Nigerian Institution of Highway & Transportation Engineers (NIHTE)

(A Division of the Nigerian Society of Engineers)

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September - December, 2023 | Vol. 5 | 6th Edition | *Think, Transform & Transcend*

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The No.1 Highway & Transportation Engineering Development Journal

THE 33RD PRESIDENT, ENGR. TASIU SA'AD GIDARI-WUDIL, FNSE, OF THE NIGERIAN SOCIETY OF ENGINEERS HANDED OVER TO THE INCOMING 34TH PRESIDENT, ENGR. MRS. MARGRET AINA OGUNTALA, FNSE, ON THURSDAY, 21ST DECEMBER, 2023 AT NSE HEADQUARTERS, NATIONAL ENGINEERING CENTRE, ABUJA.

ENGR. MARGARET AINA OGUNTALA, FNSE
(1ST FEMALE PRESIDENT EVER ELECTED)

INVESTITURE CEREMONY OF

ENGR. MARGARET AINA OGUNTALA, FNSE

AS THE 34TH PRESIDENT OF THE NIGERIAN SOCIETY OF ENGINEERS

20TH JANUARY, 2024 10.00AM
AFRICAN HALL, INTERNATIONAL CONFERENCE CENTRE, ABUJA.

NATIONAL CHAIRMAN, NIHTE, ENGR. SAIDU HASSAN, FNSE, FNIHTE, WITH THE LEAD INSTRUCTOR, SCOTT BLOXSOM, DURING THE NIHTE-IRF (MANAGING ROAD INFRASTRUCTURE ASSETS) TRAINING WORKSHOP ON 16TH-20TH OCTOBER, 2023, AT SANDRALIA HOTELS, ABUJA.

NATIONAL CHAIRMAN, NIHTE, ENGR. SAIDU HASSAN FNSE, FNIHTE, MAKING A PRESENTATION TO THE NATIONAL ASSEMBLY ON ONE-DAY PUBLIC HEARING ON: CONCRETE VS. ASPHALT ROAD.

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OUR VISION

- To transform the nation's highway & transport sector that is centered on road safety, compliance, intervention, monitoring, assets management, reform, financing and capacity building for the nation's highway and transportation professionals.

OUR MISSION

- To think, transform and transcend the nation's highway & transport practice to that of global best practices.
  To provide forum for members and partners of the highway & transport industry that foster education, innovation, research, fellowship, promoting a safe, sustainable and efficient highway & transport system.
  To bring radical changes into the highway & transport practice in design, construction, maintenance, sustainability and management of highway & transport infrastructures.
  To engage highway and transportation stakeholders.
  To hold research, conference, seminar, technical publication, workshops, lectures in line with global best practices.
  To provide professional leadership while developing and sharing knowledge, capacity building and technology acquisition.
  To develop the nation's highway design and construction standards.
  To net-work and engage with highway industry leaders from different countries of the world.
  To have unparalleled professional and business development opportunities around the globe.

Core Values

Education and Innovation.
Diversity, Inclusiveness and Ethics.
Quality life
Fellowship.

Goals

Increase visibility.
Maintain membership and extend market diversity.
Promote education.
Educating highway & transport decision makers.

Aims & Scope

As an academic journal, the ***Journal of the Nigerian Institution of Highway and Transportation Engineers (NIHTE),*** provides a platform for the exchange and discussion of novel and creative ideas, on theoretical and experimental research in the field of Highway and Transportation. This journal publishes high-quality peer-reviewed papers on engineering, planning, management, and information technology for highway transportation. The journal is committed to rapid peer review and publication.

The scope of the ***Journal of the Nigerian Institution of Highway and Transportation Engineers,*** includes: -

- Road engineering, railway engineering, environmental engineering, ITS and traffic engineering and bridge and tunnel engineering
- Automotive engineering, design, manufacture, and operation of vehicles
- Air transportation, maritime transportation, road transportation, and railway transportation
- Analysis, operation, optimization, and planning of highway and transportation systems and networks
- Travel behaviour, information technology, traffic control, and traffic flow theory
- Economics, health, safety, security, environmental and management of highway and transportation
- Multi-modal highway, transportation and logistics research
- Intelligent highway and transport systems
- Materials science,

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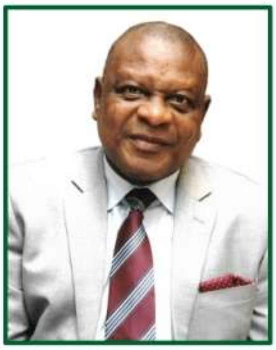

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EDITORIAL

Manuscripts, Letters, Reports, Adverts, Books, Reviews, etc, should be sent to the Editor, NIHTE: nihe2013@yahoo.com or Nihte National Secretariat, c/o National Engineering Centre, CBD, Abuja.
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A NOTE FROM THE LEAD EDITOR'S PEN

Dear Readers,

As we conclude a year marked by significant achievements and progress, I wish to extend my deepest gratitude to each and every one of us that have been source of motivation with our optimistic attitude and creative spirit. We've navigated numerous challenges, contested against enormous difficulties and fought across all frontiers, nevertheless, we propelled to new heights because of efforts of all of us. The future is filled with opportunities and I am confident that together, we will continue to excel and shape a future that is not only successful, but also sustainable.

I intend to set more ambitious tasks, targets and goals that will deliver strategic advantages for NIHTE and to also achieve progressive milestones.
I thank all of us for always exceeding expectations. We elevated the meaning of teamwork to a new level. I'm truly grateful for our professionalism and focus on excellence.

Kindly find time and peruse the Journal with so many exciting news, articles, etc. Wishing all of us a Joyful Christmas and a Happy New Year!

We wish to stay connected during this time, so please, find time to email us at: - nihe.nse2013@gmail.com or japavisca@yahoo.com

Or call 08032630023, 08023549515, 07038064059, 08065668058, 08066898981, for any submission.

Welcome again to NIHTE quarterly Journal.

Sincerely,

Jones Nwadike
Lead Editor

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About NIHTE

NIHTE – *the Nigerian Institution of Highway and Transportation Engineers* – is a non-profit, non-partisan institution representing highway and transportation in the Nigerian Society of Engineers (NSE), in Nigeria. It represents all highway and transportation modes, including air, highways, public transportation, active transportation, rail, and water. Its primary goal is to foster the development, operation, and maintenance of an integrated national highway and transportation systems.

NIHTE works to educate the public and key decision-makers about the critical role that highway and transportation play in securing a good quality of life and sound economy for our nation. NIHTE supposed to serves as a liaison between national, state and local government departments of highway and transportation and the Federal government and is supposed to be an international leader in setting technical standards for all phases of highway and transportation systems development. Standards are supposed to be issued for design, construction of highways and bridges, materials, and many other technical areas.

Construction workers are often at risk of exposure to many infectious diseases, such as coccidioidomycosis, histoplasmosis, hypersensitivity pneumonitis, disseminated histoplasmosis, dengue, asbestos-related illnesses, silicosis, legionellosis, tuberculosis, blood-borne pathogens, and COVID-19. Due to severe working conditions and possible accidents, construction fields are high-risk zones by nature. It is very important to recognize and control the preventable health and safety hazards within these environments. The need for identification and prevention of these diseases is urgent, according to NIHTE. We can be nimble and quick in illustrating to those who are exposed to theses hazards, how to spot them and, hopefully, eradicate them, with help from health workers.

COST OF DOING BUSINESS PER KILOMETER OF ROAD

By
Engr. (Dr.). Eyo, T. B.

There is no engineering argument to justify a generalized cost for the construction, rehabilitation and maintenance of roads per kilometer. Even the cost of construction of various sections within the same road corridor (node to node) cannot be the same. Generalizing the cost of road even within a local, federal, state government is not a wise inference or analogy. Each road is unique and specially designed and constructed. That notwithstanding, the cost of road within states, zones, region, country can only be averaged, ranged or benchmarked.

Several factors affect the cost of road projects in Nigeria. These variables include but not limited to; subgrade strength (CBR or modulus of subgrade reactions), soil characteristics, thickness of sub base (or non-availability of same),thickness of base and type of base (lateritic or stone base), asphaltic surface thickness (binder/wearing or wearing course only), surface dressed roads, traffic, rehabilitation, maintenance, roads with or without shoulder, number of lanes, inflation, number of bridges and culverts, unit cost ratio and ratio of length of work ,corruption and political factor.

The most influential although latent is a political or corrupt political factor. For instance. Abuja-Lokoja - a 196km federal government project was awarded in 2006 at N46bn, it was revised upward to N116bn in 2011, an increase of about 176.2%. This was in spite of the declining rate of inflation at the rate of 2.5% within the 5 years period.

Although average range of cost of road per kilometer within a vicinity may be adopted, the cost of individual roads per kilometer is akin to a thumb print of human being that are not the same anytime, anyway, anywhere. In Nigeria when government, local State and federal announce how much is spent or intend to spend on a short distance road project, the amount leaves one feeling dizzy.

According to a report by Centre for Social Justice (CSJ) and also based on earlier World Bank Study of constructing a road in Nigeria costs between N400m and N1bn/km. This is against the World Bank benchmark of N238m/km. To further prove this, in 2015, a -127km Lagos-Ibadan road was awarded for reconstruction at the cost of N167bn, ie an average cost of N1.3bn/km.

In 2006 Lagos State government signed a -30 years concession agreement with Lekki Concession Company to finance Lekki-Epe Expressway at the cost of approximately N1bn/km, this also overshoots World Bank bench mark. Also Kano-Abuja, a -397km road cost N155bn that is about N390m/km. In Oyo State a-9.5km Ibadan township road cost N5.5bn which is approximately N609.24m/km. Again, a dualised Ibadan-Oyo-Iseyin- Okeho road, a 6.2km road was awarded at the cost N6.1bn which is about N984m/km. Dualization of 7.4km Dugbe-Magazine- Eleyele-Aleshinloye –Onireke/Agbariko road was awarded at the cost of N7.1bn which is about N1.bn/km. It is also interesting to note that in 2013, Lagos-Abidjan, a-1028km-Ecowas road was estimated to cost between N167bn and N240bn. This road connects Lagos in Nigeria, Cotonou in Benin Republic, Lome in Togo, Accra in Ghana. In other words, the road is about 8 times longer than Lagos-Ibadan road but the cost is far lower. At the projected maximum cost of N240bn, the cost of Ecowas road is N234m/km. This is within the World Bank bench mark of N238m per Kilometre. Whereas the 6 -lane, Lagos-Ibadan expressway awarded at N167bn cost N1.3bn per kilometer.

END NOTE

Nigerian Institution of Highways Transportation Engineers (NIHTE) may wish to embark on a study- a Road Cost Knowledge Systems (ROCKS) to establish the root cause of wide margin cost differential in the cost of **doing business** in the road sector in Nigeria.

Performance Prediction Models of Crumb Rubber-Modified Asphaltic Concrete

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Abstract
The tyre component of solid waste is a very promising candidate for recycling, and this investigation studies the use of waste tyre crumb as partial replacement for fillers in flexible pavement wearing course. The fillers were substituted with different percentages of crumb rubber (5%, 10%, 20%, 30%, 40% and 50%). The Marshall design test was used to examine the influence of the modifier on the Optimum Bitumen Content (OBC), stability, flow and void properties of the asphalt concrete. The results obtained were then used to develop a model to predict the performance of crumb rubber modified asphaltic concrete.
Results obtained showed that partial replacement of crumb rubber up to 20% for mineral filler provided satisfactory results in terms of Stability, Flow, Void Minerals in Aggregate (VMA) and Void Filled with Asphalt (VFA) for dense graded HMA wearing course.

Keywords: Asphaltic Concrete, Crumb rubber (CR), Marshall Design, Performance Prediction Model, and Optimum Bitumen Content (OBC).

1. Introduction

One of the most important threats to the environment is the accumulation of waste materials such as rubber, glass, metal, plastic, etc. As the population increases, the amount of waste is rapidly growing and the disposal of waste is also increasing proportionally. There are three major ways to deal with waste materials: burying, incineration, and recycling. Recycling and reusing waste materials can be effective to reducing consumption of natural resources and also in mitigating environmental pollution (Batayneh et al., 2007; Marzouk et al., 2007; Canestrari et al., 2009).

The global problem with landfill disposal of automobile tyres can only be solved by the feasible option left, and that is recycling and utilization of the recycled products. It is thought that the application of recycled automobile tyres will not only solve the environmental menace of these industrial solid wastes but also act as very promising modifiers for the improvement of asphalt pavement material (M. Sienkiewicz, et al. 2012).

Tyre recycling (or rubber recycling) is the process of recycling vehicles' tyres that are no longer suitable for use on vehicles due to wear or irreparable damage (such as punctures). These tyres are among the largest and most problematic sources of waste, due to the large volume produced, their short time durability, and the fact they contain a number of components that are ecologically problematic. It is estimated that 259 million tyres are discarded annually. The same characteristics that make waste tyres problematic, their cheap availability, bulk, and resilience, also make them attractive targets for recycling (Foraminifera Market Research, 2015).

The volume of solid waste generated annually in Nigeria is growing steadily, while at the same time the available capacity of disposal sites is shrinking. There are presently several methods of solid waste disposal in use, but many have serious disadvantages. The oldest method of disposal is the open dump. Substantial quantities of used tyres are being discarded annually throughout the world and this is likely to increase in line with the growth in road traffic. Large quantity rubbers are widely used in various industry applications, such as tyres, seals and gaskets in automotive, aerospace and many more but automobile industry is the biggest consumer of rubber (Anjali B. et. al. 2017). The utilization of crumb rubber as recycled materials in pavement engineering creates landfill avoidance, reduces environmental concerns attributed to tyre dumpsites and encourages its usage as raw materials or modifiers (Zaumanis Martins, Mallick Rajib B. and Frank Robert, 2014). Recycling these wastes can save energy and decrease environmental wastes. However, in many parts of the world, recycled tyre is still at its infancy.

Due to the abundance of discarded tires, many states have pursued the reuse of rubber tyres in pavements. Adding rubber to asphalt has similar benefits to adding additives to concrete. The additives materials helped the engineers to improve the asphalt for some special required specifications. Rubber asphalt is produced either by wet process: rubber is melted in the liquid asphalt binder before mixing, or by dry process: rubber replaced by a portion of fine aggregate during mixing (Huang et al. 2007).

According to laboratory binder tests (Mashaan and Karim, 2011; 2013), it is clear that rubber crumb content played a main role in influencing significantly the performance and rheological properties of rubberized bitumen binders.

main role in influencing significantly the performance and rheological properties of rubberized bitumen binders.

Navarro et al. (2002) studied the rheological characteristics of ground tire rubber-modified asphalt. The experiment was performed in a controlled-stress Haake RS150 rheometer. The study aimed at comparing the viscoelastic behaviour of five ground tyres rubber modified with unmodified asphalt and polymer-modified (SBS) asphalt. The study displayed that rubber-modified asphalt improved viscoelastic characteristics and therefore has higher viscosity than unmodified binders. Thus, the asphalt rubber is expected to better enhance resistance to permanent deformation or rutting and low temperature cracking. The study also found that the viscoelastic properties of rubber-modified asphalt with 9% weight are very similar to SBS-modified bitumen having 3% weight SBS at −10°C and 7% weight at 75°C.

Zaman et al. (2005) found that the viscosity of asphalt cement increases with the addition of rubber, and rubber-modified asphalt-cement samples show a more uniform and higher resistance against loading as the amount of rubber increased. The degrees of shear-thickening and shear-thinning behaviour decreased by increasing the amounts of rubber in asphalt cement. The liner dynamic viscosity was increased by increasing the amount of rubber in asphalt cement. Piggott et al. (1977) mentioned that the vulcanized rubber had a large effect on the viscosity of the asphalt cement. The viscosity, measured at 95°C, increased by a factor of more than 20 when 30% vulcanized rubber was added to the mixture. In contrast, the de-vulcanized rubber had only a very small effect. The viscosity test also showed that there is no danger of gel formation when rubber is mixed with hot asphalt cement.

Mahrez (1999) investigated the properties of asphalt rubber binder prepared by physical blending of asphalt 80/100 penetration grade with different crumb rubber content and various aging phases. The results of penetration values decreased over the aging as well as before aging by increasing the rubber content in the mix. Also, the modified binders showed lower penetration values than unmodified binders. Another study (Kumar et. al. 2009) on penetration change was conducted using asphalt 80/100 and 70/100 penetration grade mixes with different crumb rubber percentage. The results showed a significant decrease in the penetration values of modified binder due to high crumb rubber content in the binders.

Mashaan and Karim (2013) reported that the softening point value increases as crumb tuber content increases in the mix. The increase of rubber content in the mix could be correlated to the increase in the asphaltenes/resins ratio which probably enhanced the stiffening properties, making the modified binder less susceptible to temperature changes.

According to Liu et al. (2009), the main factor in the increase in softening point can be attributed to crumb rubber content, regardless of type and size. The increase in softening point led to a stiff binder that has the ability to enhance its recovery after elastic deformation.

The results of Marshall Test by Samsuri (1997) indicated that incorporation of rubber increases the Marshall stability and quotient. The increase varied with the form of rubber used and the method of incorporating the rubber into bitumen. The Marshall stability for mixes containing rubber powders was increased more than twofold and the Marshall quotient increased by nearly threefold compared to the normal unmodified bituminous mix. Mixes produced using bitumen pre-blended with fine rubber powders showed the greatest improvement rather than mixes produced by direct mixing of rubber with bitumen and aggregates. Thus, pre-blending of bitumen with rubber is a necessary step in order to produce an efficient rubberized bitumen binder probably due to adequate and efficient rubber dispersions in the bitumen phase.

2. Materials and Methods

2.1 Bituminous material

The asphalt binder used was obtained from Lagos State Public Works Commission (LSPWC). Laboratory tests were carried out to determine the properties of the bitumen, including penetration, viscosity, flash point and softening point.

2.2 Aggregates

The aggregates used for this study were from stockpile with sizes (mm) of 0-0.75mm (fillers), 0-4 (fine sand), 0-5 (stone dust), 4-8 (crushed stone) and 8-16 (crushed stone). They were properly dried, cleaned from deleterious materials and sieved.

2.3 Crumb Rubber

The crumb rubber used was obtained from Lagos State Public Works Corporation (LSPWC) yard at Imota, Ikorodu.

In order to meet the objectives of this study, the following tests were conducted, as outlined in Table 1. The parameters that were varied are: bitumen content (5%, 5.5%, 6%, 6.5%, 7%, 7.5% and 8%) and Crumb Rubber (5%, 10%, 20%, 30%, 40% and 50%).

Table 1: Laboratory Tests Conducted

MATERIAL	LABORATORY TEST
1ST SET OF TESTS	
BITUMEN SAMPLE	• SPECIFIC GRAVITY • PENETRATION • VISCOSITY • SOFTENING POINT • FLASH POINT
2ND SET OF TESTS	
CONTROL SAMPLE OF ASPHALTIC CONCRETE WITHOUT ANY ADDITIVES	• SPECIFIC GRAVITY • BULK DENSITY • MARSHALL STABILITY AND FLOW
3RD SET OF TESTS	
MODIFIED ASPHALTIC CONCRETE (5%, 10%, 20%, 30%, 40% AND 50% CRUMB RUBBER AS PARTIAL REPLACEMENT FOR FILLERS).	• SPECIFIC GRAVITY • BULK DENSITY • MARSHALL STABILITY AND FLOW

3. Result and Analyses

3.1 Preliminary Test Result for the Asphalt Binder Used

The preliminary test results are summarized in Table 2

Table 2: Preliminary Test Results of the Asphalt Binder Used

Properties	Values	Standard Specification (ASTM)		Remarks
		Min.	Max.	
Specific Gravity at 25 °C	1.01	1.01	1.05	Satisfactory
Penetration at 25 °C, 100g, 5s	67.2	60	70	Bitumen 60/70
Viscosity (s)	22.5			
Softening Point (°C)	49.5	45	52	Satisfactory
Flash point (°C)	281.33	230	-	Satisfactory
Solubility in Trichloroethylene (%)	100	99	-	Satisfactory

3.2 Grading Analyses of Aggregate Used

This test reveals the blending ratios of the constituent aggregates that make up the asphalt concrete. This is expressed in Tables 3 and 4, as well as Fig 1.

Table 3: Aggregate Mix Proportion

Aggregate Size (mm)	Aggregate Type	% Proportion
8-16	Crushed Stone	20
4-8	Crushed Stone	15
0-5	Stone Dust	49
0-4	Washed Sand	8
0-0.75	Fillers	8

Table 4: Sieve Analysis of the Aggregate Mix

Sieve sizes (mm)	% Passing (Lower Limits)	% Passing (Aggregate Used)	% Passing (Upper Limits)
25	100	100	100
19	100	100	100
12.5	85	86.1	100
9.5	75	78.62	92
4.75	65	65.63	82
2.36	50	52.7	65
1.18	36	43.03	51
0.6	26	33.24	40
0.3	18	20.94	30
0.15	13	13.5	24
0.075	7	9.01	14

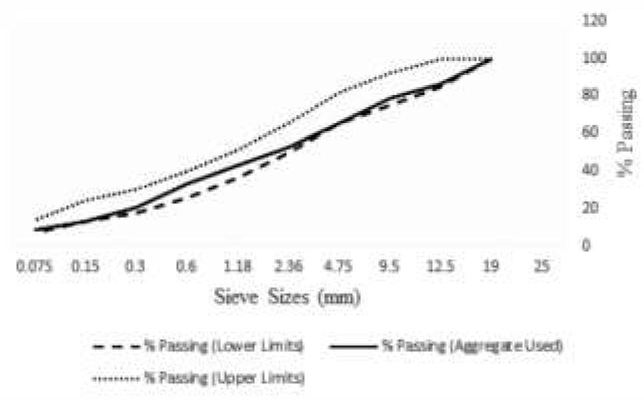


Figure 1: Sieve Analysis Curve for the Aggregate Mix

The curve shows that the mix proportion was satisfactory as the limits were not exceeded.

3.3 Marshall Test Results

This test involves the determination of the resistance to deformation under wheel loading. The Marshall Test conducted on the asphalt concrete samples (control and modified) involve determination of the following:

i. Bulk Density and Theoretical Maximum Density
ii. Void Characteristics
iii. Marshall Stability and Flow Values

The results of Marshall Test are summarized in Tables 5 to 18 and Figures 2 to 4.

3.3.1 Bulk Density and Theoretical Maximum Density

The Figures 2 and 3 show the results and trend of the bulk density and maximum density of the control and modified asphalt concretes.

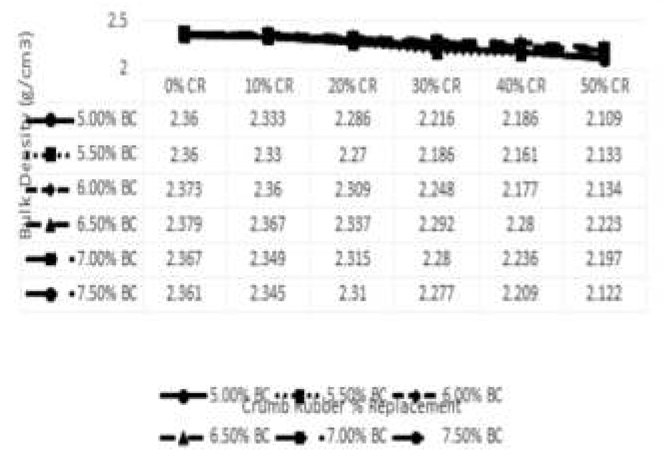


Figure 2: Curve Showing the Bulk Density of the Asphalt Concrete Samples

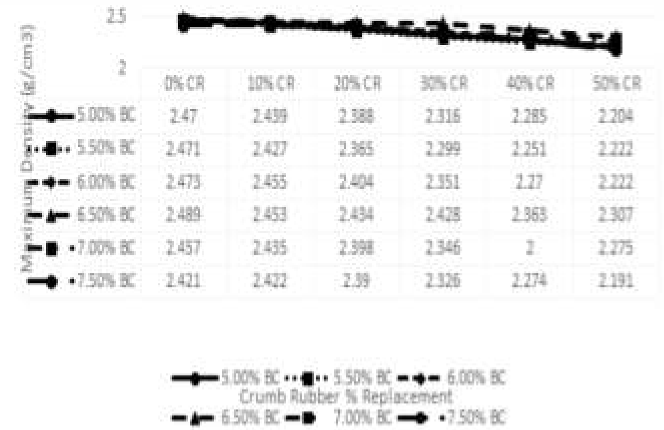


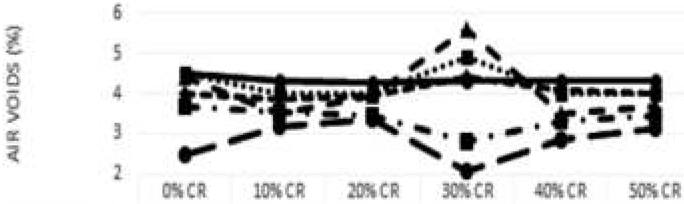
Figure 3: Curve Showing the Maximum Density of the Asphalt Concrete Samples

Discussion of Results

The results for both bulk and maximum densities show a steady decrease with increase in crumb rubber content at specific bitumen contents. This may be attributed to the low specific gravity of the crumb rubber.

3.3.2 Void Characteristics

Figures 4, 5 and 6 show the trend and results of the void characteristics of the asphalt concretes (control and modified).



	0% CR	10% CR	20% CR	30% CR	40% CR	50% CR
5.00% BC	4.5	4.33	4.27	4.3	4.32	4.31
5.50% BC	4.5	4	4.01	4.9	3.98	4
6.00% BC	4	3.88	3.96	4.4	4.1	3.98
6.50% BC	4.4	3.51	3.97	5.6	3.5	3.66
7.00% BC	3.7	3.54	3.47	2.8	3.33	3.44
7.50% BC	2.5	3.19	3.34	2.1	2.86	3.13

Figure 5: VMA Characteristics of the Asphalt Concrete Samples

Discussion of Results

At 5% bitumen content, air void decreased compared to the control sample, however, after 20% crumb rubber replacement, air void was observed to increase gradually with its peak at 40% CR replacement. At 5.5% to 6.5% bitumen content, air void decreased at 10% CR replacement, after which it increased at 20% and 30% CR replacement before reducing. At 7% bitumen content, air void decreased steadily up to 30% but after which increased but remained lower than that of the control samples. At 7.5% bitumen content, air void increased and remained higher than that of the control samples with exception at 30% CR with air void lesser than that of the control samples. This behavior can be attributed to the compaction properties for crumb rubber modified asphalt concrete. The samples which showed a lower air void compared to the control mix indicate better compaction properties.

The result also showed a decrease in VMA compared to the control sample, with exception observed at 30% CR replacement for 6.5% bitumen content. This is because crumb rubber reduces the space available for asphalt film.

VFA was observed to be higher than that of the control samples at 10% and 20% CR replacement. However, at 7.5% bitumen content, VFA was lower than that of the control samples except for 30% CR replacement. A higher VFA indicates increased durability.

	0% CR	10% CR	20% CR	30% CR	40% CR	50% CR
5.00% BC	72.29	72.83	72.7	71.94	71.57	70.88
5.50% BC	74.16	76.12	75.6	70.94	74.82	74.48
6.00% BC	77.98	78.41	77.68	75.31	76.02	76.2
6.50% BC	77.76	81.35	79.2	72.58	80.82	79.71
7.00% BC	81.67	82.21	82.29	85.01	82.38	81.65
7.50% BC	87.57	84.58	83.77	92.16	85.22	83.5

Crumb Rubber % Replacement

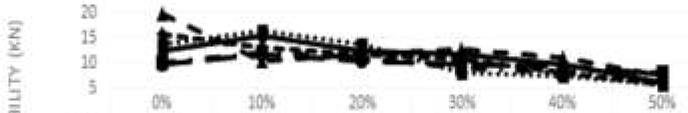
Figure 6: VFA Characteristics of the Asphalt Concrete Samples

3.3.3 Marshal Stability and Flow

Figures 7 and 8 express the trend and summarize the Marshal stability and flow results as obtained for the asphalt concretes.

Discussion of Results

Marshal stability result shows optimum increase in stability at 10% and 20% crumb rubber replacement with peak values obtained at 10% crumb rubber replacement; after which a decrease in stability was observed with increase in crumb rubber when compared to the control samples. The increase in stability observed at 10% and 20% CR replacement can be attributed to the resistance crumb rubber offers to applied load but further injection of crumb rubber into the mixture led to a decrease in the value of stability because application of excessive crumb rubber decreases the coarse aggregate contact point within the mixture. As a result, the mixture becomes more flaccid so as to contribute to the decrease in the value of stability. Low stability suggests low quality of aggregates.



	0%	10%	20%	30%	40%	50%
5.00%	12.35	15.53	12.4	11.69	9.65	6.18
5.50%	13.82	16.5	13.61	8.26	7.51	5.93
6.00%	15.86	13.25	11.74	10.78	8.12	5.66
6.50%	19.66	10.33	11.74	12.7	11.25	7.49
7.00%	10.23	12.15	11.03	9.22	8.25	7.97
7.50%	9.74	11.64	10.31	9.79	9.29	7.77

Figure 7: Marshal Stability Results of the Asphalt Concrete Samples

	0%	10%	20%	30%	40%	50%
5.00%	3.57	3.54	3.68	3.97	4.46	5.43
5.50%	4.01	3.81	3.95	4.15	4.32	5.09
6.00%	3.45	3.43	3.82	4.13	5.01	5.51
6.50%	5.37	5.11	4.78	4.51	5.08	6.64
7.00%	4.22	4.79	5.09	5.17	5.25	6.06
7.50%	4.62	3.95	4.23	4.33	4.4	5.79

Crumb Rubber % Replacement

Figure 8: Marshal Flow Results of the Asphalt Concrete Samples

3.4 Optimum Asphalt Binder Content

The results, as obtained, were used to plot graphs that facilitated the selection of the optimum asphalt binder content. The graphs plotted were:

i. Air voids versus Asphalt Content
ii. Marshal Stability versus Asphalt Content
iii. Marshal Flow versus Asphalt Content
iv. VMA versus Asphalt Content
v. VFA versus Asphalt Content
vi. Density versus Asphalt Content

The optimum asphalt binder content results as derived from the plotted graphs are summarized in Table 5.

Table 5: Summary of Asphalt Concrete Properties

PROPERTIES	0% CRUMB RUBBER		
	RESULTS	AI SPECIFICATION	REMARKS
OBC (%)	6.00	5.0-8.0	
DENSITY	2.37		
VMA (%)	18.17	Minimum 13%	Satisfactory
VFA (%)	77.98	75.0-82.0	Satisfactory
STABILITY (KN)	15.86	Not less than 3.5KN	Satisfactory
FLOW (mm)	3.45	2mm-4mm	Satisfactory
MARSHAL QUOTIENT	4.60	minimum 2.5 for unmodified and 3.0 for modified	Satisfactory
10% CRUMB RUBBER			
	RESULTS	AI SPECIFICATION	REMARKS
OBC (%)	5.50	5.0-8.0	
DENSITY	2.33		
VMA (%)	16.75	Minimum 13%	Satisfactory
VFA (%)	76.12	75.0-82.0	Satisfactory
STABILITY (KN)	16.50	Not less than 3.5KN	Satisfactory
FLOW (mm)	3.81	2mm-4mm	Satisfactory
MARSHAL QUOTIENT	4.33	minimum 2.5 for unmodified and 3.0 for modified	Satisfactory
20% CRUMB RUBBER			
	RESULTS	AI SPECIFICATION	REMARKS
OBC (%)	5.50	5.0-8.0	
DENSITY	2.27		
VMA (%)	16.43	Minimum 13%	Satisfactory
VFA (%)	75.60	75.0-82.0	Satisfactory
STABILITY (KN)	13.61	Not less than 3.5KN	Satisfactory
FLOW (mm)	3.95	2mm-4mm	Satisfactory
MARSHAL QUOTIENT	3.45	minimum 2.5 for unmodified and 3.0 for modified	Satisfactory
30% CRUMB RUBBER			
	RESULTS	AI SPECIFICATION	REMARKS
OBC (%)	6.80	5.0-8.0	
DENSITY	2.29		
VMA (%)	19.80	Minimum 13%	Satisfactory
VFA (%)	73.00	75.0-82.0	Not Satisfactory
STABILITY (KN)	10.50	Not less than 3.5KN	Satisfactory
FLOW (mm)	5.00	2mm-4mm	Not Satisfactory
MARSHAL QUOTIENT	2.10	minimum 2.5 for unmodified and 3.0 for modified	Not Satisfactory
40% CRUMB RUBBER			
	RESULTS	AI SPECIFICATION	REMARKS
OBC (%)	5.50	5.0-8.0	
DENSITY	2.16		
VMA (%)	15.81	Minimum 13%	Satisfactory
VFA (%)	74.82	75.0-82.0	Not Satisfactory
STABILITY (KN)	7.51	Not less than 3.5KN	Satisfactory
FLOW (mm)	4.32	2mm-4mm	Not

Marshal quotient is the ratio of stability to flow and it indicates the strength and quality of the asphalt concrete. The results obtained as presented in Table 5 show that the addition of crumb rubber up to 20% presented satisfactory results on all levels and can conveniently be used to replace mineral fillers in the production of asphalt concrete. Beyond 20% crumb rubber, non-satisfactory results were obtained for VFA, Flow and Marshal quotient properties.

3.5 Performance Prediction Model Analysis

The performance modeling was conducted using regression analysis. MS Excel was employed in carrying out the regression analysis. The analysis was done in order to establish relationship between Marshall properties (Stability, Flow, VMA and VFA) considered as dependent variables and percentage crumb rubber, considered as independent variable, using the optimum bitumen content (OBC) of 5.5% and for the following conditions holding true:

i. Mix temperature of 150°C
ii. Crumb rubber size of 0 - 0.075mm.
iii. 60/70 Pen Asphalt Binder
iv. Dense graded, wearing course HMA.

Figures 9-12 show the regression plot and curve of best fit for which the model was taken, R-squared, known as the coefficient of determination, shows how close the data are fitted to the regression line. The closer to 1 this value is, the better. The performance prediction model shows the relationship between the Marshal properties and percentage crumb rubber content.

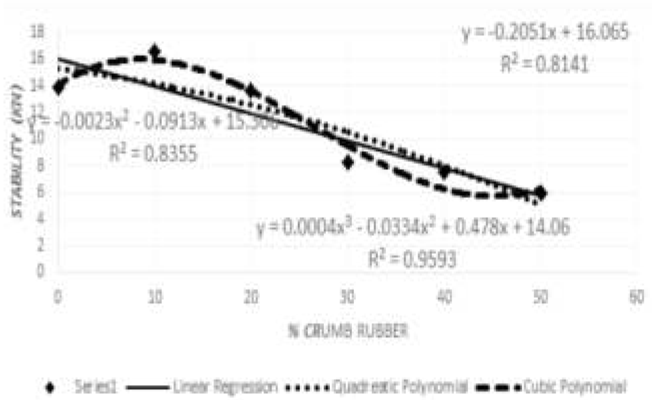


Figure 9: Regression Plot for Relationship between Marshall Stability and Crumb Rubber

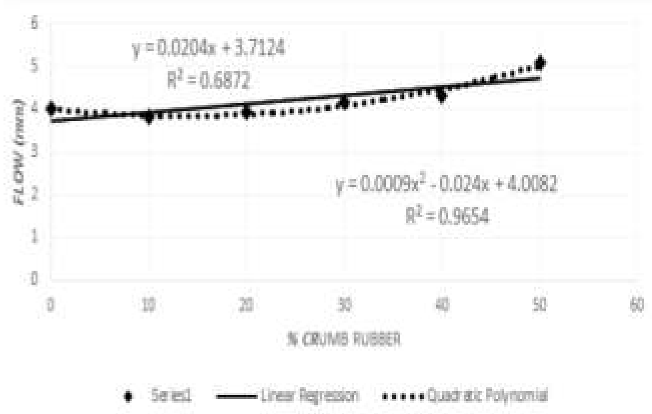


Figure 10: Regression Plot for Relationship between Marshall Flow and Crumb Rubber

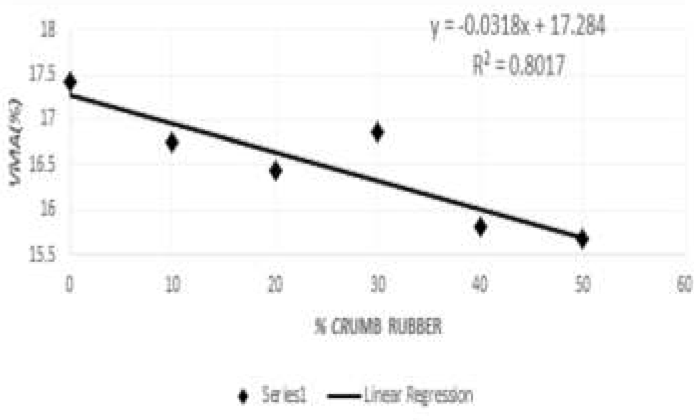


Figure 11: Regression Plot for Relationship between VMA and Crumb Rubber

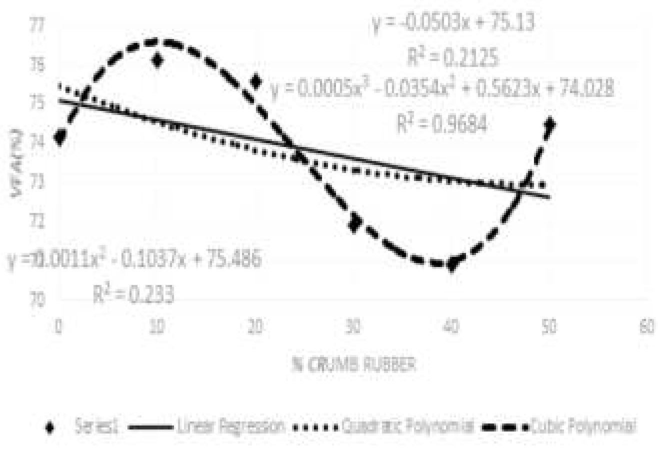


Figure 12: Regression Plot for Relationship between VFA and Crumb Rubber

The adopted performance prediction models of crumb rubber modified asphaltic wearing course are therefore summarized as follows:

Stability = $0.0004x^3 - 0.0334x^2 + 0.478x + 14.06$ ($R^2 = 0.9593$)

Flow = $0.009x^2 - 0.024x + 4.0082$ ($R^2 = 0.9654$)

VMA = $-0.0318x + 17.284$ ($R^2 = 0.8017$)

VFA = $0.0005x^3 - 0.0354x^2 + 0.5623x + 74.028$ ($R^2 = 0.9684$)

It is important to note that this performance prediction models do not however replace the need for laboratory tests.

3.6 Comparative Cost Analysis

This analysis is conducted to show the economic advantage of using crumb rubber in road construction, besides its environmental and engineering advantages. The cost of the materials was obtained through informal interviews with contractors and project managers in Nigeria. To determine the cost of wearing course surfacing material needed for construction, a road of length one kilometer (1km) and standard width 7.3 meters was used as basis for the analysis. Thickness of wearing course is taken as 50mm. The computation of the cost analysis is shown in Tables 6 and 7 while the summary of the cost analysis for the construction of the base material is shown in Table 8.

Table 6: Cost Analysis for Conventional Wearing Course Asphalt

ITEM	DESCRIPTION	QUANTITY FOR CONVENTIONAL ASHPALTIC CONCRETE	UNIT	QUANTITY	RATE (₦)	AMOUNT (₦)
	WEARING COURSE MATERIALS: 7.30 x 1000 x 0.05 = 365 m³	365 x 2.37 = 865.1 Tons.	Tons	865.10		
1	Bitumen (60/70)		Tons.	52.77	274,000.00	14,459,281.40
2	Crushed Stones 3/8" (9.5mm)		Tons.	81.23	5,800.00	471,150.76
3	Crushed Stones 1/2" (12.5mm)		Tons.	162.47	5,800.00	942,301.52
4	Quarry Dust		Tons.	568.63	4,800.00	2,729,425.10
	TOTAL					**18,602,158.79**

Table 7: Cost Analysis for 20% Cr-Modified Wearing Course Asphalt

ITEM	DESCRIPTION	QUANTITY FOR 20% CR-MODIFIED ASPHALTIC CONCRETE	UNIT	QUANTITY	RATE	AMOUNT
					(₦)	(₦)
	WEARING COURSE MATERIALS: 7.30 x 1000 x 0.05 = 365 m³	365 x 2.27 = 828.55 Tons.	Tons	828.55		
1	Bitumen (60/70)		Tons.	50.54	274,000.00	13,848,384.70
2	Crushed Stones 3/8" (9.5mm)		Tons.	77.80	5,800.00	451,244.90
3	Crushed Stones 1/2" (12.5mm)		Tons.	155.60	5,800.00	902,489.80
4	Quarry Dust		Tons.	544.61	4,800.00	2,614,108.39
	TOTAL					**17,816,227.8**

Table 8: Summary of the Comparative Cost Analysis

Specimen	Production Cost (N)
Conventional Wearing Course Asphalt	**18,602,158.79**
20% CR-Modified Wearing Course Asphalt	**17,816,227.80**
Difference in Cost	**785,930.99**
% Difference in Cost/Km	**4.22%**

4. Conclusions and Recommendations

4.1 Conclusions

From the findings of the study, the following conclusions were made:

i. Asphalt concrete containing crumb rubber, up to 20% as partial substitution for mineral filler, satisfies the minimum structural requirement for flexible pavement construction.

ii. Asphalt concrete containing crumb rubber, beyond 20% as partial substitution for mineral filler, presented unsatisfactory results for VFA and Marshall flow; and therefore didn't meet the minimum structural requirement for flexible pavement construction.

iii. Marshall Quotient decreased with increase in crumb rubber content.

iv. For a mix temperature of 150°C, crumb rubber size of 0-0.075mm, 60/70 Pen bitumen and dense graded, wearing course HMA, the following performance prediction models apply:

Stability = $0.0004x^3 - 0.0334x^2 + 0.478x + 14.06$ ($R^2 = 0.9593$)

Flow = $0.009x^2 - 0.024x + 4.0082$ ($R^2 = 0.9654$)

VMA = $-0.0318x + 17.284$ ($R^2 = 0.8017$)

VFA = $0.0005x^3 - 0.0354x^2 + 0.5623x + 74.028$ ($R^2 = 0.9684$)

v. From the comparative cost analysis, asphalt concrete with 20% crumb rubber content as partial substitution for mineral filler is cheaper than conventional asphalt concrete of equivalent Marshall properties.

vi. The comparative cost analysis shows a 4.22% savings in cost per kilometer of road.

4.2 Recommendations

The following recommendations are therefore made:

i. Proper waste disposal policies for waste tyres for their use in civil engineering practices should be developed.

ii. The use of crumb rubber in flexible road construction, up to 20%, showed satisfactory results; with 10% showing better results than conventional asphalt concrete. In addition, there is economic benefit to using it.

iii. Further studies into the possible use of crumb rubber in other aspects of civil engineering construction works should be encouraged.

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THE CONCRETE ROAD OPTION: DESIGN, CONSTRUCTION, MAINTENANCE AND EFFECTIVENESS

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ABSTRACT
The two basic highway design and construction types are the flexible and rigid pavements. The inability of roads constructed with flexible pavement to meet up with the design service lifespan without serious repair has being a major concern worldwide. This premature failure trends of flexible pavement have necessitated series of researches leading to development of its new modified types such as SUperior PERforming Asphalt PAVEment (SUPERPAVE) and the Perpetual Pavement among others. With almost all roads in Nigeria being of flexible pavement type, this has made the year to year increase in cost of road maintenance and repairs as a result of frequency of failures to be at an alarming rate. It is the backdrop of this that consideration of adopting rigid pavement otherwise known as concrete road in all future road construction and rehabilitation in the country to be made (Umahi, 2023)[1]. This paper gives the general overview of concrete roads and highlights the features that makes the flexible pavement differ from the rigid one. It discussed in details the types, components, design features, construction stages, work activities involved in the construction and effectiveness of the concrete roads. While the paper concluded that use of concrete road as the main road construction type in Nigeria is a welcome idea, it recommended that the authority need to look into the cost versus fund availability, use of pilot scheme, stage implementation and making the basic materials like cement, aggregates and reinforcement available in abundance prior to the full implementation of the option. It finally highlighted provision of joints, adequate drainage system and general adherence to strict quality control as very important implementation parameters.

Keywords: Concrete Road, Superpave; Perpetual, Flexible and Rigid Pavements.

1.0 INTRODUCTION

The failures of roads before the design service life span has becomes a common occurrence in most parts of the world. The failure trend has necessitated series of researches leading to development of new modified types of flexible pavement in the highway industry. Notable two among these new developments are SUperior PERforming Asphalt PAVEment (SUPERPAVE) and the Perpetual Pavement. Despite the development of the modified flexible pavement designs, the basic flexible and rigid pavements continued to gain prominent in the road construction industry.

In Nigeria, little has been done on the use of the modified form of flexible pavement and the basic type is commonly used. At least 95% of all roads in Nigeria were built using the basic flexible pavement type while less than 5% are of rigid pavement or concrete road. Despite usage of different forms of basic flexible pavement with different base course materials like laterite, crushed stone, soil-cement, sand-bitumen etc. as the nature of the natural route terrain demands, its under-performance continued to be a subject of discussion and this situation has made the attention of the policy makers to be focused on the use of rigid pavement otherwise known as concrete road as the alternative option.

This paper discussed the various types of concrete roads as used in the road construction industry. It emphasized on its design, construction, maintenance and the effectiveness as interstate or regional highways. It thereafter finally makes some recommendations to the authorities on the implementation of the option in the country.

2.0 THE PRELIMINARIES

The work in this paper was achieved by studying the literature on the types, developments and features of pavements used in the road construction industry. Necessary data were obtained from reports, standard books, technical journals, research publications, paper presentations and news media publications on the subject matter.

3.0 DISCUSSIONS

3.1 HIGHWAY PAVEMENT TYPES

Highway pavement is simply a well-organized combination of materials arranged in layers on an already prepared surface known as subgrade. The pavement which is always covered with a surfacing is expected to carry the design loads during the road's service life. In highway industry, the basic pavement types in use are the flexible and rigid pavements which are defined as follows; -

a. **FLEXIBLE PAVEMENT -** This is designed and constructed in layers of granular materials known as subbase and base courses laid on an already prepared surface known as subgrade. Each layer has a degree of flexibility and the stability of a layer is derived from the properties of the underlying materials. It is always covered up with an asphalt bituminous concrete riding surface.

b. **RIGID PAVEMENT** – It is designed not to depend on the layers of granular materials under it. As such, it often times does not need a base course. The top is always a cement reinforced or unreinforced concrete slab. It is the nature of the topmost layer that the name 'concrete road' was derived.

c. **MODIFIED PAVEMENTS** – These are higher grade of flexible pavement developed for more durability and performance. Two of the forms are; -

   i. **SUperior PERforming Asphalt PAVEment (SUPERPAVE)** - It is a tool developed for the design of asphalt pavements that will perform better under a very extreme weather and loading conditions in line with location of use. It consists of inter-related system elements of; [1] asphalt binder specification, [2] volumetric design & analysis, [3] test analysis, and [4] performance prediction.

   ii. **Perpetual Pavement** – This is a pavement designed and constructed to last for at least 50 years with minimum maintenance during the period. It consists of well-designed components of; [1] 1,000mm thick subgrade with minimum CBR of 15% [2] 200mm thick subbase using granular material [3] 150mm thick wet-mix macadam [4] 250mm thick dense-graded bituminous macadam comprising of 80mm as the top layer, 100mm in the intermediate layer and 70mm as the bottom layer, and [5] 50mm thick stone matrix asphalt.

3.2 FLEXIBLE VERSUS RIGID ROAD PAVEMENTS

As previously mentioned, the basic highway pavements are flexible and rigid types. The main difference between the two are as per the highlighted features presented in Table 1.

TABLE 1: FEATURES OF FLEXIBLE AND RIGID PAVEMENTS [2, 3, 4, 5, 7]

FEATURE	FLEXIBLE PAVEMENT	RIGID PAVEMENT (CONCRETE ROAD)
TOPMOST LAYER	Asphaltic bituminous concrete	Cement concrete (may be reinforced or not)
LAYERS	Subgrade, sub-base and base	Subgrade and Sub-base. Base not necessary.
FLEXURAL STRENGTH	Good; Depend on underlying layers for strength and stability	High; Does not depend on underlying layers for strength and stability
LOAD TRANSFER	To successive layers one by one	Direct to subgrade in uniform way
ROLLING AND CURING	Must be rolled for immediate use, No curing is needed	Need no rolling, but must be cured before it can be used. Takes time before use
LIFE CYCLE COST	Low initial cost; High maintenance	Very high initial cost; Low maintenance cost
JOINTS	Not needed (continuous)	Very necessary (even with continuous type)
DURABILITY	Reasonable (may last up to 20 years)	Very durable (may last up to 40 years)
MIANTENANCE	High cost of maintenance	Low cost of maintenance. Repair is complex
PERIOD OF CONSTRUCTION	Moderate; can be constructed within a short time	Relatively long due to reinforcement fixing and duration for curing.
STABILIZATION	May be necessary before use	Not necessary, loads go direct to subgrade
DESIGN DETAILS	Necessary to sustain the loads	Known to take very heavy wheel loads
HAZARDS	High (Gases, high temperature etc.)	Low (only cement fumes and air particles)
RESISTANCE	Moderate to weather & environment	High to weather and environment.
WHEEL NOISE	Moderate vehicle wheel noise	High vehicle wheel noise
SKIDDING	Moderate resistance to skidding	More resistance to skidding.
RECYCLING	Asphalt can be recycled	Concrete slab cannot be recycled.
CLIMATE USE	Good to use in cold climate	Good to use in hot climate

3.3 SELECTION OF HIGHWAY PAVEMENT TYPE IN DESIGN

Highway designers need to exercise great care when making final decision on pavement type to be used in design. The necessary factors that shall need to be strictly considered in the choice of flexible or rigid pavement type during design include; -

a. Nature of the natural soil along the alignment; a very important factor.
b. The traffic safety; important for users' safety.
c. Availability of local material; important for economy considerations.
d. Existing performing pavement; important for durability forecast.
e. Conservation of construction materials; important for economy of the overall works.

3.4 REASON FOR CURRENT ATTENTION ON RIGID PAVEMENT / CONCRETE ROAD IN NIGERIA

The basic flexible pavement type was the first to be developed and its use dated from decades of years back. The associated durability which often is far less than the design lifespan even with adequate maintenance has made various attempts to be made in the improvements on the materials used for the layers on which the strength depends. These improvements, which are geared towards increase in the strength, stability, stiffness and resistance to erosion together with reduction in sensitivity to moisture changes and plasticity were mainly stabilization of the materials for the construction in form of; treatment with lime, bitumen emulsion, cement, chlorides (sodium chloride or calcium chloride), molasses, resinous material, mechanical method, removal and replacement of bad material, raising of road's vertical alignment, electrical and thermal method, blending of soils and aggregates and use of stones.

Despite all these forms of improvements in the basic flexible pavement's materials together with prompt maintenance, other problems associated with inadequacy of; thickness of the layers, adequacy of drainages, quality of the materials, poor design among others has made the roads to continue not to last up to the design period. Research has shown that when flexible pavement is not subjected to serious repair after construction, the durability ranges from one to five years especially in the South Eastern part of Nigeria and by extension the entire south (Obeta and Njoku, 2016)[6]. The failure trend of flexible pavement is that bad.

It is the backdrop of this durability

issue together with high costs of maintenance, repair and users' operation that prompted the Honourable Minister for Works, Engr. David Umahi to disclose that Nigeria will now shift from the conventional asphaltic bituminous roads with underlying flexible pavement to rigid pavement otherwise known as concrete road. In his words during an inspection of Akure – Ado Ekiti Road, the Honourable Minister made a pronouncement that all new roads shall henceforth be designed as concrete roads while those ongoing with not more than 20% done shall be redesigned as such. (Umahi, 2023)[1]. This comment and the follow-up press briefings made it clear that Nigeria will now be adopting the concrete road as the country's road construction type.

4.0 OVERVIEW OF RIGID PAVEMENNT OR CONCRETE ROAD

4.1 THE RIGID PAVEMENT ELUCIDATED

Rigid pavement also known as concrete road is a road type that is designed and constructed to possess the strength capable of withstanding the applied loads independent of the materials under it. The top layer is always made of cement concrete slab which most times is reinforced and sometimes not reinforced. By its design, concrete road transfers the applied loads to the subgrade by the slab action.

Concrete road was first used in Inverness, Scotland in 1865, the good performance with time led to its use in Edinburgh, Scotland in 1872 while a street in Detroit, USA follows in 1909. The performance especially in heavily trafficked areas has made its use now popular.

4.2 COMPONENTS OF RIGID PAVEMENT

With (Fadire, 2022)[7] as the main reference, the rigid pavement components are; -

a. **THE SUBGRAGE** – This is the first material on the natural road bed laid in compacted layers. It serves the main purpose of bringing the natural route level to meet the desired design elevation. If the test carried out on the fill layers revealed minimum California Bearing Ratio (CBR) plus a uniform support platform for the desired design load, the topmost concrete layer may be constructed directly on it.

b. **SUBBASE** - Rigid pavement may not have subbase layer if the CBR of the subgrade is of good quality. However, since the subgrade quality is most of the time poor where rigid pavements are required, therefore, to prevent; [1] reduction in durability, [2] limited design life, [3] frequent maintenance needs, [4] hazard reduction, and [5] increased safety, subbase shall need to be provided. Presented in Table 2 is the specifications for use of subbase in rigid pavement design based on the California Bearing Ratio (CBR) of the subgrade (Cement and Concrete Association, 1958)[2].

c. **BASE** - This is generally **not necessary** in rigid pavements design and construction.

d. **THE SURFACING** – This is the topmost layer of rigid pavements. It is in form of reinforced or unreinforced concrete slab. The name of the road type is derived from it.

e. **JOINTS** – This is a very important component in all types of rigid pavements. it neutralizes the volume changes that occurred in the concrete as a result of the temperature and moisture changes. If joints are absent, high stresses may be induced in the concrete and tension cracks or buckling may results.

f. **ADMIXURES** – An optional component. It is used; [1] when there is need to control the concrete hardening period during construction, [2] as wetting agent for increase in workability, and [3] as air entraining agent.

TABLE 2: SUBGRADE QUALITY AND SUBBASE THICKNESS FOR RIGID PAVEMENTS [5]

SUBGRADE QUALITY	SUBGRAGE'S CBR VALUE	MINIMUM SUBBASE THICKNESS
WEAK	2% OR LESS	150mm
NORMAL	2% - 15%	80mm
VERY STABLE	15% OR MORE	0

4.3 TYPES OF RIGID PAVEMENT

Rigid pavement / concrete road is classified according to how the concrete surfacing is constructed. The types in use are; -

a. **Un-reinforced Concrete Rigid Pavement** – This can be;

i. **Plain Pavements** - These are constructed without neither steel reinforcement nor doweled joint. Aggregate interlock between the cracked faces below the joint's saw cut produces the necessary load transfer at the joints.

ii. **Plain Dowelled Pavements** - Constructed without steel reinforcement. Smooth steel dowel bars are used as load transfer devices at each of the relatively short spaced contraction joints which serves as crack control.

b. **Reinforced concrete rigid pavement** – It can be;

i. **Jointed reinforced concrete** – The concrete slab is in jointed panels and is reinforced with steel. Cracks that may emerge at the joints during load transfer are held tightly together by the dowel and tie steel bars for load transfer. Though most expensive type, it is the best and most frequently used in design.

ii. **Continuously Reinforced Pavements** - These are constructed without contraction joints except at the end of the day work, bridge locations and transition points to other payment type. Relatively heavy reinforcement is introduced in the longitudinal direction to neutralized very heavy traffic load it sustains. Since it is without contraction joints, cracks are developed in the transverse section at close intervals. However, the heavy steel reinforcement continues to hold the cracks together as load transfers are made.

5.0 THE DESIGN OF RIGID PAVEMENNT / CONCRETE ROAD

5.1 THE GENERAL PARAMETERS OF DESIGN

The rigid pavements (concrete road) in principle does not depend on the underlying soils. However, the designer need to make careful study of the route materials so as to ensure the stability and how permanent the support will be. (Fadire, 2022)[7] highlights the parameters on which concrete road designs are based as follows; -

a. Adequacy of the drainage system, quality of the material immediately under the topmost concrete slab is important here.
b. Volume changes must be minimized, swell and shrinkage must be prevented.
c. Mud pumping at the joints and at unprotected concrete slab sides must be prevented.
d. Quality control during the construction and care of the topmost layer concrete slab during service life must be observed especially in areas of waterproofing, skidding resistance, mud pumping at openings etc.
e. Special attention must be paid to the joints be it expansion, contraction, warping or simply construction joints.
f. The envisaged stresses like those due to the wheel loads plus warping and friction that results from temperature and moisture must be prevented.
g. Must be structurally strong to withstand the applied loads.
h. Must be designed and constructed to be durable (long life of at least 40 years) with low maintenance costs when in use under the design traffic loads.

5.2 DESIGN FEATURES OF THE TOPMOST CONCRETE LAYER

The topmost concrete layer slab is the member that differentiate concrete road from all other types. The concrete slab is often time designed with a width of between 1.2m and 4.5m to prevent irregular longitudinal cracks, while the design thickness is always between 150mm and 250mm depending on the traffic intensity. The design and construction must generally be standard to give the desired overall road quality. The two most important design parameters of the concrete slab layer are the mix proportions and the reinforcement (when it is reinforced type). Features of the two main parameters and others the designer must bear in mind are; -

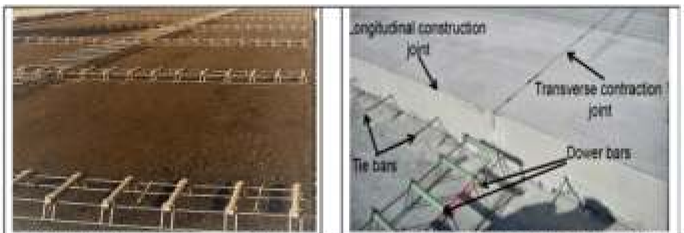
a. **CONCRETE MIX DESIGN** – This is very important for all types of concrete roads. The mix design parameters to be strictly observed are; [1] design strength, [2] degree of quality control to be exercised, [3] cement type which can be any of ordinary Portland Cement, Rapid Hardening Portland Cement, Portland Blast Furnace Cement or Extra Rapid Hardening Portland Cement depending on the condition during mixing, [4] aggregate grading and particle shape, [5] workability requirement, [6] compaction method that will be used during construction, and [7] the surface texture requirements.
b. **REINFORCEMENT** – Top and bottom reinforcement are often provided in concrete roads to; [1] control the opening of cracks in the concrete, [2] to increase the flexural strength of pavement, [3] to absorb the induced tensile stresses, and [4] to allow greater spacing of in-between transverse joints. The top reinforcement layer specifically resists the warping tensile stress at the top surface edges and corners while the bottom reinforcement resists the tensile stresses set up at the interior of the underside of the slab. However, if economy warrant use of one layer, the reinforcement must be placed near the top of the slab so as to neutralize the critical stresses that developed near the concrete top. Generally, in concrete road, main reinforcements are placed in the longitudinal direction and light bars placed in the transverse direction so that cracks can be effectively eliminated.
c. **PANEL SIZE** – When the commonly used jointed reinforced concrete road slab type is adopted, the road must be divided into panels with requisite dimension as per the specification. Panel sizes of width 1.2m to 3.5m are generally used except at intersections, curve segments and acceleration / deceleration lanes. The length is subject to the specifications for the expansion and contraction joint spacing. Figure 3.
d. **CONCRETE SLAB TICKHNESS** – The thickness of the concrete slab ranges from 150mm to 250mm depending on the number of vehicles expected to use the road
e. **JOINTS** – Joints are very important in the design of all types of concrete roads. Joints mainly allow free movement of the concrete slab for any reason, it is made not to affect the riding quality of the roadway and must not to allow water to enter it. The joint opening which may result from thermal stresses is controlled by dowel and tie bars provision which at the same time serves as the load transfer mechanism. This often times makes concrete road construction costly and its provision must not be a reason for the structural under-design of the pavement and it must also not interfere with the placing of the pavement concrete during the construction. Generally, expansion Joint spacing for reinforced concrete road slab ranges from 12m to 45m while it is from 12m to 24m for dummy contraction joints. For unreinforced concrete road slab, the expansion joints spacing ranges from 27m to 36m while it is 5m (constant) for contraction joints. The joint spacing in design generally depends on the concrete slab thickness and the quantity of design reinforcement. See figure 3.
f. **SEALS AND FILLERS** – These acts as water proof device for the joints, prevents grits and water from infiltrating into the joints, prevent subsequent spalling of the joint edges, and eliminates creation of non-uniform foundation conditions. Seals must be; [1] capable of adhering firmly to concrete under all weather conditions, [2] sufficiently ductile in cold weather to accommodate widening without cracking, [3] accommodate repeated expansion and contraction over long periods without disintegration, [4] not flow along or down the joint in hot weather, [5] effective in resisting the ingress of grit and water in all weather conditions, [6] capable of being poured at a temperature up to 165°C, [7] durable for a long time, [8] not hardened or softened with time, [9] made of non-changing contrast colour with the road surface over time, and [9] must retain the properties throughout the design live of the rigid pavement. Fillers on the other hand must be; [1] capable of being compressed without extrusion, [2] sufficiently elastic to recover its original thickness when the compressive force is released, and [3] must be able to retain the properties throughout the design service life of the rigid pavement. It must be noted that either seals or fillers can be recommended for use in expansion joints while only the seals are

recommended for use in all other types of joints.

g. **HAUNCH –** Construction of major highways connecting cities may not have continuous concrete lined drains as side supports. Haunches of thickness and height greater than that of the concrete slab are used. Generally, haunch of 300mm thick and 500mm height may be adequately used. The length of continuous haunch is subject to the designer's experience and discretion. However, when fund cannot support use of side drains or haunches, protection of the concrete road slab from mud pumping at the sides must be incorporated in the design. See figure 3

h. **LOAD TRANSFER MECHANISM –** Since all concrete roads must have joints, load transfer at the joints must be carefully designed. The dowel and tie bars effectively performs this function. The dowel bars are the load transfer devices that are placed across the joint in a rigid pavement to allow the concrete slabs to expand and contract freely and at the same time holds the slab ends on either side at essentially the same elevation. The specifications for the dowel bars depends on the concrete slab thickness, the diameter ranges from 20mm to 32mm and the length from 0.5m to 0.75m. The tie bars on the other hand are provided in the concrete road joints to bind the two concrete slabs together as well as withstand the tensile forces that pulls them together. The methods of the load transfer are generally by use of bound steel dowel-bars, tongue and groove type of joints, interlock of aggregates in dummy joints, and the **s**leeper beams. Figure 3 shows illustration of the concrete road divided into panels with use the dowel and tie bars and use of same in a typical joint.

FIGURE 3: DOWEL & TIE BAR ARRANGEMENTS AND USE IN CONCRETE ROAD JOINTS



PANEL DIVISION OF ROAD BY DOWEL & TIE BARS	DOWEL & TIE BARS AS USED IN A TYPICAL JOINT[8]

6.0 CONSTRUCTION OF RIGID PAVEMENNT / CONCRETE ROAD

Construction of concrete roads is not very special when compared to other Civil Engineering works. Since the pavement construction is same for all the road types except the topmost layer which is concrete for rigid pavement, discussions in this paper shall hence be centered on the construction of its concrete slab topmost layer. Concrete road construction works are made in line with the two under listed main features viz; 'work stages' and the actual 'concrete work activities'. Details of the features are as follows; -

6.1 THE STAGES OF CONCRETE ROAD CONSTRUCTION.

The step by step stages of construction of concrete road is as spelt out by 'The Cement and Concrete Association of the Road Research Laboratory[2]. The steps are as follows; -

a. **ROADBED PREPARATION** – With the removal of the vegetation and top soil, the resulting natural road bed must be levelled and compacted to receive the next layer.

b. **DRAINAGE SYSTEM** – A very important design parameter that must be given special attention. Design must adequately take care of surface water removal as soon as possible to prevent mud pumping at the joints and at the concrete slab sides.

c. **SUBGRADE WORKS –** This is essentially the filling works which is the first foundation layer laid on the natural roadbed. Great care must be exercised to ensure all specifications are adhered to especially the California Bearing Ratio (CBR), the grading and compaction requirements for it to function as the foundation course.

d. **SUBBASE WORKS** – This is also regarded as part of the foundation. It hence needs to be done in conformity with the required alignment, profile and cross section.

e. **CONCRETE WORKS** – This is the main element on which the classification of the road as concrete road is based. Great care must be exercised in the preparation of the final surface on which the concrete slab shall rest. The side formworks must be strong to firmly hold the fresh concrete till when hardened, it must be structurally durable and strong to withstand the applied design loads during the design service life.

6.2 THE CONCRETE WORK ACTIVITIES IN CONCRETE ROADS.

With the topmost concrete most times used as the riding surface, the construction can be done using continuous or alternate bay methods. The activities involved in the actual construction must be strictly with adherence to the following specifications; -

a. **FORMWORK PREPARATION** – This is the laying of the side formwork to receive the concrete. It can be of timber, plywood, or the modern continuous steel ones.

b. **CONCRETE MIXING** – The activity here is the batching of the concrete, mixing and placement on site using box hopper machine, moving blade, rotating screw machine and the bucket & boom machine.

c. **CONCRETE SPREADING** – This is the placement of concrete with required depth. It can be on the subbase or the subgrade if desired quality is met. The spreading is done such that minimum segregation and uniform pre-compaction are achieved.

d. **COMPACTION AND FINISHING** – The compaction must be done after the design concrete depth is attained. The finishing is done by the concrete finisher to obtain the exact surface contour desired for the completed concrete road. See figure 4.

e. **CURING** – This is very important for controlling the heat loss of the concrete during the hardening and strength gaining. The quality control can be achieved with use of spraying with water-proof membrane, water ponding and covering with damp fabric, damp sand and water-proof paper**.** A minimum of fourteen days in warm weather and 21 days in frosty weather is necessary, (Cement and Concrete Association, 1958)[2].

f. **JOINTS** - Special attention must be made for the provision of joints be it expansion, contraction, warping or simply construction joints so as to minimize the effects of volume changes. The joints must be constructed with load transfer mechanism (see 5.2e) and complete with seals / fillers (see 5.2f) so that the durability of the concrete slab shall be able to meet up with the design service life. See figure 4.

g. **WATER PROOFING** – This is the water-proof paper or plastic material placed in the form of underlay to the concrete slab. It is used to prevent; [1] cement paste from escaping into the subbase, [2] loose materials on subbase surface mixing with the freshly placed concrete, [3] chemical present in subbase soil water attacking the concrete, and [4] reduce to minimum friction between the concrete slab and the layer immediately below it during the movement caused by temperature and moisture changes in the concrete, (Cement and Concrete Association, 1958)[2]. Note that water proofing materials are different from the joints' seal and filler materials.

h. **QUALITY CONTROL –** To ensure the qualities of the topmost concrete slab, concrete cube test and cores on finished work must be done and the results must be in line with the specifications. The slab surface that will not easily wear out, have resistance to skidding (very important) as well as harsh and sharp to touch must be ensured by adopting either the sandpaper or brushed surface texture types.

i. **USE OF PRESTRESSED CONCRETE –** In some instances, prestressed concrete may be used in concrete road construction. Merits of using it include; [1] use of thinner dimension, [2] increased span length in-between the joints, and [3] more durability with longer service lifespan. However, its use is limited to straight alignment due to upward thrust of the road concrete slab in horizontal curves and buckling in vertical curves. Also, prestressed concrete cannot be used in urban areas due to the possible need to cut the road after construction for utility services.

j. **GENERAL CONSIDERATION –** With good design, the construction must generally be done for achievement of final durable road that will withstand the designed lifespan of at least 40 years with low maintenance costs. In figure 4 are illustrating pictures of a concrete road under construction others as completed.

FIGURE 4: JOINTED REINFORCED CONCRETE ROAD CONSTRUCTION

REINFORCEMNT FOR A PANEL
COUTESY – FMW, BODO -BONNY RD, RVS

CASTING OF A CONCRETE PANEL USING FINISHER
COUTESY – FMW, BODO-BONNY RD, RVS

FINISHING WORK ON A COMPLETED PANEL
COUTESY – FMW, BODO-BONNY RD, RVS

SLAB TICKNESS CHECK (QUALITY CONTROL)
COUTESY – FMW, BODO-BONNY RD, RVS

COMPLETED CONCRETE ROAD WITH JOINTS TREATED WITH SEALS / FILLERS

JOINTED CONCRETE ROAD WITH SIDE PROTECTION FROM SURFACE WATER AT CRITICAL POINT

7.0 CONCRETE ROAD MAINTENANCE

100% maintenance free service providing facility does not exist. Rigid pavement by nature is designed to last long with minimum maintenance. However, its failure can still occur as a result of negligence when; [1] poor subgrade, [2] poor joint construction (vital), inadequate sealing of joint, poor compaction, poor drainage (very important), and cracking due to fatigue were not adequately taken care of during the design and construction.

Basic maintenance areas in concrete roads are the joints and cracks. If the joints are badly constructed without use of load transfer mechanism complete with seals and fillers, failures with emergence of cracks will first emanate from them followed with brittleness of the adjacent slab areas. When concrete road slab cracked and failed, to cut it out without any effect on the continuously fixed reinforcement required great care. Also, it is always difficult to maintain a strictly crack free old and new monolithic concrete perimeter after repair. These two repair features often times makes the maintenance of concrete road very complex and costly. Therefore, failure prevention must be of paramount importance.

In view of the above, all the highlighted failure factors must be adequately taking care of during the design and subsequent construction. Another very important failure prevention is a well programmed periodic inspection of the road that must be in place. The most important areas to look into during this periodic inspection are the two basic areas of concrete slab joints and surface cracks. These two must be treated / repaired as soon as they are noticed. Not doing this early may result in depression which is permanent settlement of the underlying materials. When this happened, repair will require cement grouting after jacking the slab up, if the slab itself is affected, the repair process becomes major and complex. In figure 5 are illustrating pictures of concrete road failures that emanated from joints.

8.0 EFFECTIVENESS OF CONCRETE ROAD

Ability to assess the concrete road in terms of being able to withstand the purpose for which it is designed and constructed shall be done with consideration of the 'pros and cons'.

8.1 ADVANTAGES OF CONCRETE ROADS

When the final concrete slab of rigid pavements is constructed as designed with quality control duly observed, the following advantages (pros) shall be gained; -

a. **FLEXURAL STRENGTH** - High flexural strength of the riding surface is achieved.

b. **TYRE PRESSURE AND WHEEL LOADS** - The concrete slab is a solid or rigid member which always makes it to withstand high tyre pressure & heavy wheel loads.

c. **DURABILITY** - High durability is achieved with a life span of at least 40 years.

d. **MAINTENANCE** – Relatively low during road's entire design service lifespan.

e. **RESISTANCE TO ATTACK** - Concrete road have more resistance to attacks and are at the same time environmental friendly.

f. **PROS OF CONTINUOUS TYPE** - When the continuous type is adopted, it can be a better option when compared with segmented one due to its having; [1] less joints, [2] quick and cheaper to construct due to less formwork, [3] simpler works for the provision of drainage, and [4] higher protection of the immediate underlying layer.

8.2 DISADVANTAGES OF CONCRETE ROADS
Though concrete roads have great advantages, they also have disadvantages over the flexible pavement. These cons are in the area of; -

a. **INITIAL COST** – The initial cost of concrete road is about five times higher when all features like sealed / filled joints, reinforced concrete drainages / haunch, water proofing devices etc. are provided. This initial cost is perhaps the main disadvantage militating against its general wide scale use in major highways connecting regions.

b. **COMPLEX MAINTENANCE** – With continuous reinforcement in concrete road slab from one joint to the other, cutting a failed section without affecting the reinforcement and making the perimeter of the cut section to remain un-cracked after replacement with new concrete always results in a difficult process. When there is depression, the slab must be jacked up for cement grouting to be pumped in. All these maintenance activities are complex, needs great care and sometimes costly.

c. **LONG CONSTRUCTION PERIOD** – Construction of rigid pavement involves formwork preparation, reinforcement fixing and curing of the topmost concrete slab for at least 14 or 21 days depending on weather. All these works are time consuming and makes longer the overall construction period when compared with flexible type.

d. **PERMANENT SETTLEMENT** – The rigidity of concrete roads makes deformations due to heavy loads to be non-recoverable. That is, the settlement of the concrete top slab when it happened is permanent. This is a serious disadvantage of concrete roads in terms of complexity of repair and when cement grouting to recover the depressed area is involved, the repair becomes costly.

9.0 CONCLUSION AND RECOMMENDATIONS

9.1 CONCLUSION
With consideration to the above, it is very clear that the very high flexural strength, ability to withstand higher wheel loads, higher durability and very little maintenance are the main benefits of concrete road that makes it an exceptional better road option when compared with the flexible pavement type. These merits are so good that they override the most prominent high initial cost and other demerits. In view of this, it can be concluded that the decision of the Federal Government of Nigeria to adopt concrete road option in the construction of major roads in the country is a welcome idea.

9.2 RECOMMENDATIONS
To achieve the overall success of the decision to adopt concrete road construction nationwide in Nigeria and the envisaged benefits not to be a mirage, the Federal Government is advised to give consideration to the following; -

a. **COST VERSUS BUDGETARY PROVISIONS** – No matter how good a policy of the government is, without funding, it shall be useless. Since all road cannot be on Public Private Partnership (PPP) funding, the government need to seriously study the likely fund that will be available in road sector prior to award of contracts using the policy. This is very vital to the success of the concrete road usage nationwide.

b. **PILOT SCHEME** – It is advised that concrete road pilot scheme commence immediately with repair of relatively short failed sections of some busiest major highways in the country. Study of the performance of the sections so repaired shall in no small way help in the design and construction of concrete roads in a large scale.

c. **STAGE IMPLEMENTATION** – With solution made to funding, it is suggested that the implementation of the policy be made in stages. New contracts for selected major roads can first be awarded in phases. This can be followed with gradual review of the ongoing contracts already awarded with flexible pavement construction.

d. **AVAILABILITY OF BASIC MATERIALS** – Reinforced concrete is the most important member of rigid pavement. Materials for production of concrete is same as the ones used in the built industry. When the policy becomes fully implemented, there will likely be scarcity of cement, iron reinforcements and aggregates. To get over this envisaged problem, government shall need to provide enabling environment for individual and corporate organization for the mass production of these basic construction materials as soon as practicable. Not doing this may jeopardize with possible truncation of the good intention of the policy.

e. **VERY ADEQUATE DRAINAGE SYSTEM** – In rigid pavement, if provision of drainage system is not adequately made for surface water to freely drain out as soon as possible, ponding will eventually make stagnant water to enter the layer immediately under the slab through the joints, sides and minor cracks. Softening of the immediate underlying layer materials will follow and then pumping out of same will occur. Continuation of this process can lead to non-recoverable settlement with permanent depression of the concrete slab. With complex repair of concrete road depressions, it is necessary that reinforced concrete line drain or 500mm deep concrete haunch be provided in vital areas and if funding can sustain it, in the entire route length.

f. **OBSERVANCE OF STRICT QUALITY CONTROL** – With the depressions of concrete roads being permanent and non-reversible, strict observance of all the relevant specifications guiding the construction works especially fixing of the reinforcement, the concrete mix, construction of the joints etc. must be ensured. In the event of unlikely failures, sanctions must be strictly enforced on the earring officers.

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CEMENT AND CONCRETE: ADVANCES IN RESEARCH AND APPLICATIONS

By

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Abstract:

Cement is currently one of the most popular materials in the world today being used for the production of concrete in the construction of Buildings and Critical Engineering Infrastructure. Conventional Cement is a fine powder created from crushed limestone and clay which acts as a glue-like binder to hold the Concrete together. On the other hand, Concrete is the finished product that results from mixing sand, water, admixtures, and cement together. References to both Cement and Concrete are almost interchangeable but their use is very old, like the Roman Empire was the first civilization that used concrete for building houses from a mix of pumice, pozzolana, and lime to make concrete with one of the largest concrete domes that was built in 120 A.D. being the former Roman temple, Pantheon in Rome still standing today. Therefore, with the established and old-age practice and reliance on Cement and Concrete, it will be surprising that there can be any doubt about its use at all. However due to many reasons related to cost of cement and hence concrete; and construction as well as the need to evolve new similar products of higher early and long-term strengths, better workability/placeability and mixability, obtain better sealant qualities especially for water retaining structures and roofing concrete covers; as well as numerous other reasons, the search for better and cheaper glue products in partial or complete replacement of cement has been in the front burner of research and development as long as the history of concrete itself. Hence this presentation though acknowledging that today, Portland cement is among the most commonly used and widely available types of cement around the world, being one of the most cost-effective construction materials; nonetheless takes a huge moderating glance that numerous abuses are associated with the use of cements and concretes because of the lack of understanding of the technical scientific principles, deep theoretical knowledge and engineering applications for best practice and expected huge beneficial outcomes on application. Furthermore, with deluges of advances in research and development (R&D), many other types of Cements, apart from OPC, are available and in use, including supplementary cementing materials, SCM. Concrete replacements are now available as cheaper and optional construction products and cement additives leading to concrete strengths in excess of 170N/mm2 for Polymer Cement as example, are currently available. Drawing from experience of the author and some literary works on the subject matter, a detailed presentation is made for better and more thorough understanding in the embrace and application of Cement and Concrete in theory and practice, especially for the Nigeria construction industry.

1. INTRODUCTION: WHAT IS CEMENT AND CONCRETE

Concrete is often confused with cement since both are used synonymously, but in the most basic sense, they are not one and the same. Conventional cement is a fine powder created from crushed limestone and clay. These materials act as a glue-like binder to hold the concrete together. Apart from limestone and clay, cement can be made from many other materials, but it cannot usually be used on its own. In the old days, cement was made from burnt limestone, bricks, volcanic ash, and crushed rock. Today, Portland cement is among the most commonly used and widely available types of cement around the world, being one of the most cost-effective construction materials. Because of advances in research and development (R&D), it would be seen later that many other types of Cements, apart from OPC, are available and in use, including supplementary cementing materials, SCM.

Figure 1 (a): Cement/Cement Bricks

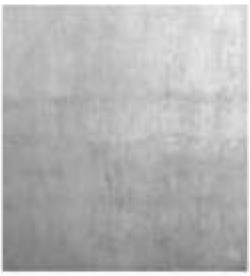

Figure 1 (b): Finished Concrete Surface

On the other hand, concrete is the finished product that results from mixing sand, water, admixtures, and cement together. This mixture must be used whilst it is in a wet state before it solidifies over time. Once the concrete mixture has hardened, it will gain strength and durability. The Roman Empire was the first civilization that used concrete for building houses from a mix of pumice, pozzolana, and lime to make concrete. The largest concrete dome that was built in 120 A.D. is the former Roman temple, Pantheon in Rome. Concrete comes in varying strengths and appearances and is typically made from **4 key ingredients**, which we must distinguish from the chemical compounds that form cement and are critically influential to its inherent properties and behaviour. These include: -

- **Water**: the most crucial element of concrete is water. The quality of concrete is determined by how much water is used. Water creates a chemical reaction when it comes into contact with cement. It also aids workability as long as the right ratio of water to cement is used.
- **Cement**: this is the binding ingredient that holds all the materials together.
- **Fine and coarse aggregates**: sand and stones
- **Admixtures**: other than cement, water, and sand, admixtures are also used before or during the mixing process. Some examples of admixtures include silica fumes, slags, and water reducers.

Just for possible reiteration, cement is an excellent construction material that is used for its high binding strength virtually in every building work and especially in structural elements where high strength is required at an early period of time. Much technical information on Cements in particular can be found in my inaugural lecture ***(Matawal 2002)*** that delves into great details about the types of cement, ranging from general use type I to higher strength type II and III as well as types IV and V. But as a construction material independently, Cement cannot be used for large-scale construction works since it has higher heat hydration than concrete, its durability is low, and it is less solid than concrete and prone to cracking. On the other hand, Concrete ingredients are easily available in every location, unlike stone it has no flaws or defects, it is highly durable and can be made into any shape, casting process can be done on-site which is economical and time-saving. Further, concrete can withstand extreme temperatures and even though concrete absorbs water, it is a mix of cement and other stuff that is not as porous as cement, and it is also an excellent soundproofing material.

But on the whole, Cement and Concrete are intertwined in the minds of many people, but so also are they truly so in actual fact. In another sense, we can assert that Concrete is the material that we interact with every day – in the structure of our homes, offices and hospitals, supporting our bridges and infrastructure, laid on our roads and pavements. Cement is the vital glue that binds the ingredients of concrete together and makes concrete the truly versatile and beautiful building material that is solving the needs of the world today and addressing the challenges of tomorrow. Cement as a glue, acts as a hydraulic binder, meaning it hardens when water is added. Cement itself is a fine powder that is made by first crushing and then heating limestone or chalk, with a few other natural materials, including clay or shale, added. The ground base materials are heated in a rotating kiln to a temperature of up to 1450oC or as hot as volcanic lava.

2. THE IMPORTANCE OF CEMENT AND CONCRETE IN CONSTRUCTION

2.1 Scope of Applications: Whether you use concrete on your walls, sidewalk, or floor, this building material is known for its **longevity**. Concrete has a great reputation for lasting hundreds of years while on the other hand, Cement is much less durable and prone to cracking. While **cement is only suitable for smaller jobs**, concrete works very well in both large and small projects. Concrete is one of the longer-lasting and sturdiest materials that is highly favored by both commercial and residential builders. However, because cement is actually an ingredient in concrete, the two materials may not be the same but in application, they are not even complementary but just one and the same stuff. Concrete is a mixture of cement, water, and aggregates, whereas cement contains limestone and clay. So we can safely say that concrete needs cement in order for it to be used in building projects. Cement comprises up to 15 percent concrete mix through a process known as hydration, where the water and cement bind together; this hardening process turns into concrete.

2.2 Concrete is fundamental in shaping our world: Concrete's inherent benefits of strength, durability, resilience, safety and affordability is harnessed to create vital infrastructure; be it road pavements and infrastructure like culverts, drainages, road barriers; bridges, railways especially the sleepers when steel ones are being stolen; buildings as homes and offices; or the cities and even country homes we live in. It is useful in sidewalks as it is in tunnels, pile and caisson foundation structures, etc. Concrete is crucial for the transition towards global sustainable development and more generally for the infrastructure to support clean energy development. Concrete also plays a significant role in the energy efficiency of buildings. As a mixture, the exact ratios and mix, and type of aggregates used depends on intended application. One of concretes key assets is its versatility which means concrete can be used in a variety of ways to solve the many needs that individuals and societies have – shelter, housing, providing clean water and sanitation, transport, business and commerce; it is indeed an extremely strong, durable and resilient material.

Looking back and now, Cement and Concrete have a long history of use in our world. Briefly, The Roman Empire accelerated the use of concrete; some of its most famous buildings still stand today built around 2,000 years ago, demonstrating the resilience and durability of concrete. Although the cement that was used was different to today's cement material – the principle was similar. Today Portland clinker based cement is the most common type of cement in use. Portland cement was first developed in the beginning of the 1800s. All member of the GCCA (Global Cement and Concrete Association) are Portland clinker based cement producers.

2.3 The Importance of Cement and Concrete in Construction

Because this amazing material has several different uses and is widely used in the construction of all over the world, concrete constitutes the most famous material used for construction purposes.

In many countries, especially Europe, Japan, America and China, **'ready-mix'** concrete has become really popular in recent years to speed up the construction process and make it more reliable and now a fashionable avenue of business for the professionals in the construction industry. Concrete is used to provide strength, durability, and versatility during the construction of any structure. These excellent properties have made concrete a reliable and long-lasting choice of construction for companies for both commercial and domestic types of constructions. Some of the primary, or better fundamental properties of concrete that make it extremely important in construction as a preferred material are:

i. **Strength:** Strength is the primary reason why concrete has been used by housing developers and construction companies for many decades. As Reinforced Concrete, it is a solid material that possesses the ability to resist both compressional and direct or flexural tension, shear and torsional stresses. In 'ready mix' concrete, construction companies can now look up to reliable concrete suppliers that provide the best readily available concrete mixes, turning it into a proprietary material for the purposes of producing best quality for efficient applications. *Maybe this is one of the established advances globally that we must take note of at this nascent stage of this address.* The strength of concrete has made it essential in the construction of buildings, foundations, water treatment facilities, factories, bridges, large industrial sectors, and other many other types of structures. The strength of the concrete is adaptable to the specific requirements of the construction project.

ii. **Durability:** Concrete can last for ages as it can survive harsh weather conditions and natural disasters. It is resistant to extreme weathers, rusting, chemical reactions, fire, erosion, compressive and tensile stress, and abrasion. As a result, the structural integrity of the concrete will not be undermined for an extended period of time which makes it suitable for every other place in the world. The high durability of the concrete means it is a long-lasting construction material for permanent buildings and strong structures like bridges and dams. The first concrete dates back to about 500 BC and we can still observe concrete of ancient times.

iii. **Versatility:** Concrete has applications in different types of construction materials. Its versatility makes it easy for the construction companies to use it for building roads, highways, sideways, garages, and any other structure. Its strength can be modified according to the construction requirements. Concrete can be formed into any shape and size to develop unique, creative and innovative structures and designs.

iv. **Environmental Importance of Concrete:** Concrete also has numerous environmental benefits, such as: survival natural disasters like floods; being recyclable and reusable, which increases its lifespan even further; and minimal transportation is required for the raw materials of the mixture as it is usually found from the local source

Figure 2 (a): Cement Types Figure 2 (b): Fresh Concrete

So far as the growth and survival of human societies are concerned, cement and concrete are therefore essential components. As a foundation and building block of long lasting and reliable infrastructure, concrete has remarkable performance across social, economic, and environmental aspects. It would become difficult to provide economical, low maintenance, and efficient infrastructure to service large cities without cement and concrete. The byproduct concrete is robust, affordable, and abundantly available. While infrastructure is imperative to develop modern societies, concrete is the best building material from which sustainable infrastructure is built. Undoubtedly, concrete is the ideal choice to build sustainable cities.

3. COMMON CONCRETE PROBLEMS AND RESEARCH SOLUTIONS

The cost of repairing, replacing and rehabilitating deteriorated infrastructures in Nigeria and across the world is becoming a major concern. The dire need to upgrade the structural capacity of our existing bridges and ageing infrastructure with modern and advanced building materials has been growing in popularity over the years. As illustration, Corrosion of reinforcement in concrete structures is a serious diffused deterioration phenomenon. Chloride attacking the carbonation of the concrete exterior is what leads to rebar corrosion and heavy maintenance requirements. Indeed, while concrete is a relatively convenient material to manage, however the construction industry has been dealing with a number of structural issues associated with cement concrete and concrete reinforcement. The rapid deterioration of many concrete infrastructures makes it difficult for the government to maintain or upgrade existing structures which would cost billions to trillions of naira every year to be effectively remediated. Intricately other demerits associated with its principal compound cement makes the search for other binders both unavoidable and inevitable. Concrete itself is subject of cracking, disintegration, spalling, discoloration, scaling, curling, and crazing, being some of the common concrete problems.

So when the question is asked about why do concrete structures such as bridges and buildings fail so frequently and flagrantly too in Nigeria or become structurally deficient, it is possible that deterioration of old public structures is factually a huge challenge for structure owners. The construction industry has been struggling to effectively address the corrosion of reinforcement which is the biggest reason why concrete deteriorates. When traditional reinforcement material such as steel corrodes, the process ultimately leads to concrete problems. Generally, corrosion of steel in concrete is induced by either carbonation or by chlorides. Carbonation means that carbon dioxide in air reacts with calcium within the concrete. This means that **the pH of the concrete is decreasing and the steel start to corrode**. In Nigeria, the poor application of Cement and concrete has led to collapse of Buildings.

Figure 3: NBRRI and Building Collapse in Nigeria (i) 1-Storey at Bukuru and (ii) Imam Street, Uyo

Hence even though concrete remains one of the most popular materials in construction and is second only to water in terms of material consumption around the globe, however, drawbacks like the material's high carbon impact can make it unattractive for some projects. Shifting to its major compound, the cement industry is one of the leading producers of carbon dioxide. Growing consumer awareness of climate change and the environmental impact of construction has some clients looking for alternatives to materials that rely on cement. There is a growing range of concrete alternatives using materials which provide similar benefits as concrete, like strength, durability, and longevity, but at a lower carbon cost, with less environmental impact, and often with an appealing and distinctive appearance. Other problems of cement are tied to its **disadvantages, namely:** Contrasted with other binding materials, the tensile strength of cement is somewhat low, Cement is less ductile, the weight in contrast is high compared to its strength, cement may contain solvent salts which cause efflorescence.

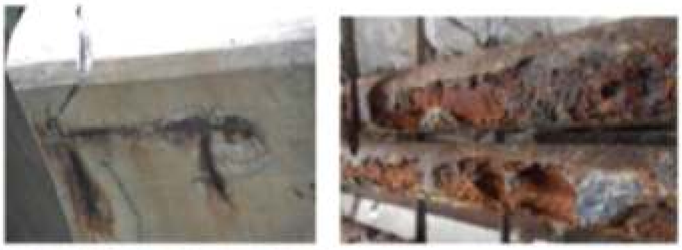

Figure 4: Typical Carbonation and Reinforcement Corrosion Effects in Concrete

The 5C framework is structured around the key elements of the cement and concrete value chain: clinker, cement, concrete, construction and the built environment, and (re)carbonation. For Climate solutions, the focus for cement and concrete industry, the key discussions target pathway to carbon neutrality.

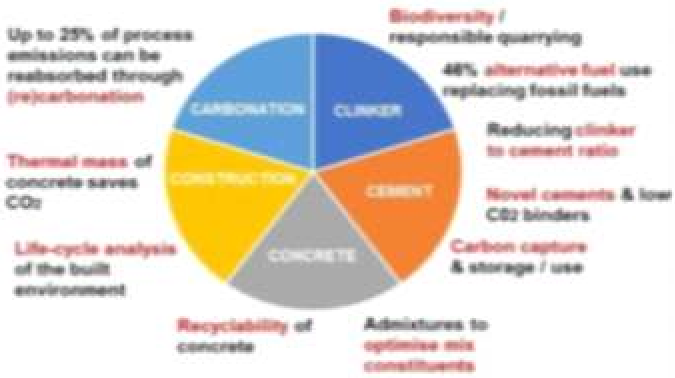

Figure 5: Innovation along the value chain: the 5C approach

The usual aims of research in *Cement and Concrete are* to investigate and improve upon the materials science and engineering of **cement, cement composites, mortars, concrete** and other allied materials that incorporate cement or other mineral binders. Usually there is focus to obtain results and make breakthroughs on the properties and performance of cementitious materials; novel experimental techniques; the latest analytical and modelling methods; the examination and the diagnosis of real cement and concrete structures; and the potential for improved materials with a view to cover:

Processing: Cement manufacture, admixtures, mixing, rheology and hydration with emphasis on all cements - Portland cements, and other mineral binders such as alumino-silicates (often referred to as ***geo-polymers***), calcium aluminates, calcium sulfoaluminates, magnesia-based cements, as well as lime and/or gypsum-based materials.

Chemical, microstructural and structural characterization of the unhydrated components and of hydrated systems including: the chemistry (structure, thermodynamics and kinetics), crystal structure, pore structure of cementitious materials, characterization techniques, and the modelling on atomistic, microstructural and structural levels.

The **properties and modelling** of cement and concrete, including: fundamental physical properties in both fluid and hardened state; transport, mechanical and other properties; the processes of degradation of cementitious materials; and the modelling of properties and degradation processes, as a means of predicting short-term and long-term performance, of relating a material's structure to its properties and of designing materials of improved performance, in particular with lower environmental impact. Corrosion related to process fundamentally affected by the interplay between steel reactivity and a surrounding cementitious material are good areas.

Applications for cement, mortar and concrete keeping a clear focus on fundamental questions of materials science and engineering focus that include: concrete technology, rheology control, fiber reinforcement, waste management, recycling, life cycle analysis, novel concretes and digital fabrication.

The construction industry has developed many techniques and materials to counter steel corrosion. Unfortunately, none of the techniques may be effective enough to address the problem but there are short term solutions that slow down the corrosion process while others introduce advantages to the many observed disadvantages of cement and concrete. Economy is one area which demonizes cement and concrete, especially in Nigeria where inflation has deeply undermined not only the capacity but also the probability (even possibility) of individuals owning homes and for most governments to intervene in affordable and/or social housing effectively. This is where GFRP concrete reinforcement offers the civil engineering community an innovative and reliable way to effectively encounter steel corrosion. There are also issues of workability or mix-ability / place-ability of concrete, setting times, strength and durability in Cement and concrete.

Glass fiber reinforced polymer (GFRP) is inherently corrosion-resistant and lightweight material which offers many advantageous structural properties ranging from ease of construction and low maintenance to electromagnetic neutrality and 2x tensile strength and one of my Students is working on metakaolin from Alkaleri Kaolin mines as geopolymer concrete and substantial progress has been recorded. Research must focus on novel strategies for reducing CO2 emissions in cement production, carbon sequestration into cement, the identification of new agents for enhancing durability, the development of ultra-high-performance concrete (UHPC) with compressive strengths exceeding 170 MPa, radiation shielding, and the enhancement of the durability of concrete in extreme environments by employing mix designs.

There may be environmental and economic advantages of utilizing refuse-derived fuels (RDF) and sewage sludge (SS) in cement kilns to decrease CO2 emissions of clinkers in order to significantly reduce the carbon footprint of cement production, a major source of greenhouse gas emissions. Alternative materials and innovative mix designs are being explored to improve concrete performance, the effects of partially substituting cement with rice husk ash, corn cobs, volcanic ash derived from some locations on the Jos plateau and even solutions for cement on the permeability and carbonation resistance of concrete. Use of tin mining ore and iron ore tailings as well as granulated blast furnace slag and quartz powder have their unique effects on concrete strength and durability and they have been studied as well as even employing wood ash as a partial substitute for cement for desired effects on concrete strength and durability.

"Innovation in the manufacture of novel low-carbon cements and the widespread use of waste derived fuels are two keys to achieve an immediate reduction in the CO2 emissions of the Spanish

Figure 6: (a) Collapse of 21-storey Apartment Block in Ikoyi-Lagos, and (b) Other Structures

4. SOME OPTIONAL MATERIALS TO CONCRETE IN CONSTRUCTION

Despite its durability, versatility, and undeniable presence in our environment, concrete is a major contributor to the emission of greenhouse gases and that can only mean bad news for the climate. The building industry today owes a long due apology to nature and using greener substitutes for concrete could lead a long way forward. There are some known substitutes that ace the sustainability charts over concrete and can be an alternate solution that offer a lower environmental impact, and even much lower costs.

4.1 Ashcrete: Fly Ash is a by-product of coal combustion that is otherwise discarded into landfills. Ashcrete is a greener alternative to concrete that replaces about 97% of its constituents with recycled material, thus discarding the use of traditional cement. It not only reduces costs but also provides greater strength and durability when compared to traditional concrete. Fly Ash also reduces the shrinkage and permeability of concrete and renders it resistant to alkali-silica reactions. Ashcrete has a wide range of applications and can be used in bridges, pavements, embankments, roads, and building.

Figure 7: Fly Ash from Coal Power Stations

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the presence of water, being:

□ Hydraulic Cement - This cement gets hardened or solidified in an extremely short span to focus in constructions for saving time and energy. The basic parts are limestone, clay, and gypsum, blended in exceptionally high temperatures to create areas of strength for an impact. The advantage of these cement types is that they are impervious to weather conditions changes even in underwater conditions like tanks, pools, and so forth; they are additionally nonreactive to chemical attacks.

□ Non-Hydraulic Cement - They have an extremely long setting period and can only work in dry circumstances. Non-hydraulic isn't pragmatic for business developments, as they can't be utilized in sites that are available to weather conditions challenges. Made with lime, gypsum, and oxychloride, these cement can't be utilized for water-related constructions and are rigorously reserved for indoor purposes to accomplish structural strength.

Thus we have **Ordinary Portland Cement (OPC)** falls under the hydraulic category and is acquired by heating the Argillaceous (clay and shale) and Calcareous (limestone, chalk, and marl) in exceptionally high temperatures, called the Calcination process. The end product is known as the Clinker, which is then crushed into a fine powder and afterward blended in with Calcium Sulfate and Gypsum to make cement. This is the most well-known type of cement utilized for general construction and development purposes. It promptly responds with water and has quick-dry characteristics.

Portland Pozzolana Cement (PPC) whose fundamental component is Pozzolona, which incorporates materials like fly ash, volcanic debris, or calcined clay. This cement is prepared in two ways – one by crushing or grinding the Pozzolanic clinker with conventional Portland cement or adding Pozzolana with gypsum or calcium sulfate. Another method is to mix the Portland cement with powdered Pozzolana. It is highly impervious to chemical attacks and falls under the hydraulic cement types. They are suitable for marine constructions, pre-casted sewage channels, dams, etc. They can be used for creating concrete artworks, as it lends a smooth and glossy finish. Portland pozzolana cement is available as 25kgs sack bags in the current NBRRI Pilot plants in Bokkos and Ota.

Quick Setting Cement whose name emanates from its quick-setting properties as it sets in quick time just in 5 minutes, with 30 minutes as the final setting time. The cement is of a proportion of Clinker and Aluminum Sulfate to increase the hydration rate. They are accessible in 25kg, 40kg, and 50kg bags.

Low Heat Cement is a unique type of cement that releases low heat of hydration, which is a chemical reaction that happens when the cement gets blended in with water. The benefit of generating lower heat of hydration is a limited risk of cracks on the body. This cement is prepared by bringing down the proportion of Tricalcium Aluminate by 6% and increasing Declaim Silicate to 46% to forestall cracks because of high heat. They are utilized in mass construction sites like dams, bridges, massive foundations, enormous slabs, chemical plants etc. They are less reactive cement and have a higher setting time contrasted with the regular OPC.

Rapid Hardening Cement for Sites that demand faster construction and development in a lesser time window, rapid hardening cement is the most ideal decision. As the name recommends, it sets in only 30 seconds initially and 600 minutes as the final setting time. The key to this strength lies in its formula which contains a higher percentage of Tri-Calcium Silicate than regular Portland Cement. This cement needs 3 days to totally create or harden contrasted with a 7-day window of a traditional OPC. They can be utilized for road repair works, pavements, and pre-fabricated constructions. Rapid hardening cement isn't suggested for mass construction sites, as the risk of developing cracks is extremely high.

High Alumina Cement is made of Calcium aluminates, rather than the Calcium silicates utilized in regular Portland cement. Therefore, it is frequently alluded to as ***Calcium Aluminate cement*** or Aluminous cement. This cement has a very high compressive strength and is fire-resistant, making it suitable for large constructions; prepared by melting bauxite and lime mixture and then grinding it with a clinker. They are suitable for building sites subjected to extreme weather conditions like high temperatures (or frost).

There are also **White Cements** (reducing or diminishing the extents or proportions of iron oxide and manganese oxide) with water-resistant properties typically utilized as a grout to set the tiles on the flooring, in pools, and in other interior and exterior decorative works, but very expensive. Also **Sulphate-Resisting Cements** developed in light of the sulfate attacks on the cement in a concrete structure. Sulfate-resisting cement falls under the hydraulic cement category. It is made by reducing or decreasing the amounts of calcium sulpho aluminates like C3A and C4AF. This is an ideal choice for construction sites wherein the soil or groundwater contains high amounts of sulfate salts like seacoasts, flowing regions, or locales nearer to the sea waters. They are ideal for water storage sumps and drainage or seepage works.

Air Entraining Cements are alternate cement variety that has an addition of a limited amount of air-entraining agents like glues or resin to create air bubbles in the concrete. This cement can withstand sulphate attacks. This method is utilized for increasing the cold resistance in cement, particularly when it is subjected to frequent freezing and thawing. The bubbles allow the space for contracting and expansion in cold climates to lower the risks of cracks and internal damage. It is not a high-strength cement and is designed for spatial use only. There are **Expansive Cements** which grow in volume when blended in with water contrasted with ordinary Portland cement. By doing so, the cement aids in limiting the shrinkage loss caused because of loss of moisture. There are three sub-types of expansive cement, particular K-type, M-type, and S-type primarily used to bring down the risk of cracks in concrete constructions and developments as well as pavements. Expansive cement isn't recommended to use alongside fly ash and other pozzolans, as they can interfere with the expanding properties and strength.

There are **Coloured Cements** because concrete isn't grey or white most of the time. With advancements in innovation, you can now find colored cement on the lookout. By blending 5 to 10% of mineral pigments into conventional cement, you can acquire beautiful colored cement like blue, green, yellow, and so forth. In the event that the pigment surpasses 10%, the strength of the cement is lost. Thus, the proportion is very important. These cements are utilized for creating decorative effect in flooring. **Hydrographic Cement** has water-repelling properties to keep away from the loss of cement in regions affected by frequent water contact obtained by blending customary Portland Clinker with Oleic acid or other water repellents to shape a thin film on the cement surface. Then there are **Waterproof Cements** or water-resisting cement has practically the same use as that of hydrographic cement. It falls under the hydraulic cement category. In many cases, the manufacturing process and the properties are different in both these cement. Waterproof cement is made by adding a water-repelling agent to normal Portland cement. Nonetheless, it isn't generally as watertight as hydro-graphic and may not be suitable for high water conditions. They are utilized for waterproofing the terrace flooring, water tanks, and submerged sumps.

Slag Cements are sorts of hydraulic cements that are prepared by finely crushing the granulated blast furnace slag (GGBFS). Nowadays, slag cement is utilized as an option in contrast to Portland cement for its better workability. It has a higher resistance and protection to chemical reactions and better compressive strengths. Likewise, adding slag cement to the standard concrete mixture can accelerate the setting time and give a superior completion. It is for the most part utilized in precast and ready-made cement and building structures that require high-temperature resistance. Then we have **ultra-High Strength Cements (UHSG)** as another variety of cement innovations, made as a feature of the new technological advancements. The cement is presently utilized as evolved in some countries, for making bridges and other massive structural designs. The ingredients utilized in this cement are Portland cement, Silica fume, Quartz flour, Superplasticizers, and organic or steel fibers. It is very sturdy in freeze-thaw conditions. They have extremely low chlorine permeability and high abrasive resistance contrasted with different types of cement.

6. SUPPLEMENTARY CEMENTING MATERIALS (SCMs)

Supplementary cementing materials (SCMs) exhibit pozzolanic and/or cementitious properties and are used in concrete to partially replace the Portland cement component. SCMs differ in source, physical properties, and chemical composition. Examples of SCMs namely: fly ash (a by-product from coal combustion), slag cement (a by-product of the steel industry), silica fume (a by-product from elemental silicon production), and metakaolin (produced from the calcination of kaolinite clay) are described here. Part of the motivation to incorporate SCMs in concrete stems from their potential to reduce greenhouse gas emissions, energy use, and waste disposal to landfill sites. Beyond the environmental benefits, the use of SCMs as a partial cement replacement can achieve similar or improved fresh, mechanical, and transport properties compared to concrete without SCMs. Concrete containing fly ash, slag cement, silica fume, or metakaolin can improve the resistance to chloride ingress, alkali–silica reaction, freeze–thaw damage, and sulfate attack, compared to concrete without SCMs. However, concrete containing SCMs are typically more vulnerable to carbonation processes and can exhibit greater deicer salt scaling mass loss than concrete without SCMs.

Supplementary cementing materials (SCMs) contribute to the properties of hardened concrete through hydraulic or pozzolanic activity. Typical examples are fly ashes, slag cement (ground, granulated blast-furnace slag), and silica fume. These can be used individually with portland or blended cement or in different combinations. Supplementary cementing materials are often added to concrete to make concrete mixtures more economical, reduce permeability, increase strength, or influence other concrete properties.

Fly ash (FA) is the most commonly used pozzolana in concrete. Commercially available fly ash is a finely divided residue that results from the combustion of pulverized coal and is carried from the combustion chamber of the furnace by exhaust gases.

Slag Cement, formerly referred to as ground, granulated blast-furnace slag, is a glassy, granular material formed when molten, iron blast-furnace slag is rapidly chilled - typically by water sprays or immersion in water - and subsequently ground to cement fineness. Slag cement is hydraulic and can be added to cement as an SCM.

Silica fume, also called condensed silica fume or microsilica, is a finely divided residue resulting from the production of elemental silicon or ferro-silicon alloys that is carried from the furnace by the exhaust gases. Silica fume, with or without fly ash or slag, is often used to make high-strength concrete.

Meta-kaolin is obtained from Kaolin clay, which is processed under carefully controlled conditions to refine its colour, remove inert impurities, and tailor particle size such that a much high degree of purity and pozzolanic reactivity can be obtained. Super plasticizers may be used to aid dispersion for good workability.

Figure 13: Green Substitutes to Cement known as supplementary cementitious materials (From the left to the right, class C fly ash, metakaolin (calcined clay), silica fume, class F fly ash, ground granulated blast furnace slag, and calcined shale)

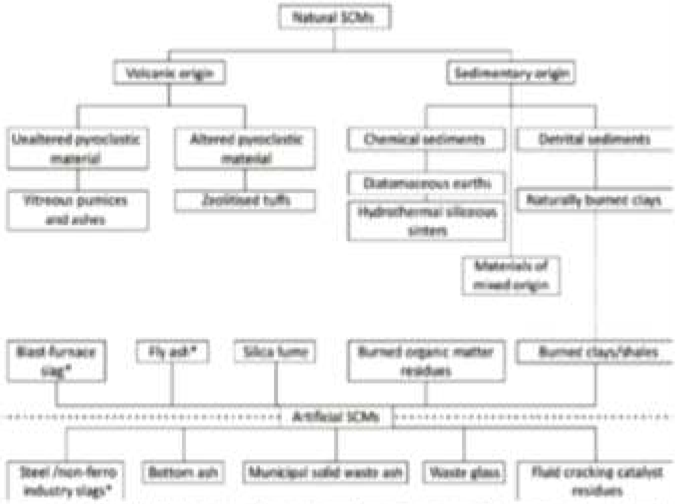

Figure 14: General classification scheme of supplementary cementitious materials. * denotes materials which can present hydraulic activity, all other materials display pozzolanic behavior. A selection of promising SCMs still largely under development are positioned below the dashed line

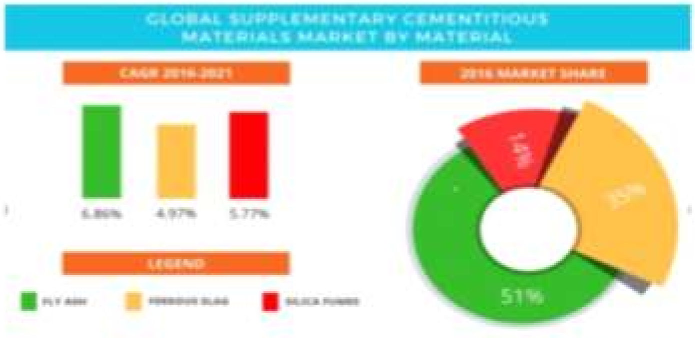

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Figure 15: Global Supplementary Cementitious Materials Market Projected to be Worth USD 100.6 Billion in 2021

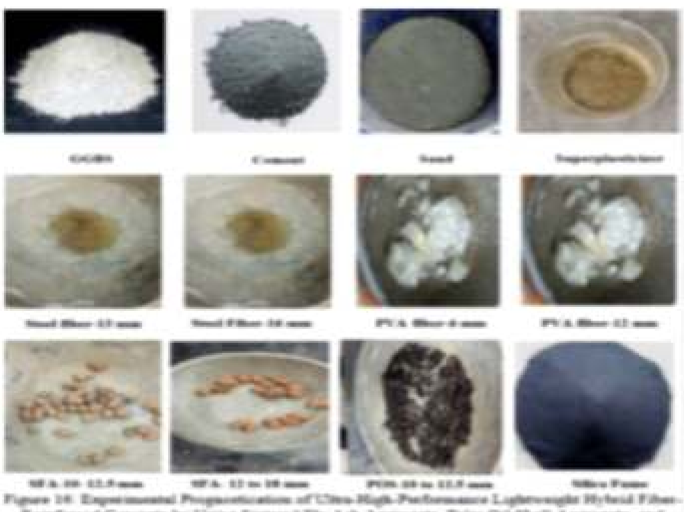

Figure 16: Experimental Proportioning of Ultra-High-Performance Lightweight Hybrid Fiber-Reinforced Concrete by Using Sintered Fly Ash Aggregate, Palm Oil Shell Aggregate, and Supplementary Cementitious Materials

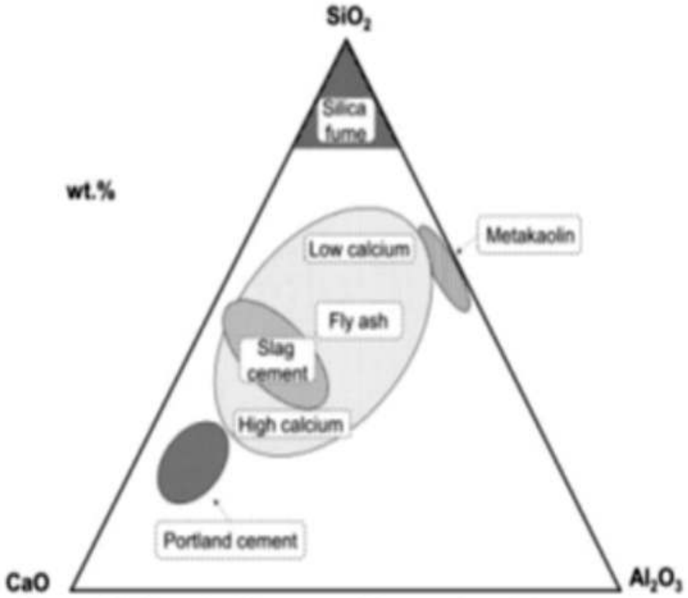

Figure 17: Triangular Placement of Cements by weight proportions

Supplementary cementitious materials	
Derived from wastes	Derived from natural sources
Fly ash	Metakaolin
Slag	Calcined shale
Silica fume	Calcined clay
Rice husk ash	Volcanic ash
Corn cob ash	Zeolitic tuffs
Sawdust ash	Diatomaceous earth
Glass powder	Limestone
Bottom ash	
Cement kiln dust	

Figure 18: Further Details about SCMs

Many studies on these supplementary cementing materials have continuously been conducted by the author and many other researchers in Nigeria ready for application.

7. SUMMARY

7.1 Summary: Cement and Concrete are intertwined in the minds of many people, but so also are they truly so in actual fact. In another sense, we can assert that Concrete is the material that we interact with every day – in the structure of our homes, offices and hospitals, supporting our bridges and infrastructure, laid on our roads and pavements. Cement is the vital glue that binds the ingredients of concrete together and makes concrete the truly versatile and beautiful building material that is solving the needs of the world today and addressing the challenges of tomorrow. Cement's central use is to bind together the ingredients of concrete – sand and aggregates. Cement is a glue, acting as a hydraulic binder, meaning it hardens when water is added. Cement itself is a fine powder that is made by first crushing and then heating limestone or chalk, with a few other natural materials, including clay or shale, added. The ground base materials are heated in a rotating kiln to a temperature of up to 1,450oC or as hot as volcanic lava.

Indeed, cement in concrete **has been fundamental in shaping our world** because from the inherent benefits of concrete of strength, durability, resilience, safety and affordability to create vital infrastructure; be it road pavements and infrastructure like culverts, drainages, road barriers; bridges, railways especially the sleepers when steel ones are being pilfered; buildings as homes and offices; or the cities and even country homes we live in. What of sidewalks, tunnels, complex foundation structures, etc. Concrete is crucial for the transition towards global sustainable development and more generally for the infrastructure to support clean energy development. Concrete also plays a significant role in the energy efficiency of buildings. One of concrete's key assets is its versatility which means concrete can be used in a variety of ways to solve the many needs that individuals and societies have – shelter, housing, providing clean water and sanitation, transport, business and commerce. Concrete is an extremely strong, durable and resilient material.

Looking back and now, Cement and Concrete have a long history of use in our world.

7.2 Plethora of Challenges: However, the cost of repairing, replacing and rehabilitating deteriorated infrastructures in Nigeria and across the world is becoming a major concern. The dire need to upgrade the structural capacity of our existing bridges and ageing infrastructure with modern and advanced building materials has been growing in popularity over the years. As illustration, Corrosion of reinforcement in concrete structures is a serious diffused deterioration phenomenon. Chloride attacking the carbonation of the concrete exterior is what leads to rebar corrosion and heavy maintenance requirements. Indeed, while concrete is a relatively convenient material to manage, however the construction industry has been dealing with a number of structural issues associated with cement concrete and concrete reinforcement. The rapid deterioration of many concrete infrastructures makes it difficult for the government to maintain or upgrade existing structures which would cost billions to trillions of naira every year to be effectively remediated. Intricately other demerits associated with its principal compound cement makes the search for other binders both unavoidable and inevitable. Concrete itself is subject of cracking, disintegration, spalling, discoloration, scaling, curling, and crazing, being some of the common concrete problems. To complicate matters, infrastructure and buildings have been collapsing or failing with unacceptable frequency in Nigeria. Hence even though concrete remains one of the most popular materials in construction and is second only to water in terms of material consumption around the globe, however, drawbacks like the material's high carbon impact can make it unattractive for some projects. Shifting to its major compound, the cement industry is one of the leading producers of carbon dioxide. Growing consumer awareness of climate change and the environmental impact of construction has some clients looking for alternatives to materials that rely on cement. Therefore, scientists in the construction sector and the Built Environment have conducted researches and made growing range of cement and concrete alternatives available. These materials provide similar benefits as concrete, like strength, durability, and longevity, but at a lower carbon cost, with less environmental impact, and often with an appealing and distinctive appearance. The 5C framework is structured around the key elements of the cement and concrete value chain: clinker, cement, concrete, construction and the built environment, and (re)carbonation. For Climate solutions, the focus for cement and concrete industry, the key discussions target pathway to carbon neutrality. Thus researches have been initiated that aim to investigate and improve upon the materials' science and engineering of **cement, cement composites, mortars, concrete** and other allied materials that incorporate cement or other mineral binders. In doing so, we focus to obtain results and make breakthroughs on the properties and performance of cementitious materials; novel experimental techniques; the latest analytical and modelling methods; the examination and the diagnosis of real cement and concrete structures; and the potential for improved materials.

8. CONCLUSION

Today as a consequence of diverse activities in research and applications, we do have options to both concrete and cement and even construction experts and organizations like NBRRI-Nigeria have engineered new construction materials, construction methods and techniques. Indeed, the emergence of numerous supplementary cementing materials including NBRRI Pozzolana Cement being produced in Bokkos and Ota are revolutionizing cement and concrete applications for potential lower cost construction and improved buildings and infrastructures. Research has introduced novel strategies for reducing CO2 emissions in cement production, carbon sequestration into cement, the identification of new agents for enhancing durability, the development of ultra-high-performance concrete (UHPC) with compressive strengths exceeding 170 MPa, radiation shielding, and the enhancement of the durability of concrete in extreme environments by employing mix designs. New classes of Cements have emerged and improvements are continually being introduced into the frontier of knowledge.

Very importantly globally today is the influence of supplementary cementing materials, SCMs, especially fly ash, slag cement, silica fume, and metakaolin, though there are numerous others researched in Nigeria and other parts of the globe. Part of the motivation to incorporate SCMs in concrete stems from their potential to reduce greenhouse gas emissions, energy use, and waste disposal to landfill sites; but one primary reason is economical to replace even partially Cement that has become so expensive. Thus supplementary cementing materials are often added to concrete to make concrete mixtures more economical, reduce permeability, increase strength, or influence other concrete properties.

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NIHTE INDUSTRY VISIT TO THE ANAMBRA INT'L. CARGO AND PASSENGER AIRPORT








Members of The Nigerian Institution of Highways and Transportation Engineers Anambra Chapter today being the 29th of August, paid an Industrial Visit to the Anambra Intl Cargo & Passenger Airport.

This is in line with the area of focus of the Institution which transportation falls into as the Students of Nnamdi Azikiwe University Civil Department, and NIHTE members were exposed to airport which is an aerodrome with extended facilities.

The MD Engr Martin Nwafor, who happens to be the speaker touched on the vital aspects and components of the Airport starting with the Control Tower and it's function, the Taxiway which is 2 one on both ends interconnecting with both the Runway which has a length of 3.7km as the 2nd Longest in Nigeria with a width of 45m, and the Apron/Ramp that can contain upto 10Airbus with a size of 200m × 300m.

Few questions and remarks were made after his presentation before it came to a close with a group picture.

The climax of the visit was the presentation of A Distinguished Meritorious Award to the *MD Engr. Martin Nwafor* for his contributions in the Aviation Industry.

Engr. Obiudu Chidi Matthew PHF
Pioneer Chairman NIHTE Anambra State.

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