Development and Design of Multipurpose Park Using Rigid Pavement and Modern-Interlocking Pavement

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Abstract- ***This study presents the development and design of a multipurpose car park using both rigid pavement and modern interlocking pavement systems, with the Unizik-Ifite Park as a case study. Key elements include Environmental Impact Assessment (EIA), land surveying, geotechnical soil analysis, and architectural modeling. Findings indicate that due to poor subgrade conditions i.e. low CBR Ratio values (California Bearing Ratio), rigid pavements require significant subgrade treatment, while interlocking pavements are more economically viable due to their adaptability and lower base preparation requirements. The study concludes with design recommendations that emphasize durability, economic viability, effective drainage, proper surface markings, and lighting to enhance safety and functionality.***

Indexed Terms – Pavement Design, Subgrade CBR, Geotechnical Analysis, Economic Evaluation, Multipurpose Car Park

I. INTRODUCTION

Nigeria, home to an estimated 170 million people, with over 40 million of who are in the growing middle class has been estimated 30% new vehicles were sold to retail customers and 70% New cars sold will be manufactured or assembled in Nigeria by 2050 [18].

In the light of this knowledge and owing to an ever increasing traffic population and the attention drawn by the growing activity system in and around the Unizik-Ifite way has summated to the occurrence of some of the major transportation problems often discussed. These problems which all-inclusive include congestion, health implications from tail-pipe emissions, noise etc. By visual inspection which can be seen on till this present day, is majorly due to the poor multi-purpose park that is to manage and handle the committal insurgence in this area. In the light of this view, putting in consideration is the very fact that erecting a Multi-purpose Park would be sustainable enough not to impinge intolerably on the basic liberties and freedoms of the people.

An aspect of multi-purpose car park design is key that the pavement design which involves the selection of the thick-ness of the pavement and its various components, is sufficient to support vehicular loadings and to transfer those loadings through successive layers of the pavement (i.e. surface, base, and subgrade) to the soil on which the pavement rests. If the load is excessive or if the supporting layers are not sufficiently strong, repeated application of vehicular loadings will result in rutting or cracking that ultimately leads to a complete structural failure of the pavement.

We will therefore be considering some major design factors that will contribute to the design of the multipurpose park using rigid pavement and modern-interlocking pavements using the Unizik-Ifite Car Park as case study

II. BASIC CONSIDERATIONS OF DESIGNING A SAFER MULTIPURPOSE PARK

Every new parking facility is different in terms of locale, design and usage. The design of a new facility can never be prescriptive, as the developments in a city centre will have different security requirements from a rural surface-level car park [15]. What can be provided is best practice guidance for designers, owners and operators on the design and incorporation of physical security features that will establish and maintain a safe and non-threatening parking environment.

Some considerations which contributes to what an ideal multipurpose park should be, include but a few;

a) Proper directional and boundary Markings

b) Proper Lightening
c) Establishing adequate Maintenance and Safety-Plan
d) Good Drainage System
e) Wheel stops

III. PAVEMENT AND ITS BACKGROUND

Pavements are composite materials that bear the weight of pedestrian and vehicular loads. The purpose of a good pavement design is to effectively dissipate/spread the load from the tyre footprints of the vehicle over a wider area of the existing natural surface, so that the strength of the natural ground will be sufficient to carry the reduced loading without causing any type of failure. [14]

Pavement thickness, width and type should vary based on the intended function of the paved area. Pavement thickness is determined by four factors: environment, traffic, base characteristics and the pavement material used. [12]

a) *Environmental factors;* such as moisture and temperature significantly affect pavement. For example, as soil moisture increases the load bearing capacity of the soil decreases and the soil can heave and swell. Temperature also effects the load bearing capacity of pavements. When the moisture in pavement freezes and thaws.

b) *Traffic;* subjects pavement to wear and damage. The amount of wear depends on the weight and number of vehicles using the pavement over a given period of time

c) *Subgrade strength;* has the greatest effect in determining pavement thickness. As a general rule, weaker sub grades require thicker asphalt layers to adequately bear different loads associated with different uses. The bearing capacity and permeability of the sub grade influences total pavement thickness.

d) *The pavement material;* or wearing surface, receives the traffic wear and transfers its load to the base, while at the same time serving as the base's protective cover. Pavements are classified as either flexible or rigid.

Possible materials that could be used as paving materials include; Asphalt, Concrete, Brick, Stone, Tile, Wood, Earth Materials, Synthetics. Now narrowing down to the choice of paving material for course of this study,

A. Concrete/Rigid Pavement:

The major paving material here is concrete which is very high in compressive stress and low in tension. Reinforcement can be provided to aid this weakness. Rigid pavements can be classified into; (See Fig. 1)

a) *Jointed Plain Concrete Pavement (JPCP);* is the most common type of rigid pavement used. JPCP is engineered with longitudinal and transverse joints to control where cracking occurs in the slabs

b) *Continuously Reinforced Concrete Pavement (CRCP);* uses reinforcing steel rather than weakened plane joints for crack control, saw cutting of transverse joints is not required for CRCP. Longitudinal joints are still used. Transverse random cracks are expected in the slab, usually at 1.0 m to 1.5 m intervals

c) *Precast Panel Concrete Pavement (PPCP);* uses panels that are precast off-site instead of cast-in-place. The precast panels can be linked together with dowel bars and tie bars or can be post-tensioned after placement. [9]

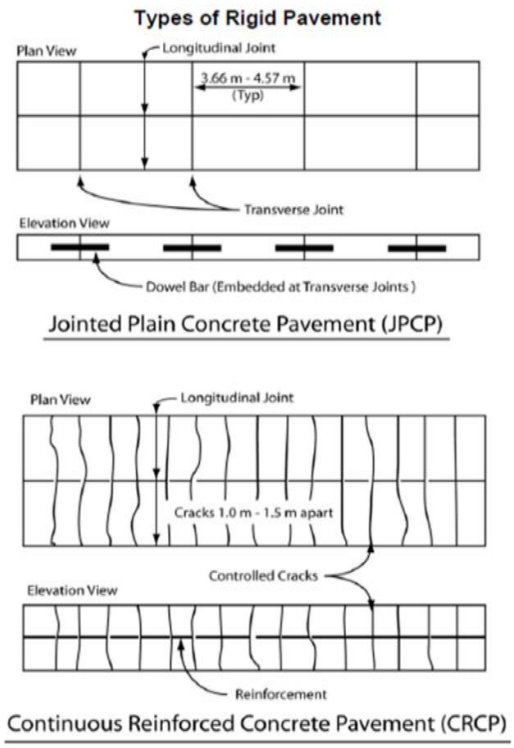

Fig.1 showing the types of Rigid Pavement

However, the provision of joints is essential in rigid pavement, and either a contraction, construction or isolation joint can be provided, or any combination.

B. Modern-interlocking/Block Pavement

It is one of the most interesting engineering developments in post-war Europe was the revitalization of the ancient techniques of segmental paving construction that followed the introduction of the modern cheaply mass-produced interlocking concrete paving block [3]. This pavement structure is commonly used for pedestrian and vehicular applications. The aggregate bases stabilized with asphalt or cement are recommended under very heavy loads, and over weak or saturated soil subgrades. The installation steps include; Job planning, Layout, Excavating and compacting the soil subgrade, applying geotextiles (optional), Spreading and compacting the sub-base and/or base aggregates, constructing edge restraints, Placing and screeding the bedding sand, and Placing concrete pavers. [11]

IV. MATERIALS AND METHODS

A general overview of the method of approach that can be applied for the development of the multipurpose park can be simply be broken down to the determining the EIA of the project, preliminary survey of the area and the activities generated by the area, obtain the soil geometrical properties and existing water path before the actual design of the pavement. These parameters in the analysis and proper design of the pavement.

Illustrating the design of each pavement with the research study carried out at the Civil Engineering CAD Lab, Nnamdi Azikiwe University, Awka, Anambra State, with materials for test and design collected from the proposed site for the siting of the Unizik-Ifite Multipurpose Car Park.

A. The EIA Report

The EIA report or impact statement is a keystone document primarily for decision [4]. It is a systematic study of impacts of proposed project activities on the physico-chemical, biological, ecological, socio-economic and health components of the environment.

The first phase of an environmental assessment carried out is called an Initial Environmental Examination (IEE) and the second is the Environmental Impact Studies (EIS) or simply detailed EIA. [13]

a) *Initial Environmental Examination (IEE);* is carried out to determine whether potentially adverse environmental effects are significant or whether mitigation measures can be adopted to reduce or eliminate these adverse effects. The IEE contains a brief statement of key environmental issues, based on readily available information, and will be used in the early (pre-feasibility) phase of project planning. However, when an IEE is able to provide a definite solution to environmental problems, an EIA is not necessary

b) *Environmental Impact Assessment (EIA);* is a procedure used to examine the environmental consequences or impacts, both beneficial and adverse, of a proposed development project and to ensure that these effects are taken into account in project design. It involves scoping, impact analysis, mitigation and

impact management, EIA Report, Review and final decision making.

Information sorting for an EIA process include the following;

1) Desk Study and Literature Review

2) Data Requirement; for the Physical Environment, Biological Environment, Socio-economic and Cultural Environment

3) Collection Methods; Households Survey, Key Informant Survey, Public Consultation, Observation, and Photographs.

B. Survey and Site Drawings

Surveying has to do with the determination of the relative spatial location of points on or near the surface of the Earth [16]. These features may be represented in analogue form as a contoured map, plan or chart, or in digital form such as a digital ground model (DGM). These can be classified into two major types;

a) *Geodetic Surveying*: The type of surveying that takes into account the true shape of the Earth. These surveys are of high precision and extend over large areas.

b) *Plane Surveying:* The type of surveying in which the mean surface of the earth is considered as a plane, or in which its spheroidal shape is neglected, with regard to horizontal distances and directions.

For the course of this project, the plane surveying method will be adopted.

C. Geotechnical Analysis / Soil Investigation

Geotechnical analysis consists of making a good foundation investigation for the adequate design and construction of a structure proposed for a site. The investigation and analysis are to be performed in compliance with the procedures generally accepted as sound engineering practice. Some key test that will be reviewed for this design include sieve analysis, compaction test, CBR test. Other include Consolidation test, Atterbeg Limit, Expansive index test etc.

D. Architectural Modelling

It is good engineering practise to put engineering models and designs into drawings. There are various techniques and procedures of making architectural design, an example is the use of graphic method of communication during the design process so therefore the design methodology refers to a broad strategy, plan of action, and a process of choosing and applying particular design methods and techniques. The Development/Modelling of the project can be done using the AutoCAD-Computer-aided design and drafting (CADD) software (AutoCAD CADD).

V. RESULTS, DESIGN AND DISCUSSION

An actual IEE report can be seen in figure 2. However, certain considerations like

1. Alternative site: It will cost more to demolish the structures (termed obsolete) already present on the proposed site and in order to reduce the noise pollution within the Perm-site learning area (Garuba Square), coming from the vehicles of the commercial drivers.

2. Report obtained from the revenue collectors showed that on less rainy days, the gain is more and it will be better if the park were to be properly paved and marked as it will help checkmate most drivers who evade being taxed appropriately.

3. By visual inspection, the major failure in pavement in this area will be due to poor treatment of the subgrade soil and the design should not allow the seepage of water into the subgrade due to the expansive nature of the soil.

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P.M.P 5025, AWKA, ANAMBRA STATE

DEPARTMENT OF CIVIL ENGINEERING

LOCATION	Unizik-Ifite Multi-purpose Car Park
EXECUTED BY	Ezema, Israel Uyo

DATE	16-Aug

KEY				
S	M	L	T	SS
Small	Medium	Large	Term	Site Secific

PRE-CONSTRUCTION PHASE

Potential Impact	Magnitude	Duration	Extent	Mitigation Measures	
				Action	Responsible Agency
Physical Environment					
Topography & Slope Stability	S	ST	SS	Minimal leveling required; maintain natural slope; monitor during earthworks	Survey Unit / Civil Engineering Dept.
Land Take and Land Use	M	LT	LA	Ensure land acquisition is documented; engage affected parties if any	School Authority / Land Management Unit
Removal of Obsolete Structures	L	ST	SS	Demolish structures safely; dispose of debris responsibly e.g old generator house	School Authority. / Security Unit
Land Clearing for New Construction	M	ST	LA	Non-existence of forest land; minimal clearance required.	Environmental Desk / School Authority
Air and Noise Pollution	M	ST	LA	Use equipment with emission controls; schedule noisy work during daytime only	Contractor / School Environmental Unit
Solid Waste and Spoil Disposal	M	ST	LA	Develop a waste management plan; reuse spoil material when feasible	Contractor / Facility Management
Biological Environment					
Disturbance to Wildlife	S	ST	SS	Conducted survey; Nil existence of wildlife due to the actively used area	Environmental Unit
Disturbance of Firewood and Timber Access	S	ST	SS	Mark and avoid valuable trees; obtain approval for tree felling	Forestry Commission / Contractor
Socio-economic and Cultural Environment					
Socio-Economic Displacement	L	ST	LA	Relocate affected drivers to a temporary site to restore upon completion.	Community Relations Unit / School Authority

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CONSTRUCTION PHASE

Potential Impact	Magnitude	Duration	Extent	Mitigation Measures	
				Action	Responsible Agency
Physical Environment					
Topography & Slope Stability	S	ST	SS	Monitor earthworks for erosion; install drainage systems as needed	Contractor / Site Engineer
Land Take and Land Use	No Impact	-	-	Not applicable	-
Air Quality and Noise	M	ST	LA	Dust suppression (water spray); restrict noisy activities to daytime	Contractor / HSE Officer
Solid Waste and Spoil Disposal	M	ST	LA	Continue pre-construction waste plan; segregate waste for reuse or recycling	Contractor / Waste Management Services
Biological Environment					
Obstruction to Bird Flight Paths	S	ST	SS	Install warning markers on towers	Environmental Unit / BirdLife
Socio-economic and Cultural Environment					
Pressure on Local Infrastructure	L	MT	LA	Coordinate with local authorities; improve/repair affected infrastructure	Contractor / School Authority.
Health Strain Due to Influx of Workers	L	MT	LA	Provide temporary clinics; health screening of workers	Health Services / Contractor

Fig. 2 Site IEE Report

Fig. 3 An Arial view of the Area using Google Earth

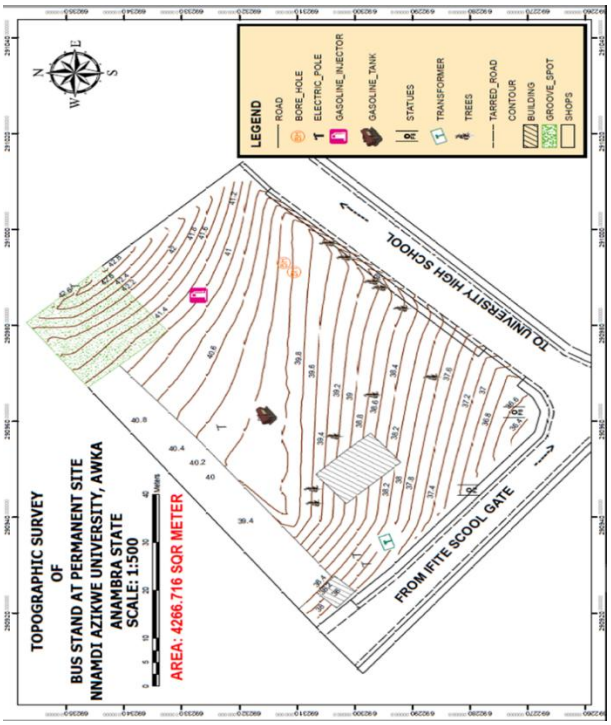


Fig. 4a the map showing Topography of the Unizik-Ifite Multipurpose Car Park

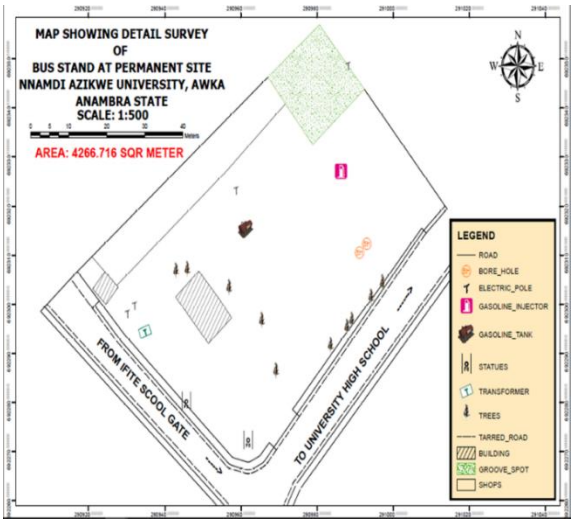


Fig. 4b the map showing existing nature of the Unizik-Ifite Multipurpose Car Park

The plane survey of the proposed site was executed in contract with the survey department of the Nnamdi Azikiwe University, See Figure 4a & 4b.

With the survey completed, the exact nature of the terrain, topography, and area of the proposed site is ascertained. With these, the architectural design and modelling of the site can be initiated (See Fig. 5) and also the geotechnical analysis of the soil sample from three choice position on the site in other to get an average nature of the existing soil.

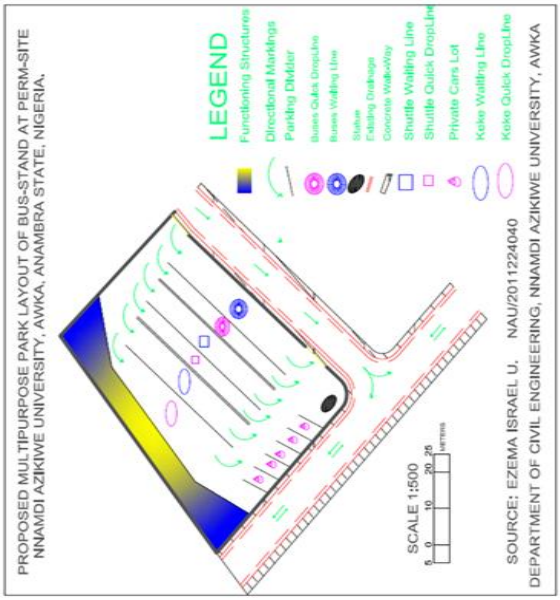


Fig. 5a A model showing the mark-up drive way of the park after pavement construction.

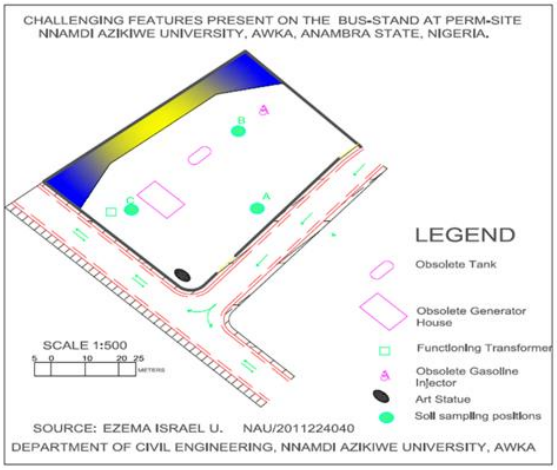


Fig. 5b a model showing the obstacles and soil sampling positions on site

The sampling was gotten from the depth 0.5m and 1m at each sampling positions i.e. at point A, A-top represent soil sample A at 0.5m and

A-bottom represent soil sample at 1m depth, and these was done for all three positions and the test results are as follows; (See Fig. 6)

An example is the sieve Analysis for Sample A-Top

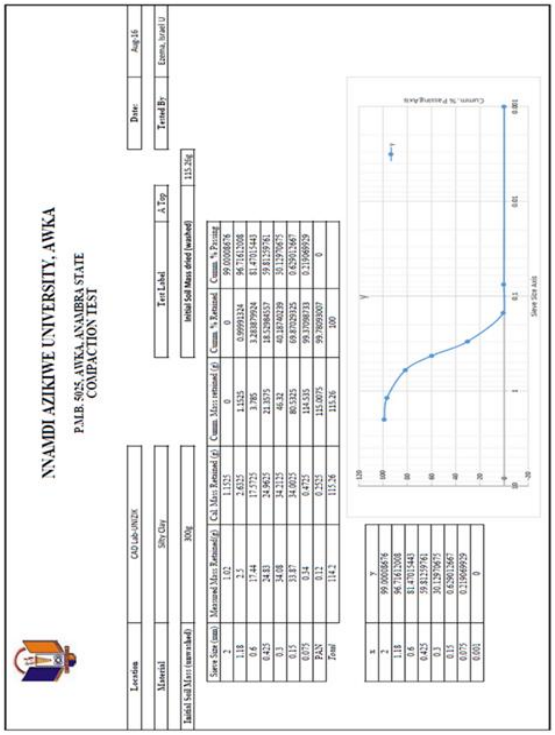


Fig. 6 Sieve Analysis Report for sample A-top

W_T (Total weight of the original dry sample)

= 300g

W_W (Total weight of the washed dry sample)

= 115.26g

Passing No. 40 (0.425 mm) = $\frac{(300-115.26)}{300}$x 100 = 61.58%

The Cu (coefficient of uniformity) = D60 / D10

Cu = 0.425/0.2 = 2.125

Cc the coefficient of curvature = $(D30)^2$ / (D60 X D10)

Cc = 0.32 / (0.425 x 0.2) = 1.058

Cumm. % Retained in sieve No. 200 = 99.3%

Cumm. % Passing in sieve No. 200 = 0.21%

The same test is carried out for A-Bottom, and an average analysis of the soil at position A obtained;

1. Av. Passing No. 40 (0.425 mm) = (55.067+61.76)/2 = 58.4135%

2. Av. Cu = (2.22+2.289)/2 = 2.2545

3. Av. Cc = (0.94+0.95)/2 = 0.945

4. Av Cumm. % Retained in sieve No. 200 = $\frac{99.3\%+\ 99.25\%}{2}$ = 99.275%

5. Av Cumm. % Passing in sieve No. 200 = $\frac{0.21\%+\ 0.49\%}{2}$ = 0.35%

Having determined for all samples the grade of the in-situ soil can now be identified by;

The Mean in-situ soil general gave

Cu = (2.115+2.2105+2.2545)/3 = 2.193

Cc = (1.0454+0.9485+0.945)/3 = 0.9795 ≈ 1

Av Cumm. % Retained in sieve No. 200 = $\frac{99.275\%+98.655\%+\ 98.3695\%}{3}$ = 98.7665%

Av Cumm. % Passing in sieve No. 200 = $\frac{0.35\%+\ 0.7035\%+0.593\%}{3}$ = 0.5488%

Av. Washed off / Passing No. 40 (0.425 mm) = $\frac{61.58\% + 68.097\% + 52.173\% + 56.57\% + 55.067\% + 61.76\%}{6}$

= 59.21%

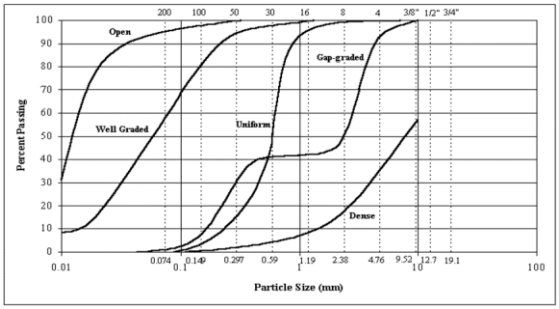
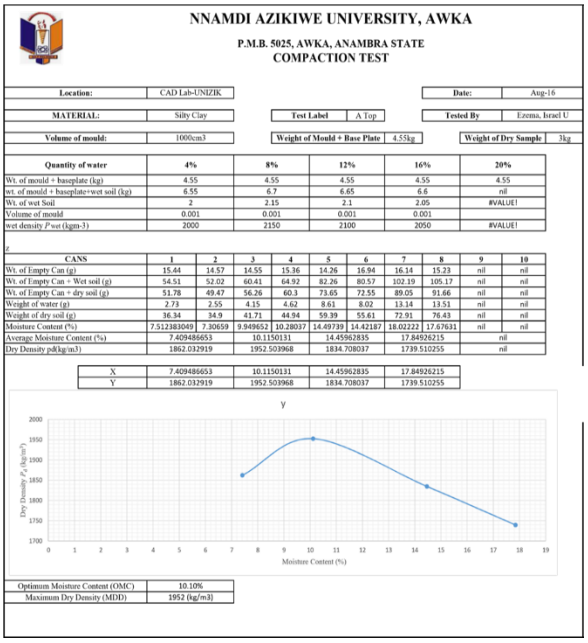


Fig 7 Grading Designations

From figure 7, it shows that the state of the in-situ soil is Uniformly Graded. However classification of Highway subgrade materials by AASHTO [8], from the analysis above having an Average washed off sample/ Passing No. 40 (0.425 mm) of 59.21% and an Average Cumm. % Passing in sieve No. 200 of 0.5488% we can say that the insitu soil contains particles way more than 35% of total sample passing no. 200 which classify it as silt-clay material subgrade and poor as well.

The Compaction Test Result showed; (See Fig. 8)



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COMPACTION TEST

Location:	CAD Lab-UNIZIK			Date:	Aug-16
MATERIAL:	Silty Clay	Test Label	A Top	Tested By	Ezema, Israel U
Volume of mould:	1000cm3	Weight of Mould + Base Plate	4.55kg	Weight of Dry Sample	3kg

Quantity of water	4%	8%	12%	16%	20%
Wt. of mould + baseplate (kg)	4.55	4.55	4.55	4.55	4.55
wt. of mould + baseplate+wet soil (kg)	6.55	6.7	6.65	6.6	nil
Wt. of wet Soil	2	2.15	2.1	2.05	#VALUE!
Volume of mould	0.001	0.001	0.001	0.001	
wet density Pwet (kgm-3)	2000	2150	2100	2050	#VALUE!

z

CANS	1	2	3	4	5	6	7	8	9	10
Wt. of Empty Can (g)	15.44	14.57	14.55	15.36	14.26	16.94	16.14	15.23	nil	nil
Wt. of Empty Can + Wet soil (g)	54.51	52.02	60.41	64.92	82.26	80.57	102.19	105.17	nil	nil
Wt. of Empty Can + dry soil (g)	51.78	49.47	56.26	60.3	73.65	72.55	89.05	91.66	nil	nil
Weight of water (g)	2.73	2.55	4.15	4.62	8.61	8.02	13.14	13.51	nil	nil
Weight of dry soil (g)	36.34	34.9	41.71	44.94	59.39	55.61	72.91	76.43	nil	nil
Moisture Content (%)	7.512383049	7.30659	9.949652	10.28037	14.49739	14.42187	18.02222	17.67631	nil	nil
Average Moisture Content (%)	7.409486653		10.1150131		14.45962835		17.84926215		nil	
Dry Density pdkg/m3)	1862.032919		1952.503968		1834.708037		1739.510255		nil	

X	7.409486653	10.1150131	14.45962835	17.84926215
Y	1862.032919	1952.503968	1834.708037	1739.510255

y

Dry Density P_d (kgm-3)

Moisture Content (%)

Optimum Moisture Content (OMC)	10.10%
Maximum Dry Density (MDD)	1952 (kg/m3)

Fig 8. Compaction Report for sample A-Top

From A Top; the text result shows an OMC of 10.10% at a MDD of 1952 kg/m3

From A Bottom; Has an OMC of 10.1% at a MDD of 1950 kg/m3

From B Top; Has an OMC of 10.70% at a MDD of 1941 kg/m3

From B Bottom; Has an OMC of 10.75% at a MDD of 1945kg/m3

From C Top; Has an OMC of 10.75% at a MDD of 1935kg/m3

From C Bottom; Has an OMC of 10.85% at a MDD of 1940 kg/m3

Having obtained the compaction readings, the individual samples are compacted to their OMC at their relative MDD.

The CBR of the in-situ soil for all three location shows Zero strength which means it is a very poor engineering soil, and is Not-Suitable as a subgrade for the proposed project (See Fig. 9). It should be CUT-TO-SPOIL to a minimum depth of 1.5m i.e. to a depth with soil of reasonable CBR ratio, then apply stone-base and sharp sand with a subsequent lateritic soil (e.g. lateritic soil with a CBR of 60%) as sub-base. However, their thickness still depends on the choice of pavement cover.

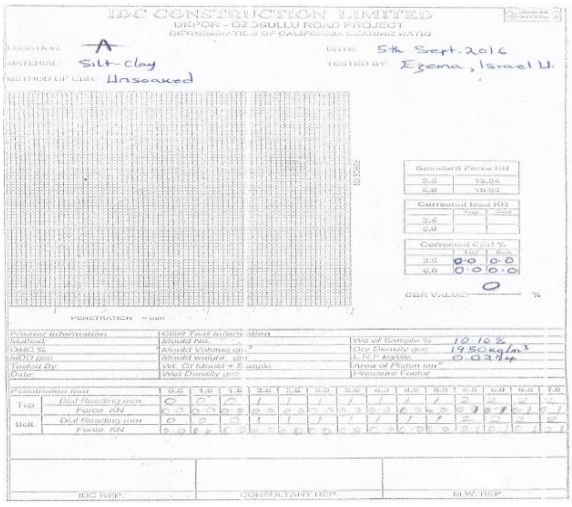

Fig. 9 CBR Report for sample A

With these parameters fully ascertain, we can now go ahead to design each pavement.

E. Rigid Pavement Design

The major design parameters required to choose the pavement cover for a rigid pavement are [2][9];

a) The determination of the loading i.e. by traffic assessment

b) The determination of the thickness of the pavement cover which is based on the type; by this, construction can be carried out. [6-8]

Traffic flow – Average Annual Daily Traffic (AADT); is the average calculated over a year of the number of vehicles passing a point in a given counting section each day (usually expressed in vehicles per day) [6]. Calculation of AADT is generally based on data information resulting from any of the type of counts; Permanent Automatic Traffic Counts and Short-Period Traffic Counts.

These result of the short-period Traffic Count were carried out on the assumed busiest-activity days of a week within the Car Park. I.e. Monday (9th May, 2016), Wednesday (11th May, 2016) and Friday (13th May 2016) and the results obtained is represented and recorded in total AADF with classification and readings shown in the Table 1.

Table 1. Traffic Assessment Result

Commercial Vehicle	CV Category	Mon. 9th AADF	Wend. 11th AADF	Fri. 13th AADF	Average AADF
Bus	PSV	210	189	198	199
Keke	-	1376	1201	1188	1255
Space Shuttle / mini bus	PSV	607	597	592	599
Private Car	PSV	21	18	20	20
Okada/Motorcycle	-	12	11	10	11
2-axle Rigid lorry	OGV 1	6	4	4	5
Total AADF					2088

In accordance to HD24 [7], The factors used to calculate the design Traffic (T) are as follows; Commercial Vehicle Flow at opening (F), Design Period (Y), Growth Factor (G), Wear Factor (W), and Percentage of vehicles in the heaviest loaded lane (P).

Weighted annual traffic = 365 x F x G x W x 10^{-6} msa

Design Traffic (T) = Total weighted annual traffic x Y x P

Which are obtained using the following charts below; (See Fig. 10, 11, & 12)

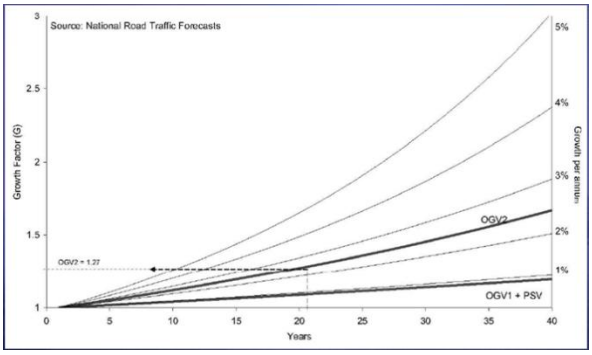

Fig 10 Growth Factor (G) for Future Traffic from the NRTF (1997) (Obtained from HD24/06)[7]

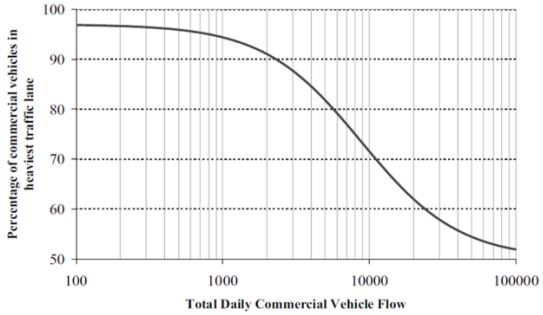

Fig 11. Percentage of Commercial Vehicles in Heaviest Loaded Lane (P) (HD 24/06)[7]

Wear Factors	Maintenance (Wm)	New (Wn)
Buses and coaches	2.6	3.9
2-axle rigid	0.4	0.6
3-axle rigid	2.3	3.4
4-axle rigid	3.0	4.6
3 and 4-axle articulated	1.7	2.5
5-axle articulated	2.9	4.4
6-axle articulated	3.7	5.6
Wear Factors	**Maintenance (Wm)**	**New (Wn)**
OGV 1 + PSV	0.6	1.0
OGV 2	3.0	4.4

Fig 12 Wear Factors for cv Classes and Categories (HD24/06)[7]

And the factors are tabulated and computed thus as;

Table 2. Design Traffic Calculation

Commercial Vehicle class	AADF (F)	Growth Factor (G)	Wear Factor (W)	Weighted Annual Traffic (msa)
PSV Bus and Coaches	818	1.19	3.9	1.38566337
OGV 1 2-axle rigid	5	1.19	0.6	0.00130305
OGV 2	nil	1.67		#VALUE!
Total daily flow (cv/d)	823	Total weighted annual traffic		1.38696642
		Percentage of vehicle in heaviest traffic lane		96%
		Design Period (Y)		40years
		Design Traffic (T)		53.26msa

Design Traffic (T) = 53.26msa for a design period of 40years. (See Tab. 2)

Having obtained the design traffic for the Unizik-Ifite Park, we can now further ascertain the required concrete thickness using figure 13 below

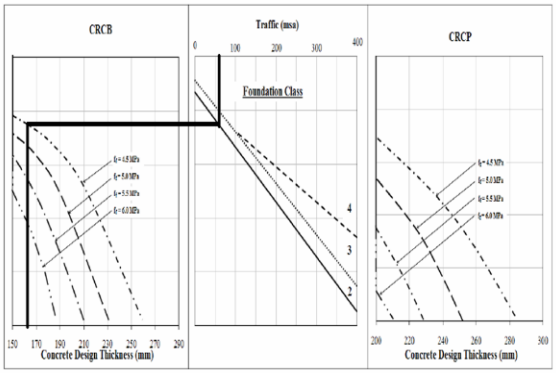

Fig 13. The design thickness for CRCB and CRCP

From the Chart above, it can be seen that the minimum required Concrete thickness for the CRCB construction for an F_f = 4.5Mpa (flexural strength of concrete) is 163mm (0.163m) and 200mm of concrete material for CRCP construction. The concrete thickness in Figure 13 does not include any asphalt surfacing. Minimum allowable asphalt material thickness is 100mm for CRCB construction [10]

The CRCB/CRCP pavement is applied because they are suitable where large or significant differential movement or settlement is expected (in this case, future Precaution), because they can withstand large strains while remaining substantially intact.

Longitudinal crack control steel in CRCB shall be 0.4% of the concrete slab cross-sectional area, comprising 12mm diameter deformed steel bars (T12 reinforcement). Transverse steel must be 12mm diameter deformed bars at 600mm spacings. [10]

Total thickness of CRCB = $\frac{100\ x\ \pi\ x\ D2}{4\ x\ t\ x\ R}$

Where;

t = concrete design thickness (mm)

R = reinforcement (%)

D = diameter of reinforcement bar (mm)

Without asphalt surfacing

T = $\frac{100\ x\ 3.142\ x\ 12x12}{4\ x\ 163\ x\ 0.4}$ = 173.5mm

With asphalt surfacing

t = 100mm + 163mm = 263mm

T = $\frac{100\ x\ 3.142\ x\ 12x12}{4\ x\ 263\ x\ 0.4}$ = 107.5mm

We could further design for Jointed Concrete Pavement;

<u>For an Unreinforced Jointed Concrete Pavement (URC):</u>

$Ln(H_1) = \frac{[Ln(T) - 3.466Ln(Rc) - 0.484LnE + 40.483]}{5.094}$

Where;

T = Design Traffic = 53.26msa

R_c = Mean Compressive cube strength = 30Mpa for concrete mix 1:1:2 [1]

E = Foundation Class Stiffness

= 17.6 x $(CBR)^{0.64}$ (MPa) [10]

In this case CBR = 0, let's assume 0.1

E = 17.6 x $(0.1)^{0.64}$ = 4.03Mpa

$Ln(H_1) = \frac{[Ln(53.26) - 3.466Ln(30Mpa) - 0.484Ln(4.03Mpa) + 40.483]}{5.094}$ Ln (H_1) = 6.2809

$H_1 = e^{6.2809} = 534.28mm = 534mm = 0.534m$

Where;

H_1 = is the thickness (mm) of the concrete slab without a tied shoulder or 1m edge strip

H_2= is the thickness (mm) of the concrete slab with a tied shoulder or 1m edge strip

$H_2 = 0.934\ H_1 - 12.5$

$H_2 = 0.934(534.28) - 12.5 = 486.52mm$

For a Reinforced jointed concrete pavement (JRC):

$Ln(H_1) =$

$$\frac{[Ln(T) - R - 3.171Ln(Rc) - 0.326LnE + 45.150]}{4.786}$$

Where;

T = Design Traffic = 53.26msa

R=providing $800mm^2/m$ reinforcement = 9.479

R_c = Mean Compressive cube strength = 30Mpa

E = Foundation Class Stiffness = 4.03MPa

$$Ln(H_1) = \frac{[Ln(53.26) - 9.479 - 3.171Ln(30) - 0.326Ln(4.03) + 45.150]}{4.786}$$

$H_1 = e^{5.755789} = 316.01mm = 316mm = 0.316m$

$H_2 = 0.934(316.01) - 12.5 = 282.65mm$

On normal bases, the Sub-base thickness is obtained from the chat below; (See Fig. 14)

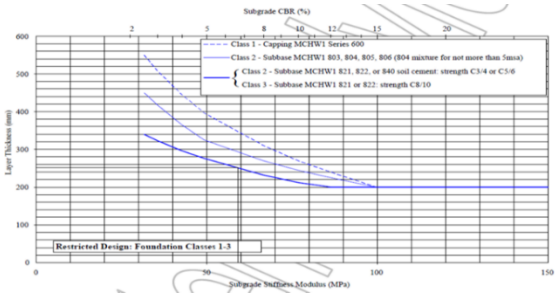

Fig 14 Chart for Subbase determination [10]

Our Sub-grade's CBR is way below 2% (i.e. 0% CBR) and from the chart, the layer thickness cannot be taken.

As said earlier on that having CUT TO SPOIL the in-situ soil to depth of about 1.5-2m and having it replaced with stone-base and sharp sand to about 0.5m and then with lateritic soil of about 1m thickness. The total Rigid Pavement Thickness Design is thus the summation of both the sub-base thickness and Concrete thickness provided.

Please it should be noted that Construction Joints should be provided for every (1.2 x 1.2) metre slab of concrete and according to Specification for Road Works, volume 1 Series 1000, At least two transverse joints and one longitudinal joint of each type that are proposed for unreinforced concrete slabs

F. Interlocking Pavement design

Based on the design philosophy by B. shackle [3], the design steps followed include;

i. The identification of the relevant design parameters.

ii. The selection of suitable performance criteria.

iii. The inter-relation of performance criteria and design parameters.

iv. Applying a design methodology based on the relationship of performance to design parameters.

However, the role of mechanistic analysis needs to be understood for proper block pavement design (CBR/thickness Relationships) and it is employed to examine the manner in which base-course thickness should be varied in a block pavement in order to achieve a constant level of performance in terms of:

(a) Elastic deflection.

(b) Rutting deformation.

On the other hand, one of the relevant design parameter is the CBR value of the soil sample present at the Car Park. The use of suitable base materials for this form of construction are expensive. Consequently, it is economically inadvisable to use this form of construction where the subgrade CBRs are low and therefore require substantial pavement thicknesses. For this reason, it was then decided to revise the design method to cover three types of pavement structure.

The structures and the recommended range of subgrade CBR for which each is thought to be most economical is as follows:

a) Granular base on subgrade (CBR > 30 %).

b) Granular base on cement-stabilized sub-base (CBR < 30 %).

c) Cement-stabilized base and subbase (CBR < 10 %). (B. Shackel)

Haven determined the CBR of the in-situ soil as below 10%, the Interlocking Pavement will be designed with Cement-Stabilized Base and Subbase (i.e. option C). Here the elastic deflection of the pavement provides the principal criterion of performance. As discussed earlier in chapter 3, the elastic deflections of block pavements with granular bases appears to be a little affected by either the load magnitude or number of load repetitions. The relationship between basecourse thickness and paving block thickness for specified levels of elastic or resilient deflection is shown in Figure 15. [3]

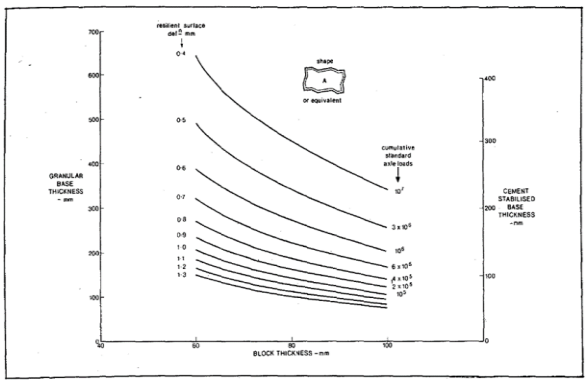

Fig 15. Base thickness as a function of block thickness and resilient deflection

From the chart above, considering block thickness 60mm, the in-situ subgrade due to its very poor CBR should be CUT TO SPOIL to a depth of 270mm (60mm + 50mm + 100mm + 60mm) basically to bring the section shown below to equal elevation such that the blocks equal the park ground-level, then provide a layer of geotextile DPM and have the excavated section replaced by a cement treated base to a depth of 60mm, a granular Base Thickness of 150mm (i.e. granular base and sand) see figure 16 below

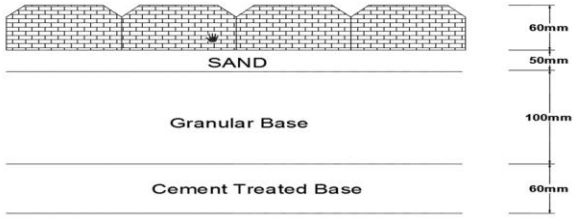

Fig 16. Section of the interlocking pavement.

G. Economic Analysis of the Pavement Types

It is expedient that we select not just a durable and atheistic pavement cover but to select that which is more economically.

Analysis of the Rigid Pavement

Concrete is a combination of cement, sand and gravel and the concrete mix that will adopted for this analysis is 1:1:2 with a mean compressive cube strength of 30Mpa. A measurement of 1.2 x 1.2 metre area will be used per slab.

The standard density of 1 cement = 1440kg/m^3 [21]

Specific Gravity Gs = $\frac{\text{Density of substance}}{\text{density of water}}$

Specific gravity of sand = 2.6

Density of water = 1000kg/m^3

Density of Sand = 2.6 x 1000 = 2600kg/m^3

Normal weight concrete unit weight = 150lbs/ft^3 = 2400kg/m^3

Prof. Kamran M. Nemati; [17]

Volume occupied by Cement = M/p

= $\frac{50\text{kg}}{1440\text{kg/m3}}$ = 0.0347m^3

Volume occupied by Sand per 50kg

= $\frac{50}{2600\text{kg/m3}}$ = 0.0192m^3

Volume occupied by Gravel per 50kg

= $\frac{50}{2400\text{ kg/m3}}$ = 0.02083m^3

Water to Cement ratio ($\frac{W}{C}$) = (0.5 to 0.7) = 0.6

Volume occupied by Water = Vol. of Cement x 0.6 = 0.0347 x 0.6 = 0.02082m^3

Total Vol. occupied by one 1:1:2 mix =

0.0347 + 0.0192 + (2 x 0.02083) + 0.02082m^3 = 0.11638m^3

Park Area = 4266.716 m2 (see survey map)

Total no. of slabs = $\frac{Site\ total\ Area}{Area\ of\ one\ slab}$ = $\frac{4266.716}{1.2\ x\ 1.2}$ = 2962.997 = 2963slabs

One slab volume = (1.2 x 1.2m) x thickness of slab

We can go ahead to quantify our materials required

For CRCB (Continuous reinforced concrete base)

Provided a thickness of = 168mm (see cal. above)

One slab volume = (1.2 x 1.2m) x 0.168m = 0.24192m^3

No. 1:1:2mix required for one slab = $\frac{one\ slab\ vol.}{Total\ vol.\ occupied\ by\ 1:1:2}$ = $\frac{0.24192}{0.11638}$ = 2.1mix

a) Amount of cement = 2.1bags

b) Amt. Of sand = (276head-pans =1trip & 50kg = 2 head-pans) = 0.5trip x 2.1= 1.05trips

c) Amt. of gravel = 1trip x 2.1 = 2.1trips

In the case of steel reinforcement provided;

Longitudinal crack control steel in CRCB = 0.4% concrete slab cross-sectional area, comprising 12mm diameter deformed steel bars.

= $\frac{0.4}{100}$ x (1.2 x 1.2) = 0.00576m of T12 deformed steel bars per slab at length 1.2m

= 0.00576m x 2963slabs x 12m = 204.8m T12 deformed steel

Transverse steel must be 12mm diameter deformed bars at 600mm spacings.

= $\frac{1.2m}{600mm}$ = 2 by 1.2m Y12 steel required per slab

= 2 x 1.2m x 2963slabs = 7111.2m of R12

We could also check for URC and JRC. And it is observed from that CRCB proves to be more economical amongst the rigid pavement design in this case of poor CBR subgrade.

Analysis for the Modern-interlock

It is observed that a granular base and sand surface treatment of each thickness 1inch (0.275mm) covering about 100m^2 will require 2 trips of each. Of course this is greatly affected by the nature of the underlying foundation. These estimate was drawn out on an actual installation of the modern-interlocking pavement cover project carried out at the parking-lot in front of the Psychology Department of the Nnamdi Azikiwe University.

For Sand base = provided 50mm thickness,

= $50mm\ x\ 2trips/0.275mm$ = 365.6 trips per 100m^2

For Granular Base = provided 350mm thickness = $100x2/0.275$ = 731.2 trips per 100m^2

For the Cement treated Base = provided 60mm

= $60\ x\ 2/0.275$ = 436.4 trips of cement treated base

The blocks are sold per square metre = 4266.716 m^2 of 60mm thick blocks

For DPM (a black nylon or tarpaulin) [22]

= provide Wickes Damp Proof Course 225mm x 30m at £10.99 each

[22]

Quantity of Sand required = $\frac{4266.716\ m2\ x\ 365.6trips}{100m2}$ = 15599.1137trips

Quantity of granular base required = $\frac{4266.716\ m2\ x\ 731.2trips}{100m2}$ = 31198.23trips

Quantity of DPM required = $\frac{4266.716\ m2}{0.225m\ x\ 30m}$ = 632 roles

For cement treated base,

Quantity of cement required thus

1trip = 276headpans = 276 x 25kg per head-pan = 6900kg

And a bag of cement = 50kg

Therefore 25% = $\frac{25}{100}$ x 436.4 trips x $\frac{6900kg}{50kg}$ = 15055.8 bags of cement

Quantity of laterite required = $\frac{75}{100}$ x 436.4 trips = 327.3trips

Total quantity of laterite required = 31198.23trips + 327.3trips = 31525.23trips

VI. CONCLUSION AND RECOMMENDATION

This study was primarily aimed at developing and designing a multipurpose park using rigid pavement and modern-interlocking pavement methods using Unizik-Ifite as a case study. In the quest to achieve this aim, interest has cut across basic EIA reporting, Land Survey, Geotechnical investigation of the ground condition of the soil sample at the site that will support the pavement, Architectural modelling and Marking, and down to the focused design pavements.

The analysis of the data collected from actual testing and field investigation of the test site can now help to ascertain the type of Pavement Cover to be selected.

The knowledge of what is required of each pavement type basically sums up the choice of what pavement is most economical.

Table 3. Bill of Engineering Measurement and Evaluation for CRCB Construction.

NNAMDI AZIKIWE UNIVERSITY, AWKA
P.M.B 5025, AWKA, ANAMBRA STATE
DEPARTMENT OF CIVIL ENGINEERING
BILL OF ENGINEERING MEASUREMENT AND EVALUATION

PREPA RED BY	Ezema, Israel U	Project Duration	12months	DATE	Au g-16

S/N	DESCRIPTION	UNIT	QUANTITY	RATE	AMOUNT (N)
1	Pre-Construction Works	Bulldose Generator house		N75,000/half day	75,000
		Removing the Tank & Pump		N20,000/day	20,000
		Clearing Site		N5000	5,000
		Cutting Down Trees		N5,000	5,000
2	Construction	Cut To Spoil of In-situ Soil	4266.716 m2	N150,000/day for 7 days	1,050,000
		Lateritic Soil for refill	315252.3trips for depth 1.5m	12,000/trip	3,783,027,600
		Grading machine for compaction		100,000/day for 7days	700,000
		T12 longitudinal Crack control Steel	204.8m	N1,400/12m (39ft)	3,440,640
		R12 Transverse steel	7111.2m	N1,400/12m	829,640
		Dangote Cement	6222.3bags	N2200/bag	13,689,060
		Gravel	7407.5trips	N20,000/trip	148,150,000
		Sand	3703.75trips	N13,000/trip	48,148,750
		water	119.55 m3	N2500/trip	298,875
3	Labour	Men-Work	8men/7days	N5000each	280,000
		Project Miscellaneous			100,000
	Total				3,999,119,565

Table 4. Bill of Engineering Measurement and Evaluation for the block pavement Construction

NNAMDI AZIKIWE UNIVERSITY, AWKA
P.M.B 5025, AWKA, ANAMBRA STATE
DEPARTMENT OF CIVIL ENGINEERING
BILL OF ENGINEERING MEASUREMENT AND EVALUATION

PREPA RED BY	Ezema, Israel U	Project Duration	12months	DATE	Au g-16

S/N	DESCRIPTION	UNIT	QUANTITY	RATE	AMOUNT (N)
1	Pre-Construction Works	Bulldose Generator house		N75,000/half day	75,000
		Removing the Tank & Pump		N20,000/day	20,000
		Clearing Site		N5000	5,000
		Cutting Down Trees		N5,000	5,000
2	Construction	Cut To Spoil of In-situ Soil	4266.716 m2	N150,000/day for 3days	450,000
		Lateritic Soil	31525.23trips	12,000/trip	378,302,760
		Grading machine for compaction		100,000/day for 2days	200,000
		sand required	15599.1137trips	N15,000	233,986,706
		DPM	632roles	£10.99 @N550 per £1 / role	3,820,124
		Dangote Cement	15055.8bags	N2200/bag	33,122,760
		block pavement	4266.716 m2	N1,600per SqrMetre	6,826,746
3	Labour	Men-Work	8men/7days	N5000each	280,000
		Project Miscellaneous			100,000
	Total				657,194,095

The knowledge of what is required of each pavement type basically sums up the choice of what pavement is most economical and from the BEME shown in Table 3&4, and it's obvious that for this form of construction where the subgrade CBRs is low and therefore require substantial pavement thicknesses that the modern-interlocking pavement will serve the best option both in terms of cost and durability in comparison with the CRCB pavement type which having to be more economical compared to the other type of rigid pavement. Reference [19] agrees.

It is recommended that the in-situ soil present at the Unizik-Ifite Park should be treated with great concern and whatever pavement that will constructed should be designed not to allow seepage of water into the underlying foundation let alone allowing waterlogging on the surface. It is also recommended that proper

marking and lighting of the park area based on the architectural model designed.

ACKNOWLEDGMENT

I sincerely appreciate the support and guidance I received throughout the course of this work. My gratitude goes to the Department of Civil Engineering, Nnamdi Azikiwe University, for providing the enabling environment and access to laboratory facilities used in conducting the necessary analyses and tests.

Special thanks also go to my supervisors and lecturers whose constructive feedback and insights were instrumental in shaping the direction of this research. I am equally grateful to the staff and colleagues from the Environmental Department involved in the surveying and environmental assessment stages, as well as those who assisted with data collection and site analysis.

This project would not have been successful without the encouragement of my Family, friends, and colleagues who offered their time, suggestions, and moral support. I remain deeply appreciative of every contribution that made this work possible.

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