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Quantification of Earth Material for Sustainable Road Works in Southeast Nigeria

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Abstract: This paper examines the use of earth materials in sustainable road construction in South East, Nigeria. The study aims to determine factors associated with the use of earth materials, identify limiting factors, and examine strategies to improve their use. The study population comprised 60 engineers and craftsmen using local materials. The results show limitations in the use of earth materials in sustainable road works. The study recommends contracting firms to develop better storage facilities for earth materials to prevent damage and wastage. It also suggests incorporating earth materials into construction education curriculums to sensitize students to their potential benefits. The government should adopt a policy of adapting earth materials that require minimal capital and foreign exchange and utilizing available raw materials and skills in small-scale operations. The study's findings highlight the importance of sustainable road construction in Nigeria's socio-economic growth.

Keywords: Earth Materials, Development, Local Materials, Road Construction, Sustainability.

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1. Introduction

Roads are very important in tapping resources and connecting people, places and businesses together. According to [1] Nigeria has the largest road network in West Africa with about 200,000km of surfaced roads. It is only about 28,980km that were paved and 179,220km unpaved by the Federal Ministry of Works Bulletin [2]. Road construction has an important impact on the economic development of any Nation, therefore it cannot be evaded. However, road construction projects are acknowledged to have impacts on buildings within the area of construction. The construction of roads influences human activities and behaviour both positively and negatively [3]. For the positive influence, road construction facilitates traffic flow, human mobility, and the movement of products and services, while negative, implications include taking up valuable areas and distorting the ecosystem functions [4]. Its negative consequences on groundwater and river flow cannot be over-emphasized. Because road construction has such a large environmental impact, it must be done with caution. According to [5], there are notably, three high-profile negative effects of road construction such as noise, dust and vibrations. There are also many benefits of road construction, even though the benefits are more economic and social rather than environmental. According to [6], roads are used to enhance the provision of public services and other security services. Also, roads are necessary for the development of market areas, which further improves the economy of the nation, Nigeria.

Good roads, drinking water, electricity, security and good maintenance practices must be captured in the sustainable development plan of every nation [6][7][8][9]. Every economy needs good roads to thrive. Roads are directly proportional to the socio-economic development and gross domestic product of the country and should be maximized [4]. One of the ways to enhance the sustainability of a country is to take past and new detailed engineering geological records of soils to generate engineering geological maps of different regions in Nigeria for characterization [10][11]. This will perfectly assist in the construction of new roads and the reconstruction of old roads. Most of the federal and state roads have experienced all kinds of failures ranging from technical to maintenance and structural [12]. Access to major roads provides relative advantages consequent upon which users locate to enjoy the advantages. Modern businesses, industries, trades and general activities depend on transport and transport infrastructure, with the movement of goods and services from place to place becoming vital and inseparable aspects of global and urban economic survival [13]. The researcher in [14] suggested that sustainable road works can be constructed locally to minimize cost and these local materials are extracted from the earth's substance.

United Nations Development Programme (UNDP) opined that road construction and sustainable human development are closely linked together since roads can either enhance or degrade human development. The researcher in [14] identified the availability of earth materials as one principal factor affecting the effective performance of Nigeria's construction industry. The problem of providing affordable road works has long been a concern not only to individuals but also to the government. A decent and palatable road is the basis of the possibility for obtained safety of life, as well as other basic needs such as privacy, health and social integration. Local earth material (Laterite, granite, etc.) are available everywhere and exists in different compositions, especially in South East, Nigeria.

The raw earth is a material used ages as a building material; earth architecture has many benefits not only on technical terms but also on economies and environmental factors. Earth is readily available and accessible on-site requiring no transformation; it is the simplest natural material we have at our disposal, used by man in construction, with sustainability and techniques that are living testimony to history, cultures and identity [15]. According to [16], earthen architecture is one of the oldest forms of construction. It is composed of structures made from unfired earthen materials, including adobe (laterite or sun-dried mud brick), rammed earth and a host of other earthen components. The traditional earth material is evidenced all over the world, in many parts of Africa, Asia and South America, earth remains a prevalent construction material [17]. The energy expended in the manufacture of materials, transportation and construction of roads is estimated to equal the energy necessary to heat, light and ventilate or condition the road between five and ten years [18]. Researcher in [19], substantiates further that, sustainability favours the retention of existing earth material stock. Improving and maximising the use of existing earth material is the cheapest and lowest-impact sustainability solution to the provision of sustainable road works in South East, Nigeria.

Each layer of pavement needs to be stabilized or improved in order to withstand repeated or cyclic traffic loads that tremendously increase day by day. The pavement system must be able to withstand

and absorb the stress that is produced from repeated traffic loads. Researchers have found that repeated traffic loading can cause the fine particles from the subgrade layer to migrate into the subbase layer, leading to road settlement and the reason for the bumpy road. The characteristic of existing soil at the construction site is not always totally suitable for supporting structures, especially when dealing with soft soil such as peat soil, clay soil and sandy soil layer [20]. Such soils are problematic soil, with high moisture content, low bearing capacity, low shear strength, and high compressibility and its characteristics are highly dependent on the environment [11]. In the past few years, the construction activities under this kind of soil recorded a lot of geotechnical issues such as unsatisfactory bearing capacity, extra post-construction settlement and instability. The researcher in [21] claimed that the settlement of roads was deflected from the construction of roads on the soft soil. The authors in [22][23] also found that the road settlement failure was due to the construction of peaty soil. Figure 2 shows an example of road failure on the peaty soil. Particularly, soft soil is not preferred as a foundation soil due to its limited geotechnical properties. However, the geotechnical proper-ties of the subgrade soil can be stabilized or improved by using various methods such as preloading, sand or stone column, pre-fabricated vertical drains, piles, fiber-reinforced and chemical stabilization.

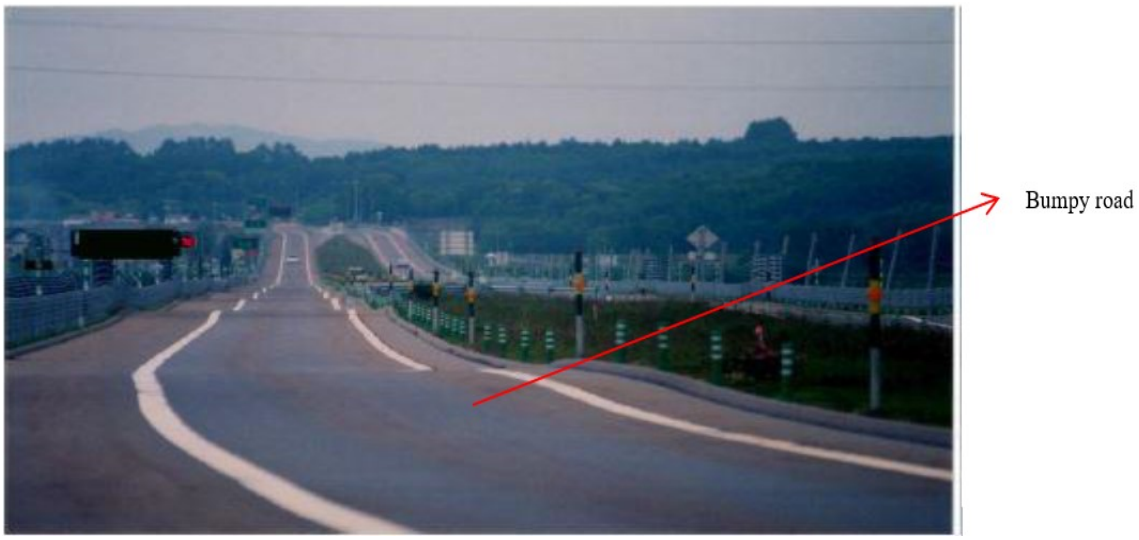

Figure 1. The road settlement failure due to the construction on peaty soil [22]

The use of locally available and indigenous earth materials has several advantages in terms of sustainability of road works in Nigeria [24]. They are Reduction of energy costs related to transportation. Reduction of material costs due to reduced transportation costs, especially for well-established industries. The earth mixture is poured into a hand-operated or motorised hydraulic made, compressed earth bricks are uniform in size and shape. Nowadays, improved technology induced people to use CEB as alternatives for earth laterite and bricks in road construction because they do not require much cement for bonding, during construction thereby further reducing the construction cost and their mechanical cost, with a view to ascertaining which is more applicable in road construction. It is on this basis that this study aims to determine the quantification of earth material for sustainable road works in South East, Nigeria.

Good road networks are vital to the socio-economic growth of any nation, especially a developing country like Nigeria. The government at all levels in Nigeria is presently embarking on road construction to provide networks of good roads to facilitate the transport of goods and services. However, many highways and roads particularly the Enugu-Portharcourt express road in South East Nigeria are considered unsafe for vehicular movement because of their attendant pavement failures arising from the development of potholes and all sorts of failing characteristics in the early life of the road between two to three years. Some of the major factors generally responsible for pavement failure in southeastern Nigeria include; the use of sub-standard materials for construction, and applications of temperate region specifications on tropical regional roads [25] [11]. Road transport is a critical

infrastructure for sustainable development as its efficiency is related to consumption, distribution and production [26]. According to the National Planning Commission 2018, the structure of road maintenance and management is among the three tiers of government viz: Federal, State and Local Government. Regrettably, local governments that used to be responsible for arterial routes and Trunk C roads' have since failed to perform their responsibility perhaps as they are now taking orders from State governments. The reason for this is because the subservience of Local governments under the State connotes they do not have autonomy. Nigerian road transport is one of the overstressed modes of transport infrastructures in Nigeria and this is partly due to inadequate and inefficient services of other complementing modes of transport services. Transportation of goods and passengers is the major activity done on the Enugu-Portharcourt express road. More than 90% of the people coming from the north and west are involved in the road which makes it so busy. Roads linking with the major express road are not graded and have no drainage. These roads become worse during the rainy season which resorted to the use of earth materials such as laterites and granite to construct the road to a motorable extent.

The Federal Road Maintenance Agency (FERMA) was established to monitor and rehabilitate federal roads in Nigeria but, they lack the funding, equipment, innovation and motivation to execute their jobs. The researcher in [27], said that postponing maintenance or construction costs increases both direct and indirect costs. If a defect on the road is noticed and neglected; the entire section of the road may fail completely and require re-construction at three times or more of the initial cost. The researcher in [28], explained that repair cost for road construction rises to six times the maintenance cost when you neglect road maintenance for three years and eighteen times after five years of neglect. Scientists observed that the damage to Nigerian roads always starts from cracking, and potholes either by the edge of the road or at the center. Sustainable development according to [29], is connected with long-term food security, energy generation, human settlement, climate change, health system, transport system and other infrastructures. There is an expected level of road transport development which has not been realized for the sustainable social, political and economic development of south-western Nigeria. The researcher in [30], expressed that the performance of Nigerian roads is yet to be satisfactory in spite of several efforts to make it so. This current paper presents the result of the quantification of earth material for sustainable road works in South East, Nigeria. This research work aims to examine the quantification of earth material for sustainable road works in South East, Nigeria. It will determine the factors associated with the use of earth materials for sustainable road works in South East, Nigeria and also find out the factors limiting the use of earth materials in the construction of sustainable road works in South East, Nigeria. This research will finally, examine the strategies that will improve the use of earth materials in the construction of sustainable road works in South East, Nigeria.

2. Literature Review

2.1. Road Maintenance

Road maintenance can be described as the necessary action taken to repair, construct or upgrade roads in order to prevent damage to enhance smooth driving and negative consequences like accidents, pollution, tear and wear of vehicles. Road maintenance involves activities like keeping the pavement, shoulders, drainage facilities, slopes and other structures [31]. The causes of road degradation like the action of traffic, ingress of water, oxidation process, inadequacies in design, specifications and construction standards and lack of adequate support from lower layers. Bleeding, cracking, deformation and disintegration are the signs of road construction problems. The major issue in Nigeria is that there are good plans and procedures on papers for road construction and maintenance but to adhere, enforce and implement are serious concerns. Decisions to be made both in design and operations in traffic engineering require expertise and knowledge in information technology, research methodology and analyses, modelling, and simulations so as to improve traffic flow and safety with support from enforcement and education. Road transport is a critical infrastructure for economic health as it untold hardship condition of people with congestion, delay, the cost of movement and accessibility. According to the National Planning Commission 2018, the structure of road maintenance and management is among the three tiers of government viz: Federal, State and Local Government. Regrettably, local governments that used to be responsible for arterial routes and Trunk C roads' have since failed to perform their responsibility perhaps as they are now taking orders from State governments. The author [32], noted that the Federal Road Maintenance Agency (FERMA) was established to monitor and rehabilitate federal roads in Nigeria but, they lack the funding, equipment,

innovation and motivation to execute their jobs. Virtually all processes of road construction used to pass through a series of approvals for the allocation of funding and other statutory and not statutory procedures to pay contractors. He further noted that FERMA only exists and is known by those who created it and those who are not doing anything regarding themselves as staff of the agency [32]. Almost all the states in Nigeria fashioned in line with the formation of FEMA's similar agencies yet; the roads are still not properly managed. The researcher [33], observed that the damage to Nigerian roads always starts from cracking, and potholes either at the edge of the road or at the centre.

2.2. Earth Consideration as Sustainable Construction Material

Earth construction is one of the most interesting low environmental impact materials. It encompasses a wide range of materials and techniques, stemming out of strong historical tradition. Earth construction exhibits good environmental characteristics and could make a significant contribution to the improved sustainability of construction and it has a high potential for making earth buildings of high quality and durable. However, earth in its fullest sense is presently widely used in construction, as primary construction materials such as sand and bricks. In many forms of earth construction, there is potential for on-site or near-site sourcing of adequate earth materials. This reduces to a minimum of about 1 percent of the energy required by the commonly used cement-based alternatives [34]. In the production of earth materials there are no wastes or by-products, any defective product can be recycled and re-used. Where other materials are mixed with earth, these are generally the waste products of other industrial or agricultural processes. Earth materials create minimal pollution from the selection of material stage all through the production cycle and construction process, earth materials require a very low level of processing and create very little polluting waste. It is important to note that at the end of a good building life span the materials can easily be re-cycled or returned to the ground.

Earth as a constructional material has inherently good environmental characteristics and can improve the sustainability of construction. The surviving earth structures in Nigeria most especially the Oba's palaces, exhibit appropriate use of local material, which has resulted in diverse and distinct cultural patterns. The maintenance of this cultural diversity and local knowledge is central to effective sustainable development. Previous work by [35], asserts that earth materials are environmentally friendly; and that the dense form of earth construction has high thermal mass and is able to store heat and thereby release it slowly to balance the indoor climate. Furthermore, in many forms of earth construction, there is the ability for on-site or near-site sourcing of materials. This reduces to the barest minimum the energy used in material production.

The production and construction process of the earth materials comes with little or no material wastage or by-products. The researcher in [35], further opined that earth materials are cost-effective and available. Earth employed in the building has an appreciable strength in compression, but it is weak in tensile strength especially when damp. When the earth is used as a load-bearing material, forces must be transmitted within the thickness of the earth's structure to the ground. The author in [37], further restated that the compressive strength of the earth can be increased by compaction, which of course raises the density of the structure. The study further asserted the durability properties of the materials. Earth materials have also been proven according to German building standards, that earth with a high straw content is not combustible if the density is higher than 1700kg/m3. Light earth fibre mixes are fire-resistant and can be enhanced with the use of earth.

2.3. The Construction Industry in Nigeria

According to [38] construction activities in the context of the Nigerian economy cannot be treated with a wave of hand. They claimed that the construction industry contributes between 3 and 6% of the gross development product (GDP) in developing countries and records from the Federal Office of Statistics specifically ascertain that the contribution of the construction industry to Nigeria's gross development product (GDP) has hovered around 2% for the past 15 years and this accounts for about 69% of the Nation's Gross Fixed Capital Formation. The researcher in [39] emphasized that the cost of material alone in the building construction project is 55% to 65%. To reduce the cost of construction projects, optimum material control on site should be therefore adopted. Construction waste is a growing problem in many countries [38]. The construction industry in particular and the built environment in general has been found to be among the main consumers of resources and energy. Moreover, the construction sector is reported to be generating unacceptable levels of material and manpower waste. Generally, construction activities which produce wastage can be grouped into

off-site and on-site operational activities [40]. Off-site activities include prefabrication, project design (architectural, structural, mechanical and electrical design), and manufacturing and transporting of materials and components. On-site construction activities relate to the construction of a physical facility which consists of the substructure and superstructure of the building. Some degrees of waste materials are inevitable in the construction process. All estimators allow wastage factors in pricing a bill of quantities. Over the years, experience has shown, however, that unless site management control is tight, wastage can frequently exceed, often by a large margin, the figure allowed in the tender document [38].

3. Methodology

The research design used was a descriptive survey design. According to [41], survey research design refers to the logical structure of an inquiry. So observational and survey methods are frequently used to collect descriptive data. This method was successfully used by [42] in a similar research work. This study was conducted in Southeast, Nigeria, focusing on the Enugu-Portharcourt express road. The population of the study was sixty (60) respondents made up of 40 engineers and (20) craftsmen who are specialists in local materials in the study area. Since the population is manageable, there was no need for sampling. The instrument for data collection was a structured questionnaire. It consisted of two parts (Part A and B); Part A indicate the Bio-data of the respondents and Part B is divided into three sections A, B and C. All items are to be responded to by indicating the appropriate perception using a four-point rating scale. Strongly agree = 4 points (SA), Agree (A) = 3 points, Disagree (D) = 2 points Strongly Disagree (SD) = 1 point. Sixty (60) copies of the questionnaire were distributed and all were retrieved. The data collected were analyzed using means and standard deviation. The items mean (x) and criterion mean (2.50) were computed and utilized to measure the level of agreement and or disagreement. The decision adopted was that if item mean (x) is equal to or more than the criterion mean (2.50), the adoption is positively rated (Agree); but if otherwise, the adoption is negatively rated (Disagree).

This section deals with the description of the characteristics of all the respondents (60) involved in the study by randomly selecting respondents from the study area. The characteristics of respondents include age, sex and marital status.

Table 1. Age, Sex and Marital Status Composition of the Respondents

Variable Name	Categories	Frequencies	Percentages	Respondents	%
Age	30-35 Years	18	30%		
	36-45Years	30	50%	60	100
	46-55Years	12	20%		
Sex	Male	54	90%		
	Female	6	10%	60	100
Marital Status	Single	21	35%		
	Married	39	65%	60	100
	Divorced	0	0%		

Table 1 shows the age, sex and marital distributions of the respondents. The result indicates that 18(30%) of the respondents are in the age bracket of 30-35 years, while 30(50%) are in the age bracket of 36-45 years and 12(20%) of the respondents are into the age bracket of 46-55 years. Also, from the table and chart, 54(90%) of the respondents were male, while 6(10%) were female. The result equally shows that 21(35%) of the respondents were single, 39(65%) of the respondents were married and none of the respondents were divorced. This implies majority of the respondents were male and were married and fell into the age category of 36-45 years.

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Data in Table 2 shows the mean responses on the factors associated with the use of earth materials for sustainable road works in South East, Nigeria. All the items had mean ratings above 2.50. The grand mean rating was 2.53 which was also above the criterion mean. This signifies that all the respondents agreed with the factors associated with the use of earth materials for sustainable road works in South East, Nigeria.

Table 2. The Factors Associated with the Use of Earth Materials for Sustainable Road Works in South East, Nigeria

S/N	ITEMS	SA (4)	A (3)	D (2)	SD (1)	∑FX	$\bar{X}$	SD	Decision Rule
1	Earth materials are not used for road construction in the South East because of low levels of commercialization.	27	16	10	7	183	3.05	1.05	Agreed
2	Earth materials are not used for road construction in the southeast because of poor engineering design	16	19	14	11	160	2.67	1.07	Agreed
3	Earth materials are used for road construction in the South East because they are largely available in our locality	27	15	6	12	177	2.95	1.17	Agreed
4	Earth materials are not used due to poor inspection of roads by the road inspection agency in South East, Nigeria	19	22	12	7	173	2.88	0.99	Agreed
5	Earth materials are not used because of low patronage of earth materials for sustainable road works in South East, Nigeria.	25	18	12	5	183	3.05	0.98	Agreed
6	Earth materials are not used due to the Government's lukewarm attitude towards the use of local materials for sustainable road works in South East, Nigeria	16	25	9	10	167	2.78	1.03	Agreed
7	Earth materials are used because they are easily worked upon and available in abundance using simple tools for sustainable road works in South East, Nigeria.	25	21	10	4	187	3.12	0.92	Agreed
	Grand mean						**2.53**		

Data in Table 3 shows the mean responses of the factors limiting the use of earth materials in the construction of sustainable road works in South East, Nigeria. All the items had mean ratings above 2.50 except item 7 which had a 2.12 mean score. The grand mean rating was 2.80 which was also above the criterion mean. Based on this, the study revealed that the respondents agreed with all the items except item 7 which was below the criterion mean. This implies that most of the respondents agreed with the factors limiting the use of earth materials in the construction of sustainable road works in South East, Nigeria.

The data presented in Table 4 on the strategies that will improve the use of earth materials in the construction of sustainable road works in Southeast East, Nigeria, revealed that the respondents agreed with all the items with mean scores ranging from 2.82 - 3.05. This signifies that most of the respondents agreed with all the strategies that will improve the use of earth materials in the construction of sustainable road works in South East, Nigeria.

Table 3. The Factors Limiting the Use of Earth Materials in the Construction of Sustainable Road Works in South East, Nigeria

S/n	ITEMS	SA (4)	A (3)	D (2)	SD (1)	∑FX	$\bar{X}$	SD	Decision Rule
1	Earth materials give poor road finishes in road works construction in South East, Nigeria.	19	18	9	14	162	2.7	1.15	Agreed
2	Local materials like laterite suffer shrinkage and cracking which dangers the sustainable road works in South East, Nigeria.	26	15	13	6	181	3.02	1.03	Agreed
3	Doubtful durability and longevity lifespan of earth materials hampers the sustainable road works in South East, Nigeria.	19	25	7	9	174	2.9	1.02	Agreed
4	Deterioration of earth materials as a result of absorption of moisture content limits the use of earth materials in the construction of sustainable road works in South East, Nigeria.	26	15	8	11	176	2.93	1.14	Agreed
5	Small-scale production of earth materials limits the use of earth materials in the construction of sustainable road works in South East, Nigeria.	22	24	10	4	184	3.07	0.89	Agreed
6	Poor road networks to transport materials to the site limit the use of earth materials in the construction of sustainable road works in South East, Nigeria.	20	20	12	8	172	2.87	1.03	Agreed
7	Earth materials are easily worked on during the construction of sustainable road works in South East, Nigeria.	9	11	18	22	127	2.12	1.08	Disagreed
	Grand mean						**2.80**		

Table 4. The Strategies That Will Improve the Use of Earth Materials in The Construction of Sustainable Road Works in South East, Nigeria

S/n	ITEMS	SA (4)	A (3)	D (2)	SD (1)	∑FX	$\bar{X}$	SD	Decision Rule
1	Reduction in development of foreign construction materials in construction sectors.	21	23	10	6	179	2.98	0.97	Agreed
2	Co-operative effort by the government in the developing of bamboo and earth materials to meet the housing need	16	26	9	9	169	2.82	1.00	Agreed
3	Government should increase import duties on the importation of building materials that can be sourced locally	25	20	10	5	185	3.08	0.96	Agreed
4	Government should grant fiscal incentives to the manufacturing of bamboo and earth materials.	10	25	13	12	153	2.55	1.00	Agreed
5	Government should encourage large-scale production of bamboo and earth materials.	21	17	14	8	171	2.85	1.05	Agreed
	Grand mean						**2.86**		

4. Finding and Discussion

The result obtained from Table 2 revealed that all the items identified are the factors associated with the use of earth materials for sustainable road works in South East, Nigeria. This is in line with the view of [43] which postulated that earth material is widely used as a construction material around the world. The availability is in line with the study items. The result obtained from Table 3 revealed that all the items identified except item 7 are the factors limiting the use of earth materials in the construction of sustainable road works in South East, Nigeria. This is in line with the view of [44], who stated that foreign materials require high technology and energy in their production, transportation and usage. The result obtained from Table 4 revealed that all the items identified are the strategies that will improve the use of earth materials in the construction of sustainable road works in South East, Nigeria. Harrison and Sinha corroborate this finding that sustainability and durability an issues of great importance for the construction sector and society. Most developing nations are facing a real road deficiency, therefore, it is mandatory to construct roads that are more sustainable and durable at low cost [45][46].

5. Conclusion

A study in Southeast, Nigeria, found limitations in the use of earth materials in sustainable road construction. The research, involving 60 engineers and craftsmen, recommends better facilities for well-storing earth materials, introducing earth materials in construction education, and adapting earth materials to require minimal capital and foreign exchange. The findings underscore the importance of sustainable road construction in Nigeria, which has the largest road network in West Africa. Roads facilitate traffic flow, human mobility, and product movement, but also have negative impacts on groundwater and river flow. Sustainable development plans should capture good roads, drinking water, electricity, security, and maintenance practices.

Having conducted this research and analyzed the field data, the study recommendations are as stated. The study suggests incorporating indigenous road construction materials into Nigerian tertiary education curriculums. Contractors should play a crucial role in reducing waste during construction by implementing effective strategies for resource management, waste minimization, procurement policy, project control, and communication. Contracting firms should develop better storage facilities for earth materials to prevent wastage. The findings could help governments formulate policies for enhanced accessibility and road network development, impacting commercial property values and urban economy growth. Sustainability knowledge in construction should be integrated across geographical boundaries and encouraged for designers to design designs that consider the relationship between natural resources used in construction.

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