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An Appraisal of Models for Roads Pavement Failures in Ebonyi State Nigeria

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Abstract: ***Nigeria road pavement is subjected to have low road density of 23km/m2 of the pave land area and justification for this material stress, functional disability and loss of cohesion. In Ebonyi state there is needs to assess the impact of failed road pavement on economic growth and social stability of the state. Most of the state urban roads failed because of many vehicles passing in definite section of the road per unit time at any suitable period, subjecting the paved areas into physically disintegration of crystalline aggregated material informed of ruttings, pothole, raveling and cracks and some deteriorate or decomposed in a large number of cement aggregate into organic matter causing chemical separations and moisture attack on the paved area by attacking the fabric bond of the binding pavement. The aim of this research is to analyze roads pavement failures for effective cost management. The research design comprised extensive literature. This research was to facilitate the measurement of variables on affected areas causing surface depression and surface deterioration on large number of aggregated crystalline material from rehabilitation of the respective road projects. The research was design to measure stress types, stress values, stress seventy and stress density derive from affected paved area. The data collected were presented in tables, percentage, and pie chart and analyzed with multiple regressions. The findings will establish the state of stress over strain will be sustainable for road pavement in urban areas. The model implies based on the data collected the cause of stress values in urban roads increase by 0.284 (28.4%) were trigger increase in road rehabilitation, repairs and remedial works by 0.77, 0.31 and 0.60 and which were ascertain the level of cost implementation for effective life cycle costing on urban roads in the state.***

Keywords: Stress Severity, Stress Density, Stress Types and Cost Effective

I. INTRODUCTION

Pavement performances in some developed countries ease transportations, boost economy and social network. According to World Bank collection of development indicates Singapore road density km of road per sq. km of land was reportedly to be 473 sq. km in 2009. This was higher than in Japan 320 sq. km, higher than in Germany 180 sq. km for the same period and higher than United Kingdom reported to be 172 sq. km according to the World Bank collection of development. The reasons for this include client's growing demand, maintenance, introduction of new innovations and advancement in technology (Cai, Liu & Cao, 2009, [3][4]).

In developing country like Nigeria that has low road density index of 21 sq km, which means pavements in Nigeria road usually constructed on weak small embankments and a little above the general ground level and acceleration lane of roads constructed with insufficient width to enable vehicles to accelerate to the design speed, virtually making the pavements not to hold its original shapes and have a tendency to develop functional failures that resulted into material stress, functional disability, tensile stress, material aging and loss of adhesion. This is primarily reasons for pavement failures. The irony is that Ebonyi State there is a need to assess the impact of failed road pavement on growth and economy stability of the state. Most of the roads in the state failed because many vehicles of all types in different magnitude, occupying passing in direction and definite section of the road per unit time at any suitable period subjecting the pave area into stress, chemical reaction and moisture attack. It encompasses the landscape littered with congestions, higher fuel consumptions and high cost of arranging road maintenance works. Several roads in the state, which would have impacted positively on the economy social development, cultural interrelationship and industrial activities of the state, left on the corner unconstructed, un-rehabilitated and unmaintained. The paved roads in Ebonyi State are all made up of 68% flexible and 42% rigid pavement. The nature of the roads is made of flexible and rigid pavement which was composed of many materials used for the sub-grade, base course, sub base and surfacing. Most of the defects like cracks, potholes, raveling, shoving and ruts in the state paved roads are characterized by temperature variation in climate changes scenario all over the world or globally by World Bank Data 2010, which revealed temperature increase from 1.4 ^{0}C to 5.8 ^{0}C over the next 100years, if no action is taken globally to control it. It will definitely lead to progressive rise in temperature and rainfall (Twerefou, et al 2015, [13][14]).

The global change in weather has a direct impact which characterized by abnormal rainfall and high temperature applying stress to the paved road. And also, high temperature may cause roads pavement to increase in dimensional length on non-crystalline solid viscous materials and easily developed cracks within a short period after construction and existing roads to easily developed potholes while existing pothole will deepen fast (Taylor & Philip, 2011, [12]).

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Asphalt mixtures are viscous elastic plastic materials, the strength and modulus of these materials clearly change under thermal stress resulted from temperature and rainfall. Thus, the choice of asphalt binder is closely related to the local temperature conditions to satisfy structural and functional requirements. For instance, at low temperature, asphalt becomes hard and the asphalt layers are exposed to thermal and fatigue cracking. On the contrary, at high temperatures resulted from high traffic volume, low speed produces thermal stress causing asphalt to be vulnerable to rutting and cracking, asphalt becomes soft and more viscous and thus it is more prone to rutting. The variation in temperature effect on pavement cannot be ignored. (Abu El-Maaty, 2012, [2])

II. LITERATURE REVIEW

2.1. Conceptual Review

AASTHO (1998) provided a guide for design of pavement structures in 1993, which was based on the AASTHO Road test [1]. The design made consideration for climatic condition, drainage consideration and the ability for precise predictions of design life and provision for rehabilitation. With changes in the construction methods, materials, traffic loading conditions, rehabilitation and performance requirement since the time of AASTHO. This incited the need for development of mechanistic – empirical design method (NCHRP, 2004, [10]). They provided guide for mechanistic – empirical design of new and rehabilitated pavement structures (MEPDG) was developed under NCHRP) projects, the term mechanistic refers to the use of engineering mechanics principle, and it leads to a rational design approach. The three major elements of this approach are, the theory pertaining to the prediction of critical pavement responses as a function of input.

Pavements, evaluation of material properties in relation to the chosen theory and findings of a relationship between distresses observed in the field against the critical pavement response (FHWA, 2014, [6]). They provide guide which allowed for incorporation of the impact of climatic conditions, aging phenomenon of the materials in the pavement and realistic loading condition in the design procedure. Also, it will allowed for the consideration of the condition of standing pavement in the design of new pavement repair of the standing pavement or for analysis of the current pavement structure.

Pavement performances depend on functional ability of structures, under applied loads, pavement conditions and environmental factors, such as asphalt mix temperatures and moisture content in unbound materials (Flavio & Leadro, 2012, [5]). The temperature of an asphalt mix is a determining factor of its performances. Asphalt mix properties changes depended on temperature, hereby it response to traffic loads will also be different (Gang, Eric & Roger, 2007, [7])

Pilard (2010) [11] highlighted traffic daily pattern for flexible pavement in Botswana road network. The studied maintain that the stress concentration which is on the highest peak in traffic volume is during the working days (Monday to Friday). The study captured the key structures for the development of Botswana road network that are responsible for a large portion of transportation of goods and people in urban road in Botswana. Nigeria has different setting in daily transportation system, 24 hours traffic congestion, poor maintenance culture and induced loads are of different types on urban state road.

Mohamad & Shah (2002, [9]) revealed effective maintenance program management of road network. The study maintained that the stress concentration on traffic volumes, truck types and average road damage per vehicles and future volume increase. The study also revealed of the use of truck routes to preserve the road pavement and good management techniques. The study is different from Nigeria roads, where different types of vehicles applying at the same time and magnitude on the acceleration carriage way subjecting this pave road into induce stress.

2.2. Conceptual Bases for This Work

As found from literatures this section will isolate key factors that are involved, to go through the study successfully and then explain the presumed relationship between them. The conceptual frame work, which is particularly useful for streamlining the researcher's understanding and holistic thinking for this research, as illustrated in the objectives from the literature review, it can be deducted that in order to developed models for managing pavement failures, the key factors should be taken care off. These concepts and key factors extracted from the literature review from the basis of the conceptual frame work which directs the investigation to be made at the data collection stage. Although the conceptual frame work has illustrated the concepts similar to portraying the relationship between independent – mediating – dependent variables. It should be noted that this research is mathematically in form of exploratory in nature, which was indicated by the research objectives in chapter one of this thesis. Furthermore, the aim of this research is to develop suitable models for Ebonyi urban road projects. This requires in-depth exploration of concepts, barriers and challenges that indicates in research context. Therefore, this conceptual frame work serves only as visualization of concepts for further exploring in the real world the concepts identified in the conceptual world, which in this context are the errors in literature. The key factors in this study are stress concentration under common cause of functional failures and models for effective cost reconciliations. Each of these is explained here under together with the relationship between them.

ii). The impact of vehicles that produce stress through physical damage and thermal stress generated from the motion, vibration from heavy traffic movement, lateral pressure, excessive shear force, overloading and physical wear and tear. It is asserted that to solve a problem, the causes of the problem must be discovered. It is necessary to first determine the causes of functional failures from the state urban roads. This will be evaluated from the stress concentrations that derive from high influx of vehicular movements and disintegration of non-crystalline viscous aggregated material on the pave roads due to the loading condition.

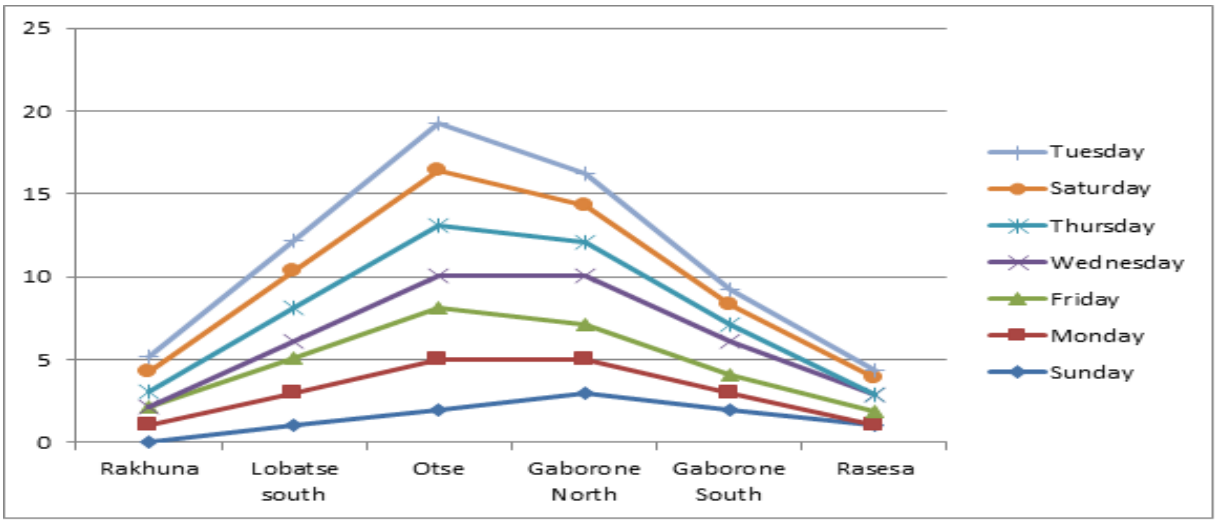
The step taken to remove pavement failures is by providing the guidelines to extract stress and strain from the state roads pavement.

ii). To explore the impact of rainfall as resulted from climate changes excessive thermal stresses due to temperature variation, increased pressure on sub base due to excessive rainfall, thermal movement and moisture movement. This is also determining from causes of functional failures from the state roads. This will also be evaluated from the stress concentration derive from rainfall infiltrated and attacked the bond between binding and aggregate of the pavement causing capillary suction, self-desiccation, external drying, excessive warping, water absorption and distress. The steps taken to remove the changes which was characterized by abnormal rainfall is to improve the guidelines.

2.3. Theoretical Framework

2.3.1. Traffic Daily Pattern in Pavement

Pilard (2010) evaluated traffic daily volume pattern in Botswana road network. The study reported that traffic volume varies throughout the week.



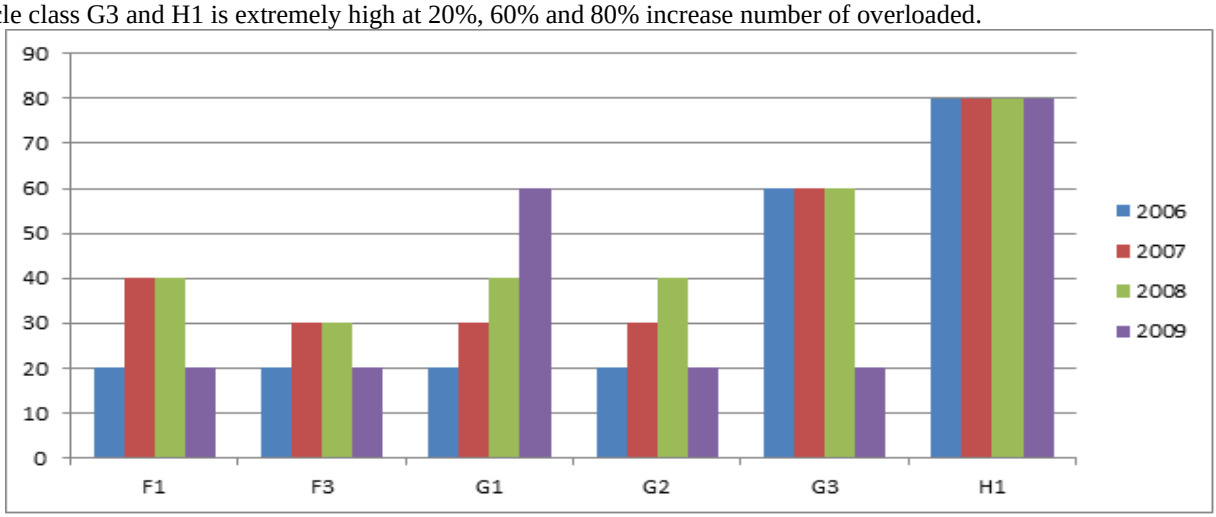
Source: Lambert (2017)[8]

Fig. 2.2.1 Represent Graphically Traffic Daily Pattern

From fig. 2.2.1 graph traffic volume during the weekend is likely to differ from the working days on different direction. Urban population goes to the rural areas during the weekend, hence a high variation of traffic on the urban – rural connector roads during weekdays and weekends. The peak in the morning show a number of distinguishable peak follow by afternoon and a new peak in the late evening.

2.3.2. Vehicle Classification in Pavement

Pozzi & Madanal (2004, [12]) explained a model on graphical classification of vehicle classes and maxima legal load in provision of information for the transformation of pavement functional failures. The graph in fig. 2.2.3 represents the increment in traffic volumes, truck types and future vehicle volume increases in year 2006, 2007, 2008 and 2009 [15]. The vehicle class G3 and H1 is extremely high at 20%, 60% and 80% increase number of overloaded.



Source: Prozzi & Madanat (2004)

Fig 2.2.3 Graph of Vehicle Classes and Maxima Legal Load

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The number of overloaded were related to the level of loading. If the average axle load increase, the percentage of overloaded vehicles will also increases. The percentage of overloaded vehicles rises substantially as year increases. The information enables them to change from what they ought to be.

2.3.3. Summary and Gap in Literature

S/n	Author(s)	Title of a Paper	Findings	Limitation
1	Pilard (2010)	Overload control practices in eastern and southern Africa.	The report showed that traffic volumes generally varies throughout the week with a number of distinguishable peaks	i). Types of the available data ii). The results lack expressions on pavement stress applications and cost in use of stress over strain iii). When and where the data was source iv). The approach to result lead to literary criticizes v). The data failed to capture expression on the impact of moisture attack in a paved area
2	Prozzi & Madanal (2004)	Development of pavement performance models by combined experimental and field data	From the graph, highest class of overloaded vehicle (H1) was 80% higher than (G3) was 60% in 2009. The report showed that it was extremely high	i). Types of the available data ii). The result of the data undermines geographical surface structure of a particular region iii) the scholar failed to express the stress type in pavement iv). the data failed to capture the impact of moisture attack in a paved area

Source: referenced authors

Most of the author studied road project outside the Nigerian road construction project, in South-East Nigeria most road projects were characterized by low land relief, poor maintenance culture, low road density, low road intensity, high population density, abnormal rainfall, denudation (high water table), unlawful deposition of refuse, temperature variation, high classification of vehicle and high traffic volume of road users outflow.

From all the work carried out, there are still many questions that need to be investigated for future research studies. The type of road design, the stress concentration derive from common cause of functional failures from the increase in mechanic movement on paved area and moisture attack due to change in atmospheric conditions of a place. This study will measure vehicular impact load distribution volume and weight, moisture attack, waste attack and to drive a models for appropriate cost reconciliation that will hold preserve the road pavement to effective lifecycle with specific properties against time. The responses and stress dependency of the unbound layers and their correlation will be evaluated using back calculation of the surface deflection data. Direct measurement of in situ stresses and strains using pressure and deformation gauge along with moisture sensors under moving traffic loads and their response to seasonal moisture variation will be evaluated with Pie chart, multiple regression and Spss.

III. RESEARCH METHODOLOGIES

The research was done only based on measurement of surface deformation, depression and moisture attacked on affected urban pave roads in Abakaliki and Afikpo metropolis. The secondary data helped establish the theoretical background and research problems, aim and objectives and significance of the study. The secondary data sources used included journals articles and newspapers conference/workshop papers and proceedings

Table 3.1.1 Pilot Survey of Affected Urban Roads in Ebonyi State

S/n	Projects	Location	Remark
A	Road Rehabilitations	Abakaliki	Started in 2014 and above from financial report, completed or not
B	Road Rehabilitations	Afikpo	Started in 2014 and above from financial report, completed or not
C	Repair on affected failed roads	Abakaliki	Stated in 2014 and above from financial report, completed or under completed
D	Repair on affected failed roads	Afikpo	Stated in 2014 and above from financial report, completed or under completed
E	Remedial work on affected roads	Abakaliki	Stated in financial report but not actually carried out
F	Remedial work on affected roads	Afikpo	Stated in financial report but not actually carried out

Percentage Scale for Occurrences
i). High > 75%
ii). Moderate 45% - 70%
iii). Low 10% - 30%

S/n	Stress Types	Percentage	Frequency
1	Ravelling		
2	Potholes		
3	Ruttings		
4	Cracking		
	i). Fatique Cracking		
	ii). Block Cracking		
	iii). Longitudinal & Transverse Cracking		
5	Shoving		
6	Bleeding		
7	Polishing		
8	Depression		

IV. PRESENTATION OF DATA

i). Surface Deformations/Deflections of affected roads in Abakaliki and Afikpo for Rehabiltation

To analyze the stress concentration derives on the state road which was carried out through measurement of surface deformations. Below are the answers as deduced from the data.

Table 4.1 Represent Data Analysis of the Pavement Failures on the Affected State Roads for Rehabilitation

Table 4.1 identifies the surface deformations on the state urban road for rehabilitation by rating the scale of stress values and severity effect on urban roads as ranges from **0 -7 low, 7 -14 medium and 14-24 high** in block cracks, longitudinal, traverse, rutting, potholes, alligator cracks, shoving and raveling.

S/n	Stress types	Percentage (%)	Severity	Remark
1	Block cracks	7.04	Low	
2	Longitudinal	6.37	Low	
3	Traverse	6.0 3	Low	
4	Ruttings	12.4	Medium	
5	Potholes	15.07	High	
6	Alligator cracks	11.06	Medium	
7	Shoving	14.4	High	
8	Ravelling	13.73	High	
9	Fatique cracks	12.4	Medium	

Field work of the researcher (2022)

Fig. 4.1

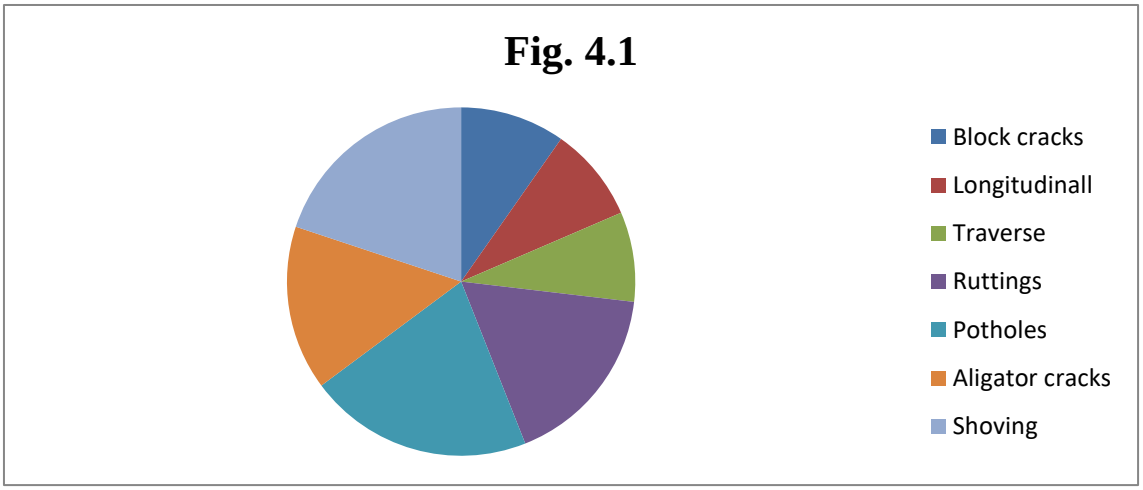

Figure 4.1 in the pie chart above discovered that pothole, shoving, ravelling and ruttings with 15.07%, 14.40%, 13.73% and 12.40% have high stress values and severity effects occupying the highest disintegration of large number of surface deformation in the stress value of the road pavement. Inadequate weak seal coat is the major cause of the disintegration.

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While traverse, longitudinal and block cracking with 6.03%, 6.37% and 7.04% low stress values and severity effects emerges as the lowest rate of disintegration of non crystalline viscous aggregated material due to vehicular impact in volume and weight for surface depressions

Surface Defects of affected roads in Afikpo and Abakaliki for Remedial and Repairs Work

To analyze the stress concentration on the state road the research was carried out through measurement of surface defects. Below are the answers as deduced from the data.

Table 4.2 Represent Data Analysis of the Pavement Failures on Affected Roads for Remedial and Repairs Work

Table 4.2 identifies the surface defects and moisture attack on the state roads for remedial and repair works, by rating scale of stress values and severity effect on urban roads as ranges from **0 -7 low, 7 -14 medium and 14-24 high** in ruttings, raveling, potholes, shoving, alligator cracks and fatique cracks.

S/n	Stress Names	Percentage (%)	Severity	Remark
1	Shovings	7.04	Medium	
2	Ruttings	15.7	High	
3	Alligator cracks	3.02	Low	
4	Fatique cracks	3.69	Low	
5	Ravellings	14.07	High	
6	Potholes	8.38	Medium	

Field work of the researcher (2022)

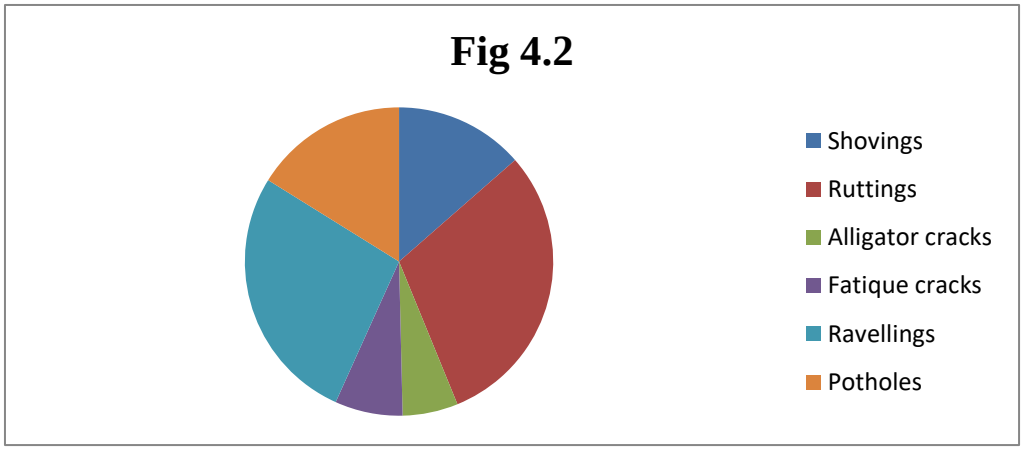

Figure 4.2 in the pie chart above discovered that ruttings and raveiling, raveling with 15.07% & 14.07% have high stress values and severity effects occupying the highest disintegration of large number of surface defect in the stress value of the road pavement. Inadequate compaction is the major cause of the disintegration. While alligator cracks and fatique cracks with 3.02% and 3.69% low stress values and severity effects emerges as the lowest rate of disintegration of non crystalline viscous aggregated material due to moisture attack and deformations.

Table 4.3 Showed the Model Summary

Model	R	R^2 square	Adjust R square	Std error of estimation
1	0.996[a]	0.993	0.988	0.52872

a. Predictors: (Constant), Surface defects, Structural Supports, Surface depressions, Moisture Attack and Surface deformations

b. Dependent Variable: Total Length

ANOVA

Model	Sum of square	Difference (df)	Mean Square	F	Significance
Regression	316.614	6	52.769	188.70	0.000
Residual	2.236	8	0.280		
Total	318.850	14			

a). Dependent Variable: Total Length
b). Predictors: (Constant), Surface depressions, Moisture Attack and Surface deformations
a). Dependent Variable: Total Length

Table 4.4 Showed the Test Statistics
Coefficients

Model	Unstandardized coefficient Beta(β)	Standard effort Std	Standard coefficient Beta (β)	T-value	Sig
(Constant)	0.356	0.310		1.147	0.284
Surface deformation	-0.487	1.346	-0.431	0.727	0.727
Moisture attack	1.318	1.233	1.228	0.316	0.316
Surface depression	0.767	1.405	0.089	0.56	0.600

a. Dependent Variable: Total Length

From table 4.4 showed the test statistics, T < 0.00, df = 6 for the moisture attacked, surface depression and surface deformation in surface rehabilitation, remedial and repair works. The conclusion from the result is that there is strong evidence of a difference in mean = 3.79 in rehabilitation. Therefore, this shows that there is significant difference on the causes of the stress factor and cost effectiveness of rehabilitation. Also, considering the standard deviations from both rehabilitation, remedial and repair works. It was concluded the cost of maintaining the rehabilitation, remedial and repair works will continue to cost

Table 4.5 Showed the Residuals Statistics

Predicted value	Minimum	Maximum	Mean	Std deviation	N
Predicted value	0.7984	19.6749	3.7920	4.75555	15
Residua	-0.62703	0.67058	0.0000	0.39967	15
Std predicted value	-0.629	3.340	0.000	1.000	15
Std residual	-1.186	1.268	0.000	0.756	15

a). Dependent Variable: Total Length

From table 4.4 showed the test statistics, P > 0.05, df = 6 for surface factors. The conclusion from the result is that no significant difference in the mean rehabilitation. Therefore, there is no significant difference between rehabilitation and stress factor. Also, considering the standard deviation from both in road rehabilitation, remedial and repair works. It is concluded that both their close deviation values from stress factor.

From the table 4.4, the model result based on multiple regression analysis identified project variable on surface deformation, surface depression and moisture attack on road rehabilitation, remedial and repair works to have significant impact on low project maintenance cost at T = -0.362, 1.069 and 0.546 respectively with correction results at significance of 0.727, 0.316 and 0.600 (P<0.05) respectively showing that there is a significant direct correction (zero order at 5%) between the causal factors and effect on cost. The results are supported by the goodness of fit index R –square = 0.99367 (99.367%) at T – value = 0.528 (P<0.05). also, the VIF (variance inflation factor) and Ogundapo test show no evidence of multicollinearity among the independent variables. **Constant = 0.284 (28.40%) + deformation 0.727 + moisture 0.316 and + depression 0.600**

Also, the results in table 4.6 reveal that since P = 0.001 < 0.05, the test reject the null hypothesis (Ho). This indicates that stress factor have significant relationship with maintenance cost on road rehabilitation, remedial and repair works. the model implies that based on the data collected the stress values increases by 0.284 (28.4%) will trigger increases in road rehabilitation, remedial and repair works by 0.727 (72.7%), 0.316 (31.60%) and 0.6000(60.00%)

4.1. Model Validation

From table 4.4, having developed the model to predict maintenance cost from factor that are causing stress in road pavement. There is the need to test the generalizability of the result for wider applicability in rehabilitation of pavement in road. The multiple regression analysis gave R^2 value to be 0.9930 (99.3%) implying that the predictive use of the model will yield satisfactory result.

V. CONCLUSION

The study reveals that maintenance cost of road rehabilitation, remedial and repair works are caused by several factors which are surface depressions, surface deformations and moisture attack. The impact of these causes on rehabilitations, repair and remedial works of pavement roads varies from one project to another. However, the study discovered that deformation and depression causes have more impact on rehabilitation.

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RECOMMENDATION

The following recommendation is made based on the study conclusion. It is recommended that rehabilitation cost should be mitigated by reducing the multiple stresses. The models also establish the level of cost of stress over strain and implementation of road pavement preventive maintenance for effective life cycle costing of the urban roads.

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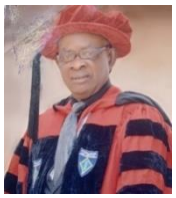
Journals and Conference Publications

a). Impact of Personnel Characteristics on Construction Sites Productivity in Ebonyi State. Journal of Advanced studies in Agricultural Biological and Environmental Sciences ISSN:2455-0221(P), 2394 – 2606(0) (JABE).
b). Impact of Low Labour Characteristics on Construction Sites Productivity in Ebonyi State. International Journal of Advance Research in Science, Engineering and Technology ISSN: 2350 – 0328 VOLUMN 5, ISSUE 10 (IJARSET).
c). Impact of Thermal Stress in Pavement Performance and Life. Conference paper presented to Faculty of Environmental Science, Enugu State University of Science and Technology (ESUT) Enugu in Nigeria
d). Effect of Design Error in Abia State Roads project. Conference paper presented to School of Engineering Technology, Akanu Ibiam Federal Polytechnic, Unwana Ebonyi in Nigeria
e). Analysis of Pavement Failures in Urban Road Projects (Perspective Study of Abia State) Conference Paper presented to 6th Research Conference at University of Uyo, Akwa Ibiom in Nigeria (Unpublished).

Onyekachi Victor Nwosu has published many journals and conference papers in both Local and International. He has worked in Construction and Consultancy firm as Site Manager and Quantity Surveyor before joining the services of Akanu Ibiam Federal Polytechic, Unwana in Ebonyi State Nigeria.



QS Dr. Ezichi Kalu

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Dr. Ezichi Kalu Holds the following Qualifications

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b). M Sc in Quantity Surveying
c). Post Graduate Diploma in Education
d). Master Degree in Financial Management
e). Higher and Ordinary National Diploma in Quantity Surveying

He is Member of the Following Professional Bodies

a). Member, Association for the Advancement of Cost Engineering U.S.A
b). Member, Institute of Construction Industry Arbitrators
c). Registered Quantity Surveyor by the Quantity Surveyors Registration Board of Nigeria (QSRBN)
d). Member, Nigeria Institute of Quantity Surveyors (MNIQS)

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