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Developing a Maintenance Model for Pavements Vulnerable to Climate Change in South Eastern Nigeria

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Abstract

The South East region of Nigeria faces widespread flood during rainy seasons as a result of inadequate drainage channels, poor drainage management and most often the absence of drainage. The increase in rainfall can be attributed to climate change. Climate change has become one of the most common sources of road pavement failure in the region which leads to rapid need of maintenance as a result of flooding and this problem is becoming worse yearly. Most roads in the region suffer submergence because of flooding. In this research work, a predictive model will be developed to control maintenance of road infrastructural systems in the South-East in terms of fatigue. This work is limited to pavement behavior with respect only to fatigue life using the mechanical/elastic properties as the input parameter using additives in the established failure conditions considering Federal roads in the South East as case studies. It is also important to note that the research has a well-defined assumption within the scope to expectancy is 20 years. The loads causing pavement failure are ≥80 KN single axle. Passenger cars will not be included in the passenger. The performance of flexible pavement in real life is synonymous with performance of hot mix asphalt concrete (HMA) in the laboratory. The fatigue life of a pavement is the number of load repetitions ≥80 KN single axle load and finally, traffic loads and moisture are the only contributors to pavement damage.

Keywords

Pavement Vulnerability, Climate Change, Global Warming

1. Introduction

The climate change debate has moved away from whether or not there is evidence of climatic change to what must be done to reduce the magnitude of further changes and minimize the impacts [1]. There is now an overwhelming body of scientific evidence highlighting the serious and urgent nature of climate change, largely due to emissions of greenhouse gases as a result of human activities [2]. In recent decades, changes in climate have caused impacts on natural and human systems on all continents and across the oceans [3].

[2] reported that evidence of climate-change impacts is strongest and most comprehensive for natural systems. In many regions, changing precipitation or melting snow and ice are altering hydrological systems, affecting water resources in terms of quantity and quality. Glaciers continue to shrink globally due to climate change, affecting runoff and water resources downstream [4]. Climate change is causing permafrost warming and thawing in high latitude regions and in high-elevation regions. Impacts of such climate-related extremes include alteration of ecosystems, disruption of food production and water supply, damage to infrastructures and settlements, morbidity and mortality, and consequences for mental health and human well-being [1].

These changes are set to have significant impacts on the design, construction, maintenance and operation of global road infrastructure. For example, drier and hotter weather will lead to more incidences of infrastructure subsidence and heat damage to pavements and structures; more frequent heavy precipitation events will result in increased incidences of flooding in low-lying areas and floodplains; and sea level rise may make some networks and assets temporarily or permanently inaccessible. These impacts will lead to disruption to services and increased operational, maintenance and emergency repair costs. Communities, businesses and localities that rely on the networks will be impacted if part of a network becomes inaccessible as a result of the impacts of climate change or an extreme weather event. Impacts from recent climate-related extremes, such as heat waves, droughts, floods, cyclones, and wildfires, reveal significant vulnerability and exposure [5] [6].

Vulnerability is the degree to which a system is susceptible to, or unable to cope with, adverse effects of climatic change, including climate variables and extremes. Vulnerability, in the context of this framework, is a function of the character, magnitude and rate of climate change and variation to which a system is exposed (its exposure); and the degree to which something is affected, either adversely or beneficially, by climate-related stimuli (its sensitivity) [4]. Vulnerability is also determined by the type of asset, location or operation's adaptive capacity; essentially the system's ability to cope and adapt to existing climatic variability and future changes [7]. The term "vulnerability" is addressed as facilities that are "at risk" of some impact associated with climate change due to its condition, location, etc. Currently there is no comprehensive inventory of the vulnerability of road pavement to climate change including the extent of exposure or damage costs [8].

The Delphi method is a structured process for collecting and distilling knowledge from a group of experts using a series of questionnaires with controlled opinion feedback [9]. The Delphi technique has been used in a variety of applications, such as planning, environmental impact assessment. Wide use of this technique has led to significant deviations from the original technique and the creation of a family of Delphi-related processes [10] [11]. However, the Delphi technique has not been widely used in the determination of road vulnerability [12].

When rain falls, some amount of the rain water runs on the road or soil surface and some of it penetrates through the soil mass to the ground water aquifer. Some elements of the water remain in the soil pores and on the surface of soil. These waters cannot be drained by normal gravitational techniques. It is essential that rain water on the roadway or thoroughfare and road shoulders be well drained so as to avoid percolation of the water into the sub grade. The surface water from adjacent or nearby land must also be prevented from flowing into the roadway through the provision of side drains with adequate capacity and slopes needed to take away all the surface water runoff. With faulty drainage systems, failure of road pavements is eminent as moisture content increases causing decrease in strength, mud pumping, waves and corrugations formation, stripping of the asphalt, frost action and pavement edge cutting [13]. In the South Eastern Nigeria, most of the roads do not have drainages; thus, most of these road pavements are exposed to excessive water submergence resulting in failure. Therefore, the present study focused on the fatigue life of wearing course of flexible pavements and their behavior as a result of the climate change which has led to pavement exposure to extreme moisture conditions. Also, the roads to be considered are trunk A, trunk B and trunk C respectively.

1.1. Literature Review

Scientific evidence of climate change and the potential for serious global impact is now stronger than ever [14]. The Intergovernmental Panel on Climate Change (IPCC) states that there is a ninety-percent probability (very high confidence) that greenhouse gas emissions produced by human activities have caused most of the observed global warming since the mid-twentieth century [15]. The phrase "climate change" is used to signify alterations in the Earth's "pattern of weather, meaning the averages, the extremes, the timing, the spatial distribution not only of hot and cold, but of cloudy and clear, humid and dry, drizzles and downpours, snowfall, snowpack, snowmelt, blizzards, tornados, and typhoons" [16]. These changes are in addition to rising temperatures (which is referred to as global warming), that has already and will continue to occur in response to atmospheric amplified warming. Amplified warming is the result of high concentrations of carbon dioxide emissions and other greenhouse gas emissions (methane, nitrous oxide, halocarbons, and ozone) trapping additional infrared energy beyond what occurs naturally [17]. The process of natural warming can be seen in **Figure 1** which is based on the greenhouse effect where the majority

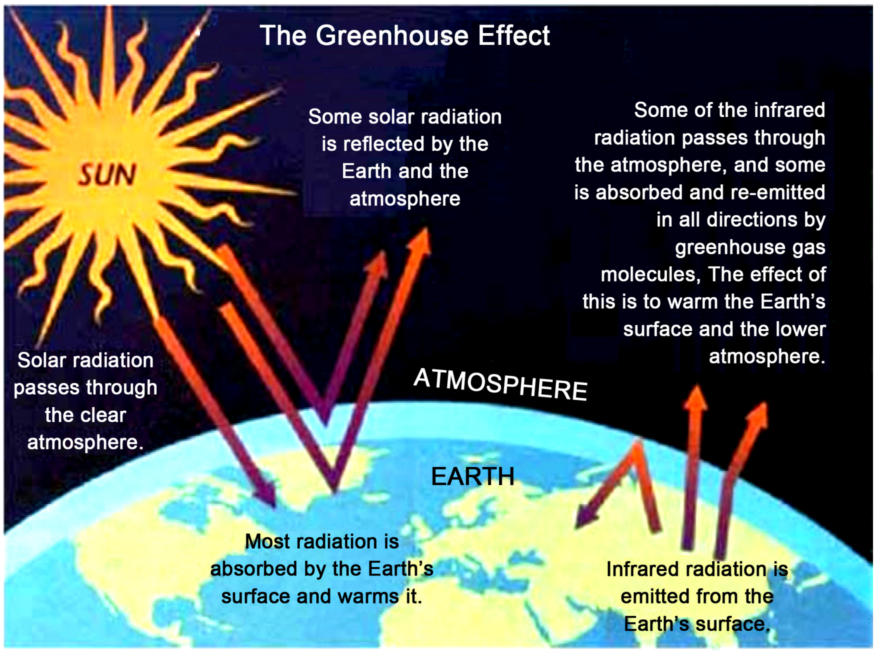

Figure 1. The greenhouse effect (National Academies, 2008).

of sunlight emitted onto the Earth's surface is absorbed by the oceans and land. The remaining infrared energy radiates outwards from the Earth and is either absorbed by the greenhouse gases, emitted into space, or reflected back toward the Earth's surface [17].

Since the mid-1700's human activities have been influencing the global atmospheric concentrations of carbon dioxide, methane, and nitrous oxide leading to a disruption in the natural warming process [18]. The increased release of greenhouse gas emissions is responsible for the amplification of this process where additional infrared energy is trapped, further warming the atmosphere and the Earth's surface. As a result, long-term climatic changes have been observed and are projected to continue, including increased temperatures, heavy precipitation, droughts, rising sea level, heat waves, tropical cyclone intensity, and extreme weather events [19]. Therefore, rising temperatures along with additional indicators (increased ocean temperatures, shrinking mountain glaciers, and decreasing polar ice cover) indicate that the threat of climate change is undeniably requiring an urgent global response [20].

1.2. Global Warming

Recently scientific evidence has proven that global warming has occurred at a rate of 0.2˚C per decade, leading to observable changes such as varying rainfall patterns, sea level rise, ice and snow melt, and increase in intensity and frequency of extreme weather events [4]. Over the past thirty years there has been a more pronounced warming trend and even more recently, nine out of ten of the warmest years occurred over the last decade [21]. **Figure 2** displays the global temperature increase for both the annual and five-year mean. Although these

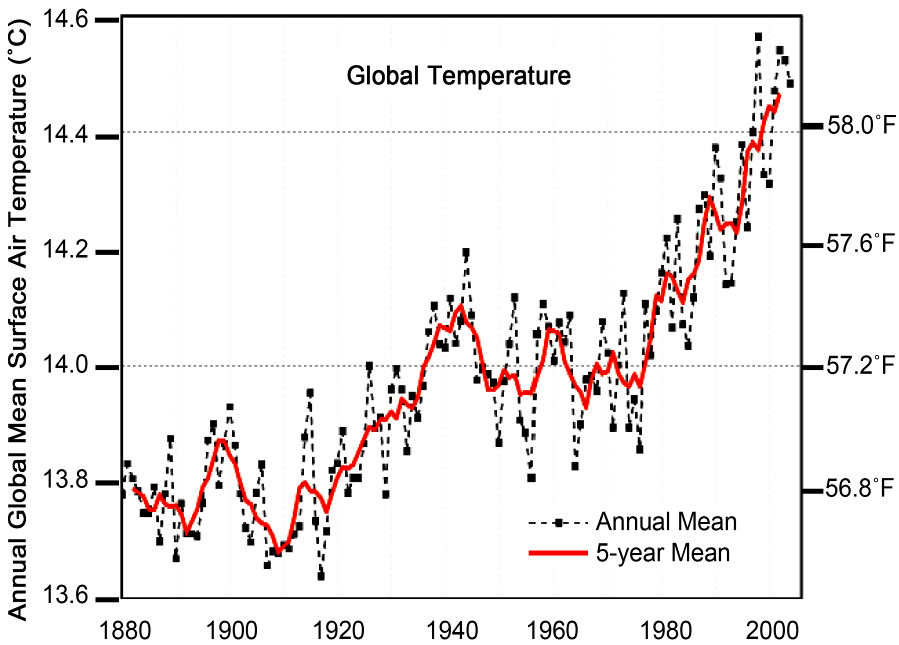

Figure 2. Global temperature: Land-ocean surface (National Academies, 2005).

upward trends are indisputable, there are questions regarding whether the warming trend is unusual compared to trends prior to the 20th century. Based on scientific analysis on tree rings, ice cores, ocean sediments, and other "proxies", it has been identified that there is a "high level of confidence that the global mean surface temperature was higher during the last few decades of the 20th century than during any comparable period since at least 1600 A.D." [22]. This warming process has been extremely rapid, placing undue stress on both social and environmental systems, leading to additional disruptions in long term weather patterns. As a result, researchers believe that the term "global warming" does not serve justice to the problem and rather it should be called a "global climatic disruption" [6]. There is a strong link between global average surface temperature and global climate. The surface temperature serves as an index for the state of climatic patterns and a small alteration in the index results in large changes in the patterns [23]. These small changes in temperature (0.2˚C per decade) are leading to extreme changes in sea level rise, and widespread melting of ice and snow. The reasons are as a result of observable changes such as varying rainfall patterns and increase in intensity and frequency of extreme weather events.

1.3. Anthropogenic Influences

In 2007, the Intergovernmental Panel on Climate Change reported that there is a "very high confidence" behind the relationship of anthropogenic activities and global warming [15]. Through fossil fuel burning as well as land use changes, humans are pushing the climate toward the heating direction and further away from natural cooling [16]. Scientific evidence supports this claim by modeling natural patterns against direct observations which take into account human activity.

1.4. Greenhouse Gases

The main cause of global warming has been attributed to the release of greenhouse gas emissions including carbon dioxide, methane, nitrous oxide, halocarbons, and ozone [24]. As of 2006, the current level of carbon dioxide is 430 ppm (parts per million) and is rising at more than 2 ppm each year [14]. In order to stabilize carbon dioxide emissions, annual costs of 1% of global GDP/year are required to maintain a level between 500 ppm and 550 ppm, assuming immediate action is taken [14]. Releasing carbon dioxide is just one of the multiple contributors of anthropogenic warming. The following is a list of the greenhouse gases that are imposing external warming on the Earth's surface [25]:

- Carbon dioxide—associated with the release of carbon dioxide from the combustion of fossil fuels, deforestation, and other land use changes.
- Methane—released primarily through raising livestock, growing rice, filling landfills, and using natural gas.
- Nitrous oxide—resulting from agricultural activities and land use changes.
- Ozone—associated with a warming effect when produced near the Earth's surface via reactions involving carbon monoxide, hydrocarbons, and nitrogen oxide.
- Halocarbons—attributed to the use of (chlorofluorocarbons) CFC's including refrigerants and fire retardants which is also responsible for damaging the ozone layer. In addition to these aforementioned greenhouse gases, other human activities are forcing temperature changes. The most prominent activities are [26]:
- Aerosols—industrial processes are associated with the release of aerosols which cool the planet by reflecting sunlight back into space.
- Black carbon particles (soot)—produced by the burning of fossil fuels or vegetation and responsible for a warming effect since they absorb incoming solar radiation.
- Deforestation—removal of trees leads to a modification in the amount of sunlight that is reflected back to space.
- Land use changes—alteration in the use of land such as increased impervious cover which influences the amount of sunlight reflected back into space.

1.5. Trends in Climate

Climate change is a phenomenon that will affect all countries throughout the world at a national, state, and local level [14]. Although everyone is at risk for impact, the costs and degree of impact will vary based on regional context. Influences such as latitude and longitude, coastal regions, islands, sea level, and terrain will lead to unique circumstances at the local level. For example, coastal regions are more at risk for flooding, a symptom of sea level rise, while countries in the upper Northern hemisphere are more at risk for widespread snow and ice melt.

Key IPCC (Intergovernmental Panel on Climate Change) projections are that:

- The Earth will become warmer;
- Some regions will become wetter overall and some will become drier;
- Sea levels will rise and storm surge height will increase;
- Snow cover and the extent of sea-ice will reduce; and,
- The frequency and severity of extreme weather events (such as storms, heat waves, drought and periods of prolonged and heavy precipitation) will increase;
- There will be further warming and changes in all components of the climate system;
- Global surface temperature change for the end of the 21st century is likely to exceed 2.0˚C in most emission scenarios. Warming is very likely to continue beyond 2100 and this warming will exhibit interannual-to-decadal variability and will not be regionally uniform;
- Changes to the global water cycle in response to the warming over the 21st century will not be uniform. The contrast in precipitation between wet and dry regions and between wet and dry seasons will increase, although there may be regional exceptions;
- It is very likely that the Arctic sea ice cover will continue to shrink and thin and that Northern Hemisphere spring snow cover will decrease during the 21st century as global mean temperature rises. Global glacier volume will further decrease; and Global mean sea level will continue to rise during the 21st century. The rate of sea level rise will very likely exceed that observed during 1971 to 2010 due to increased ocean warming and increased mass from glaciers and ice sheets. Climate change is also expected to exacerbate the frequency and magnitude of extreme weather events, such as drought, heat waves, storms, prolonged and heavy precipitation events and periods of very hot or very cold days. The most recent Assessment Report (AR5) of IPCC (2001, 2014) reinforces the conclusions of the previous four assessment reports which state that "the balance of evidence suggests that there is a discernible human influence on global climate" with the result being that we have now driven the climate beyond natural variability. The key observed climatic change impacts and vulnerabilities highlighted by the AR5 are recast as follows. Rising global temperature are already altering weather patterns, causing sea level to rise and increasing the frequency and intensity of extreme weather. It is very likely (90% - 100% probability) that the number of cold day and nights has decreased and the number of warm days and nights has increased at the global scale. Whilst precipitations changes are harder to analyze it is likely (66% - 100% probability) that there are more land regions where the number of heavy precipitation events has increased than where it has decreased. Even if anthropogenic (human) emissions stop today, evidence indicates that changes to the climate will continue for at least the next

three decades. There is a consensus that a temperature rise of over 2˚C will have major consequences globally.

1.6. Characteristics of Road Pavement

The characteristics of a road pavement, including its vulnerability to climate will be determined by both the materials from which it is constructed and its design structure.

1.7. Pavement Materials

The main types of material used for roads construction are asphalt or concrete, but modular surfaces are increasingly used in shopping centres and residential areas. Footways are most commonly surfaced with asphalt, but modular paving and concrete are also used [27]. [28] reported that thin flexible or thin rigid footways are constructed similarly to road pavements, but without the structural layer as they are not designed to take heavy vehicular traffic (although, they may be designed to withstand vehicle overrun).

2. Materials and Methods

2.1. Materials

In course of achieving the research aim, the study was carried out in six stages: field survey, material sampling, sample preparation, laboratory experiments, and the application of mathematical models in the determination of dynamic modulus and fatigue life and finally the development of predictive model to know the extent of damage and when maintenance needed for a hot mix asphalt concrete pavement in different moisture conditions. In this study, river sand, gravel and bitumen were used.

2.2. Field Survey

A wide-ranging of factors causing rapid road failure as a result of climate change which leads to unwanted maintenance was produced from the road users and professionals in practice using the Delphi method. Three major causes were listed in well-structured questionnaire and administered to 300 persons which includes the road users and professional engineers in highway design construction and maintenance. The questionnaire results were analyzed using the Relative Importance Index (R.I.I) method of analysis.

To determine the actual cause of road failure due to climate change, the Relative importance index was used. As shown in Equation (1), it is a four-scale system converted to Relative Importance Index (R.I.I) for each factor [29].

$$\text{R.I.I} = \frac{4n_1 + 3n_2 + 2n_3 + n_4}{4N} \tag{1}$$

where:

n_1 = Number of persons who strongly agree;

n_2 = Number of persons who agree;

n_3 = Number of persons who disagree;

n_4 = Number of persons who strongly disagree;

N = Number of persons who responded.

2.3. Sampling of Materials

Materials used for the preparation of asphalt concrete samples to simulate the actual flexible pavement wearing course under examination were obtained from a variety of sources in order to achieve the research aim. The asphalt came from Reynold Construction Company (RCC), while the aggregates (gravel and sand) came from roadside building material dealers in Owerri town.

2.4. Laboratory Experiments

This entailed testing materials in order to determine the following:

1) Aggregate and binder specific gravity.

2) Aggregate mechanical gradation (fine and coarse).

3) Binder physical properties such as penetration, viscosity, and softening point.

4) Sample preparation for HMA concretes and subjecting them to major failure conditions.

5) Crushing samples to failure to determine the mix design properties of the HMA, such as stability, density, voids in mineral aggregates, air voids, and flow, which were used for further analysis.

2.5. Sample Preparation

The Marshal Mix Design procedure for asphalt concrete mixes, as presented by [30] and the Asphalt Institute was used to arrange the samples. The procedure entails preparing a series of test samples for a variety of asphalt contents in order for the test data curves to show well-defined optimum values. The tests were planned with 0.5 percent asphalt content additions with at least 2-asphalt contents below and above the optimum asphalt content. To ensure an adequate data base, three test samples were prepared for each asphalt content used. The samples were 64 mm thick and 100 mm in diameter. Furthermore, each sample required about 1.2 kg of the total weight of the mixture by weight. The samples were prepared for heavy, medium and light traffic conditions at 1 Hz, 5 Hz and 10 Hz frequency of traffic load on the pavement.

The pure HMA samples were prepared by blending aggregates and heating them for about 5 minutes before adding asphalt binder to allow absorption into the aggregates. Following that, the mixture was emptied into a sample mould and compacted on both faces, depending on the traffic class, with a rammer freely falling at 450 mm and weighing 6.5 kg. Five asphalt content ranges (between 4 - 6 percent) were used to prepare briquette with 0.5 percent increments for the three traffic categories. **Table 1** displays the various traffic categories as

Table 1. Traffic types and the number of blows applied.

Traffic type	Light	Medium	Heavy
No. of blows applied on each face	35	50	75

well as the number of blows delivered to each face.

Following compaction on every face, samples were weighed in air and the results were recorded as Wa, for each mix and for each traffic load. This was followed by weighing the samples when they were fully immersed in the water bath and recording the results as Ww for the various samples prepared for each traffic load. Following that, the samples were heated for about 15 minutes in a controlled system (water bath) at a specified destructive temperature of 54˚C. The samples were immediately crushed to failure, and the maximum load that caused failure was recorded, along with the flow resistance value of the concrete at the point of failure. The peak resistance value of the asphalt concrete between zero loading and maximum load in Newton was obtained for each sample, while the flow in mm was determined by attaching a flow gauge concurrently to the samples during the crushing process, and the maximum resistance to flow was noted as the flow value for each sample for the various traffic categories. These were the average values of the three samples. A total of 45 samples were prepared (15 for each traffic category), as shown in **Table 1**. The sample results were then subjected to density and voids analysis, which were then used to determine the optimum asphalt content for preparing the control concrete sample. Using the Bruce Marshall Design procedure, the optimum asphalt content was determined as follows:

Plot a graph of each design property against asphalt content: that is, a graph of the following:

1) Stability against asphalt content;

2) Flow against asphalt content;

3) Density against asphalt content;

4) Air voids against asphalt content;

5) VMA against asphalt content.

1) Determination of the following parameters:

a) Asphalt content at maximum stability (x);

b) Asphalt content at maximum density (y);

c) Asphalt content at median limits of air voids (*i.e.* at 4% air voids) (z).

2) Determine their arithmetic average asphalt content which is equal to the design asphalt content or optimum asphalt content of concrete (O.A.C). That is,

$$\text{O.A.C} = \frac{1}{3}(x + y + z) \tag{2}$$

After determining the optimal asphalt content, the value was used to prepare control samples, which were then soaked from day 1 to day 10. Following that, the Marshall Design properties were determined, as well as the dynamic modulus, which controls fatigue life.

Table 2 displays the standard method of test for sieve analysis. The test was done preliminarily on aggregates, Bitumen and as well as mix design properties. This was conducted using AASHTO standards with different samples and parameters.

Table 2. Plan of experimentation with applied standards [31].

Preliminary Test	Test Conducted	Standard Used	Total Number of Samples	Parameter Measured
Test on Aggregates	Sieve Analysis	AASHTO T27 (2020), BS: 812-103 (103)		Coefficient of Uniformity
	Coarse		3	
	Fine		3	
	Specific Gravity	ASTM D854-14 (2014), BS 812 Part 2: 1999		Specific gravity
	Coarse		3	
	Fine		3	
Test on Bitumen	Bulk Specific Gravity	AASHTO T53 (2010)	3	Bulk Specific Gravity
	Viscosity	ASTM (2014)	3	Flow
	Softening Point	AASHTO T53 (2010)	3	Softening and harden point
	Penetration	ASTM D946 (2006)	3	Consistency
Mix Design Properties	Stability	ASTM D6927	9	Stability
	Flow		9	Flow
	Density		9	Density
	Air voids		9	Air voids
	Voids in Mineral Aggregates		9	Voids in Mineral Aggregates

[31]: Standard method of test for sieve analysis.

2.6. Dynamic Modulus Determination Using the Asphalt Institute Model (1993)

[32] developed a design method in which the dynamic modulus is calculated using the equations (3)-(9) as shown below::

$$E^{*} = 100000 \times 10^{\beta_1} \quad (3)$$

$$\beta_1 = \beta_3 + 0.000005\beta_2 - 0.00189\beta_2 f^{-1.1} \quad (4)$$

$$\beta_2 = \beta_4^{0.5} T^{\beta_5} \quad (5)$$

$$\beta_3 = 0.553833 + 0.028829\left(P_{200} f^{-0.1703}\right) - 0.03476V_a + 0.07037\lambda + 0.931757 f^{-0.02774} \quad (6)$$

$$\beta_4 = 0.483V_b \quad (7)$$

$$\beta_5 = 1.3 + 0.49825\log f \quad (8)$$

$$\lambda = 29508.2\left(P_{77^\circ\mathrm{F}}\right)^{-2.1939} \quad (9)$$

where;

E^* = dynamic modulus (psi);

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

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 (m^3);

$P_{77^\circ\mathrm{F}}$ = penetration at 77˚F .

2.7. Fatigue Life Determination Using Asphalt Institute (1982)

According to the Asphalt Institute [33], the number of load repetitions represents the relationship between fatigue cracking and tensile strain.

$$N_f = S_f \times 10^{4.84(VFA-0.69)} \times 0.00432 \times E_t^{-3.291} \times E^{-0.845} \quad (10)$$

where;

E = dynamic modulus;

VFA = voids in aggregate filled with asphalt (%);

$$VFA = 100\% \times \frac{VMA - V_a}{VMA} \quad (11)$$

VMA = voids in mineral aggregate (%);

V_a = air voids (%);

S_f = shift factor to convert laboratory test result to field.

The relationship or difference among E, E^* and E_t are:

E = dynamic modulus;

E^* = Dynamic Modular (psi);

E_t = Dynamic Modulus at a mixing temperature.

To mitigate the effects of shift factors S_f, the Asphalt Institute model was further modified to account for shift factors resulting from various combinations of asphalt binder types and grades [33]. The resulting equation is of the type that will be used in this work.

$$N_f = 0.0796\left(\varepsilon_t\right)^{-3.291} E^{-0.845} \quad (12)$$

where;

N_f = number of load repetitions to failure;

E = dynamic modulus;

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

2.8. Nonlinear Regression Model Development for Prediction

The Eureqa software was used in the research to develop predictive models. In the iteration process, this software employs artificial intelligence (AI). In order to develop the nonlinear regression using Eureqa, the variables (dependent and independent) were first placed in the cells, and settings were made to ensure that the model developed satisfies the condition as expected.

The following nine nonlinear models were proposed, tested, and used to validate the experimental results.

Predictive Model for Low Volume Traffic at Frequency = 1 Hz

$$Y = a + bx^2 + cvw^3 - dv - ew \tag{13}$$

1) Predictive Model for Low Volume Traffic at Frequency = 5 Hz

$$Y = a + bx + cw^2 + d\cos(ev) - fw \tag{14}$$

2) Predictive Model for Low Volume Traffic at Frequency = 10 Hz

$$Y = a + bwv + cw^3 + dwx^2 - ev - fw \tag{15}$$

3) Predictive Model for Medium Volume Traffic at Frequency = 1 Hz

$$Y = a + bx + cw^2 + dx^2 - ew - fwv - gxw \tag{16}$$

4) Predictive Model for Medium Volume Traffic at Frequency = 5 Hz

$$Y = a + bx + cw^2 + dx^2 - ew - fwv - gxw \tag{17}$$

Equation (16) is the relative importance which was used to determine the actual cause of road failure due to climate change while Equation (17) is a non-linear model proposed, tested and used to validate the experimental results.

5) Predictive Model for Medium Volume Traffic at Frequency = 10 Hz

$$Y = a + bw^5 + cwv^2 + dv - ew^2 \tag{18}$$

6) Predictive Model for Heavy Volume Traffic at Frequency = 1 Hz

$$Y = a + bw^3 + c\sin(dw) + ewv^2 - \frac{f}{\cos(gw)} - hv - iw^2 \tag{19}$$

7) Predictive Model for Heavy Volume Traffic at Frequency = 5 Hz

$$Y = a + bw^5 + cwv^2 - dv - ew^2 - f\cos(gwv) \tag{20}$$

8) Predictive Model for Heavy Volume Traffic at Frequency = 10 Hz

$$Y = a + bw^4 + cwv^2 - dv - ew^2 \tag{21}$$

where:

Y = Fatigue;

x = Soaking days;

w = Strain;

v = Dynamic Modulus.

a, b, c, d, and e are constants to be determined using the Eureqa software.

3. Conclusion

In South East Nigeria, roads are usually designed and constructed without considering the peculiarity of the area, in this area where there is high rainfall with pro-violent flooding. As a result, the roads are continually submerged because of poor hydraulic system management, inadequate drainage channels or lack of drainage. The need to improve the pavement performance under this condition is pertinent to increase the time required for maintenance. This research work is premised on the justification that several efforts to provide the best performance and reduce cost of maintenance still falls short of expectation and it has kept engineers on the path of continuous search for a better solution. Dynamic modulus will be determined using the Asphalt institute model, [33]. Also, fatigue life will be determined using Asphalt Institute [33]. The eureqa software will be used in the research to develop predictive models.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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