ October 2022 ǁ PP. 83-87

Fatigue Performance of Calcium Carbide Residue Modified Asphalt Concrete Pavement in Extreme Moisture Condition

Magnus, Emuzani Brother &Ogboda, Chiwokwa Emmanuella
Department of Civil Engineering, Rivers State University, NkpoluOroworuko,
P.M.B 5080. Port Harcourt, Rivers State, Nigeria

Abstract
One of the main concerns of Nigerian civil engineering professionals, particularly among the people of the Niger Delta owing to floods, is improving the fatigue performance of flexible pavement wearing course subjected to submergence. Because it has been noted that pavements are constantly submerged in water, which causes quick failure, the government now spends a sizable sum of money every year on road building and rehabilitation. Based on this, the current study's objective was to evaluate the fatigue performance and life span of flexible pavement made of calcium carbide residue (CCR) under submerged settings. The hot mix asphalt concrete was altered at 1%, 2%, 3%, 4%, and 5% to achieve this. For 0 to 5 days, the modified asphalt concrete was submerged in water. According to the study's findings, as the number of soaking days grows, the fatigue life was improved with at least a 5% modification utilizing CCR.

Keywords: *Calcium Carbide Residue, Modified Asphalt, Fatigue, Moisture Condition*

Date of Submission: 20-09-2022 Date of acceptance: 04-10-2022

I. Introduction

Numerous reasons, including bad design, shoddy construction, an insufficient maintenance program, incorrect usage, and a host of others, can shorten the design life of asphalt concrete pavement. Any of the aforementioned factors can readily lead to moisture-related damages. Moisture and traffic volume have been identified as factors impacting pavement performance in a study by Otto and Amadi (2020).Recent research in Nigeria's Niger Delta region have shown that moisture has a significant role in the deterioration of pavement (Ottos &Nyebuchi 2018; Igwe 2019; Igwe et al 2016).

According to Qing (2005), due to water's solvent qualities, the increasing deterioration of asphalt mixes in the presence of moisture results in a loss of adhesion between the asphalt binder and aggregate surface or a loss of cohesiveness inside the binder. Stripping is the term used to describe this process. The pavement stays flooded for hours, days, and even weeks because moisture is always present due to rainfall and there is no working drainage system to remove water. As a result, the performance of the pavement is severely reduced, making it impossible for it to be used for the duration of its design life, which should ideally be between 15 and 30 years and 5 to 20 years for overlays.

Several researchers have used additives or modifiers in an effort to increase the performance and durability of flexible pavement in extreme moisture conditions. Waste polythene bags were employed as a modifier in asphalt concrete pavement by Ottos and Amadi-Oparaeli (2018). In terms of the Index of Retained Stability, the investigation showed that the modifier can function as a waterproofing agent at 3% addition. According to a further study by Otto and Amadi-Oparaeli (2019), the use of waste polythene bags to modify asphalt is cost-effective.

In order to increase the fatigue life under normal conditions, without taking submergence as it does in the Nigerian Niger Delta region into consideration, certain modifiers or additives have been added throughout time to asphalt concrete compositions.Polymers, recycled plastics like polyethylene, blast furnace slags, municipal waste combustion ash, and used tires are a few of the additives or modifiers employed.Shredded tire chips introduced as filler material to increase the dynamic modulus of asphalt concrete pavement in a study conducted by Igwe (2015).According to the study, when considering frequencies between 0.1 and 25 Hz, the dynamic modulus increases linearly as the amount of shredded tire chips is added.

Unexpected temperature rises that has been observed in some regions in Nigeria can cause asphalt bleeding.Research works have shown that the environment also has an impact on their strong qualities, especially stability and density.These variables control the pavement's stiffness, stresses, responsiveness, and behavior throughout its design life, regardless of whether it is subjected to extremely high moisture levels.

(Igwe *et al* 2016; Igwe *et al* 2016;Igwe *et al* 2016; Igwe & Ottos 2016; Igwe & Ottos 2017; Otto &Akpila 2020; and Otto *et al* 2020).

The goal of this current study is to use calcium carbide residue (CCR) to improve the fatigue performance of asphalt concrete in extreme moisture condition. The purpose described is the basis for the entire findings in this study, together with a clearly defined assumption that might be seen as the study's limiting circumstances.

II. Materials and Methods

2.1 Materials

During this investigation, materials like coarse and fine aggregates, binder (asphalt), and modifier (calcium carbide) were used.The fine aggregates (River Sand), and the coarse aggregates were procured from Mile 3 building material market in Diobu, Port Harcourt, while the asphalt was procured from Setraco Construction Company, Port Harcourt.Laboratory tests such specific gravity, asphalt grading, and sieve analysis of the aggregates used for mix-proportioning (using the straight-line method) were performed after the materials had been sampled. The calcium carbide residue (CCR) used was gotten from mechanical workshops around Port Harcourt metropolis.

2.3 Sample Preparation

As mentioned in Asphalt Institute(1997), the Bruce Marshall method was used to prepare samples for this study. Numerous test samples were created for varied asphalt contents in order for test data curves to demonstrate clearly defined ideal values.There were at least three experiments with concentrations above and below the recommended level in applications of 0.5 percent asphalt binder.Three test samples were created for each asphalt content in order to provide enough data.

The aggregates were heated for a total of five minutes, both fine and coarse.Binder was then used to prepare the pure and modified asphalt concrete samples, allowing it to appropriately soak into the particles.The material was then placed into a mold and subjected to 75 blows with a 6.5 kg rammer to achieve compaction.Compacted specimens were assessed for bulk specific gravity, stability and flow, density, and voids at temperatures of 60 degrees Celsius, according the AASHTO Design Guide (2002).Based on the findings, the ideal asphalt content for pure asphalt concrete was established.In order to create changed concretes with different mix design qualities, particularly air voids content, the samples were then amended utilizing the same Marshal Design Procedures as before using various amounts of the calcium carbide waste. They were added to the samples at the ideal asphalt content (1 to 5 percent of the total mix). This samples were then subjected to extreme moisture conditions to establish the moisture resistant ability of calcium carbide in asphalt concrete at a constant frequency of 1Hz.

2.3. Theory

2.3.1 Optimal Binder Content (O.B.C) Determination

Equation 2.1 was used to determine the optimum binder content (O.B.C.) for conventional bituminous concrete in accordance with the Marshal Mix Design Procedure mentioned in (Asphalt Institute, 1956; National Asphalt Pavement Association, 1982).

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

2.3.2 Dynamic Modulus Calculations

As demonstrated in Huang's (1993) Equations 2.2–2.8, The Asphalt Institute (1993) created a design approach in which the dynamic modulus is calculated using the following equations:

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

$$\beta_1 = \beta_3 + 0.000005\beta_2 - 0.00189\beta_2 f^{-1.1} \quad 2.3 \qquad \beta_2 = \beta_4^{\;0.5} T^{\beta_5} \quad 2.4$$

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

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

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

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

Where;
E^* = dynamic modulus (psi)
f =loading frequency (1Hz,)

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

2.3.3 Fatigue Life Determination Using Asphalt Institute (1982)

A model was created by the Asphalt Institute in 1981, however it had significant restrictions.
However, the Asphalt Institute model was subsequently adjusted to account shift factors from various combinations of asphalt binder types and grades in order to mitigate the impacts of shift factors Sf, which were perceived as limits (Asphalt Institute, 1982).The equation that results takes the following form, which was used in this work:

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

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

All sample's horizontal tensile strains were measured directly, and Equations 2.2 to 2.8 were used to calculate the stiffness modulus.

III. Results and Discussions

The findings from this investigation are shown in the table and figure below.

Table 1: Results of Dynamic Modulus and Fatigue at Frequency = 1Hz

% CCR	Soaking Days	Dynamic Modulus (E)	Strain (ε_t)	Fatigue (N_f)
0	0	94075.33	0.00877	770103.9772
	1	93924.86	0.00897	714279.7226
	2	93699.61	0.00918	662909.0921
	3	93400.1	0.00933	629959.3222
	4	93029.1	0.00945	608013.1495
	5	92581.4	0.0095	599908.3006
1	0	107451.6	0.00837	801924.6382
	1	107279.8	0.00857	741122.4757
	2	107022.5	0.00879	685409.0136
	3	106680.5	0.00894	649772.9804
	4	106254.3	0.00905	626072.2671
	5	105745.3	0.0091	617241.4816
2	0	122800.1	0.00796	844398.4519
	1	122603.7	0.00817	777217.0544
	2	122309.7	0.00838	715954.1937
	3	121918.7	0.00853	676895.6435
	4	121431.8	0.00864	650950.5022
	5	120850	0.00869	641217.5983
3	0	140418.3	0.00756	892506.309

	1	140193.7	0.00777	817913.2344
	2	139857.5	0.00798	750247.1374
	3	139410.5	0.00813	707261.0908
	4	138853.7	0.00824	678750.1765
	5	138188.5	0.00829	667986.7449
4	0	160649.6	0.00715	955982.2068
	1	160392.6	0.00736	871731.1162
	2	160008	0.00757	795761.4254
	3	159496.5	0.00772	747703.0767
	4	158859.5	0.00783	715888.6241
	5	158098.4	0.00788	703803.9026
5	0	183889.4	0.00677	1021950.088
	1	183595.3	0.00698	927041.8129
	2	183155	0.00719	842001.2809
	3	182569.6	0.00734	788446.3518
	4	181840.4	0.00745	753070.2246

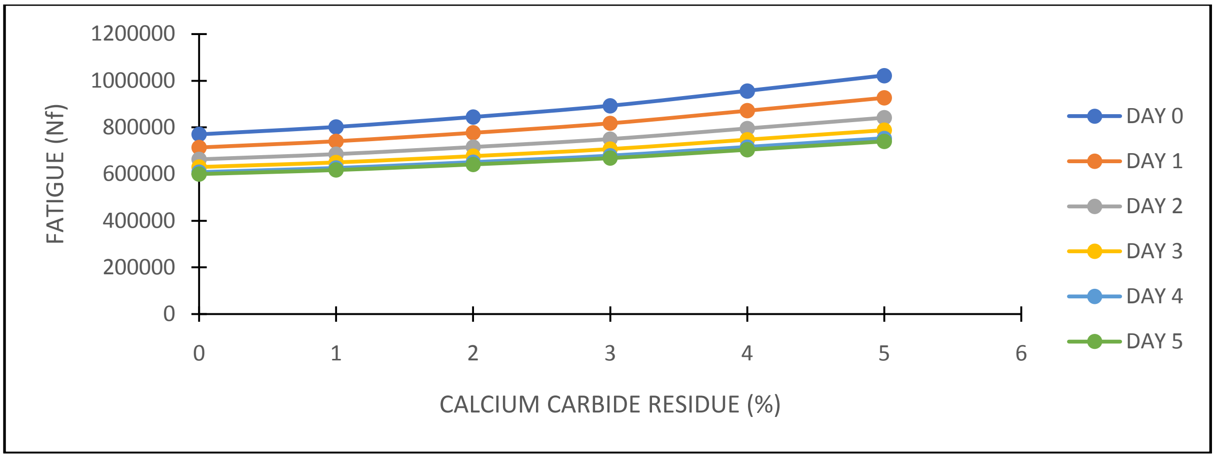

Figure 1: Fatigue results against % CCR Modification at 1Hz

The findings, which are shown in Table 1 and Figure 2, indicate that adding CCR up to 5% increased N_f, of hot mix asphalt concretes, which is equivalent to the number of load repetitions before failure.As the number of soaking days increased, it was seen that the N_f was decreasing as a result of increasein tensile strains.The degradation of pavement materials caused by moisture submersion, which results in excessive voids in the pavement, causes the pavement to lose stiffness (dynamic modulus) and fatigue life, which causes the increase in tensile strains.This supports the findings of Otto *et al*(2020).

IV. Conclusions

The findings of this study's research serve as the foundation for its conclusions.Theinfluence was discernible based on the research findings.Because the modified HMA concrete outperformed the standard HMA concrete in terms of dynamic modulus, strain, and fatigue values.These findings can be summarized as follows:

1. The addition of CCR improved the dynamic modulus that varied from Day 1 to Day 5 of soaking condition.
2. For the Day 1 to Day 5 soaking condition, the addition of CCR up to 5% reduced tensile strain.
3. The number of load repetitions (Fatigue) before failure was enhanced by the addition of CCR up to 5%.

References

[1]. AASHTO Design Guide Draft (2002). – 2.4 Modulus of Elasticity for Major Material Groups, NCHRP Project 1-37A.

[2]. Asphalt Institute (1956) “Mix Design methods for Hot-mix Asphalt Paving”, University of Maryland, Manual Series No.2. Lexington.

[3]. Asphalt Institute (1982). Research and Development of Asphalt Institutes’ Thickness Design Manual, (9thedn.). Research Report 82-2.

[4]. Igwe, E. A. (2015). “Contributions of Shredded Tire Chips as Filler Material on Stiffness of HMA Concrete”, Global Advancement Research Journal of Engineering, Technology and Innovation (GARJETI) 4(5), 80-85.

[5]. Igwe, E. A, Ottos, C. G, &Ekwulo, E. 0. (2016). „The role of Candle Wax as Non-bituminous Modifier in Material Recharacterization of Bituminous Concretes used Synonymously for Flexible Pavement- Study on Voids and Flow”. IOSR Journal of Mechanical and Civil Engineering,13(5), 74-81.

[6]. Igwe, E. A., Ekwulo, E. O. & Ottos, C. G. (2016). “Moisture Effect on Stiffness of Asphalt Concretes for Low Volume Roads: Comparative Study of Asphalt Institute and Witczak 1-40D Models”, International Journal of Constructive Research in Civil Engineering (IJCRCE) 2(4), 1-8.

[7]. Igwe, E. A., Ekwulo, E.O. & Ottos, C.G. (2016). “Correlation of Tensile Strength of Split Cylinder Test and Double Punch Test of a Rubberized Asphalt Concrete used in Flexible Pavement Design” International Journal of Constructive Research in Civil Engineering, 2(5), 8- 15.

[8]. Igwe, E. A., & Ottos, C.G. (2016). “Investigating the Effect of Air Voids Content in Fatigue Life of Hot Mix Asphalt Mixtures: Case Study of Rubberized Asphalt Concrete”. International Journal of Innovative Science, Engineering & Technology” 3(5), 56-64

[9]. Igwe, E. A. & Ottos, C. G. (2017). “Increasing Durability of Bituminous Pavements using Hydro Carbon Void Fillers produced from Recycled Polyethylene Wastes” (RPEW), Journal of Scientific and Engineering Research, 4(12), 24 – 30.

[10]. Igwe, E. A., (2019). “Response of Material Properties of Flexible Pavements to Moisture Resulting from Poor Drainage Conditions: Case of Niger Delta Region of Nigeria”, International Journal of Constructive Research in Civil Engineering 5(4), 13-22.

[11]. Ottos, C. G., &Nyebuchi, D. A. (2018). “Swell Behavior of Asphalt Pavement Wearing Course with ESAL >106 Under Submerged Conditions”. International Journal of Trend in Research and Development, 5(2), 242-244. ISSN 2394-9333

[12]. Ottos, C. G., & Amadi-Oparaeli, K. I. (2018) “Influence of Waste Polythene Bags on the Idex of Retained Stability of Asphalt Concretes Under Moisture for Low Volume Roads” International Journal of Trend in Research and Development, Vol. 5, issue 2, pp 209-214. ISSN 2394-9333

[13]. Otto, C. G., & Amadi-Oparaeli, K. I.(2019), “Cost Effectiveness of Waste Polythene Bag Modified Asphalt Concrete Submerged in Moisture” International Journal of New Technology and Research, Vol. 5, issue 6, pp 01-08. ISSN:2454-4116

[14]. Otto, C. G., &Amadi, C. P. (2020). “Laboratory Investigation of the Effect of Traffic Load Frequency and Moisture on the Fatigue Life of Asphalt Concrete Pavement”. International Journal of Trend in Research and Development, 7(4), 205-208. ISSN 2394-9333

[15]. Otto, C. G., Igwe E. A. &Ekwulo, E. O. (2020). “Fatigue Performance of Asphalt Pavement Wearing Course in Submerged Condition Modified with Shredded Tyre Chips”. International Journal of Scientific & Engineering Research 11(11), 167-172. ISSN 2229-5518

[16]. Otto, C. G &Akpila S. B. (2020). “Performance Analysis of Candle Wax Modified Asphalt Pavement Wearing Course Submerged in Moisture”. International Journal of New Technology and Research, 6(11), 15-17. ISSN 2454-4116

[17]. Qing, Lu (2005). “Investigation of Conditions for Moisture Damage in Asphalt Concrete and Appropriate Laboratory Test Methods”, PhD dissertation, graduate division of the University of California, Berkeley.