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Full Length Research Paper

Assessment of environmental hazards: Linking borrow pits, gully erosion, and road failure

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Highway failure linked to the action of erosion initiated by active or abandoned borrow pits in no small measure affects environmental quality and safety. This study has investigated the Owerri-Okigwe-Enugu highway, Nigeria. Environmental assessment of the study area through photographs showed prevalence of landslides, at risk structures, and motor accidents. Soil samples were collected at three abandoned borrow pits at Ihube, Leru and Ngeru for laboratory tests, while three surface electrical resistivity measurements were conducted to understand the subsurface complexity of the area. Average values are 2.05 mg/m^3 (MDD) and 12.96% (OMC) of the three locations. The soil is non-plastic, and non-cohesive. Particle size analysis confirms the soil as sandy, thus easily erodible and not a suitable road fill material. Resistivity measurements showed presence of underlying shale sequence which continues below 88 m, with 5.05 m as average depth of overburden. This near surface shale accounts for the frequent failure of the highway. Factor of safety and probability of sliding is affected by: Sliding angle, overburden stress, resisting base, water saturation, pit slope angle, distance of tension crack to pit crest, and pit effective depth.

Key words: Geotechnics, Geophysics, roadside excavation, erosion, road failure, sustainability.

INTRODUCTION

Geo-environmental hazards associated with abandoned borrow pits in Nigeria are on the rise and a major concern to citizens, environmentalists and governments. Several highway failure spots are directly linked to the action of erosion initiated by active or abandoned borrow pits situated close to the roads. This study was carried out along Owerri-Okigwe-Enugu highways in south eastern Nigeria (Figure 1). The first pit is located at Ogbulubi by Okitankwo stream valley along the Owerri-Okigwe road. The second is the abandoned borrow pit at Ngeru River at Umuna Junction. The third pit at Ihube lies at Limca junction, while the fourth pit is situated at Leru Umuchieze. The climate of the study area is characterized by high humidity (80 to 100%), moderately high temperature of 25 to 27°C and predominantly southern winds except slight harmattan influence in December through February. It has a mean annual rainfall about 2250 to 2500 mm obtained from the state metrological department. The vegetation is typically rain forest, although some parts consist of guinea savanna. On both sides of the highway are cashew trees, palm trees, Melina, and bamboo trees that were planted to check erosion.

Borrow pit is a term used in civil engineering; it describes an area where material (usually soil or sand) has been dug for the use at another place or location. The term literally means a pit from where materials were borrowed without an intention of someday returning the collected material.

Indiscriminate roadside excavation of borrow pits for road construction and other civil Engineering works without the intention of restoring or reclaiming the pits have left much to be desired in terms of the potential hazards. Therefore this paper will x-ray hazard potentials

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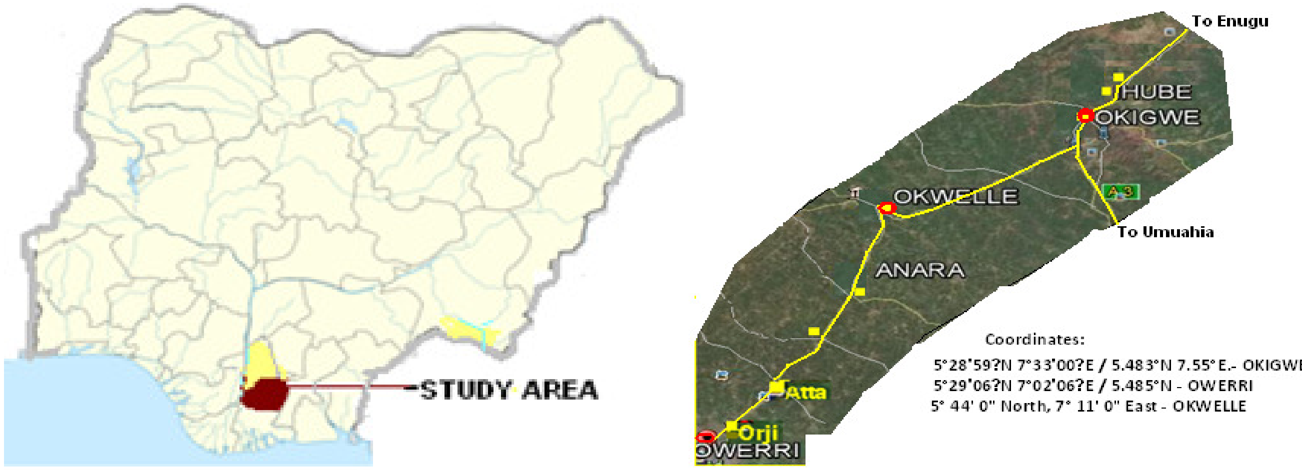

(1a) (1b)

Figure 1a. Map of Nigeria showing Imo state and 1b: shows the Owerri-Okigwe-Enugu highways and reference points.

and sustainable borrow pit operation. Little work has been done in the area of abandoned borrow pit, making literature materials very scanty. This study will provide a framework for government to make laws or strengthen existing laws on borrow pits and roadside excavation. To date, there is no operational code of practice for sitting and operating borrow pits in Nigeria. When such established codes are in place, borrow-pit operators will consider environmental safety, and impact of abandoned borrow pits. For example, indiscriminate uses of abandoned borrow pits as waste disposal sites will be stopped as part of environmental protection. There is urgent needs of a standard operating procedure (S.O.P) for borrow pits.

The process of sand and gravel excavation from borrow pit started at about 1800 when slave masters used their subjects (slaves) to dig the ground to borrow soil materials which they used for small construction purposes. The slaves used non-sophisticated tools like hand diggers, shovel and head pan which they used to carry the borrowed soil materials to construction sites (Bloxam, 2011). However, as population increased and the need to constructing infrastructure became necessary, bigger equipment were also developed in order to meet up with the increased demand for sand and gravel (Etuk, 2008). Between 1940 and 1950, modern scientific methods were developed in the borrow pit business. Apart from using earth moving equipment like bulldozers of different capacity, graders and heavy duty trucks for haulage, computer aided software were also developed by geotechnical engineers to carry out proper geotechnical site investigation for precision survey and to calculate the amount of soil that can be excavated from a particular site without necessarily causing a shift on the earth’s equilibrium (Ogbe, 1975). Sand and gravel excavation is becoming an environmental issue as the demand for sand increases in industry and construction.

The use of geophysical method such as vertical electrical sounding (VES) in the investigation of borrow pit site will minimize the trial pit traditional methods that has left behind abandoned pits Nwachukwu at el. (2012). The presence of such small trial pits have led to several pits littering the study area. Although the area degraded by borrow pit excavation might be small in one location, the combined acreage nationwide is substantial. In Nigeria several acres of land are degraded by abandoned borrow pits that turn to ponds or waste dumping pits. Laterite soil which is the product of borrow pit excavation is used as a sub-base and base course for construction of highway embankments (Head, 2010). However, most of the laterite soils used for the construction of many Nigeria roads is gotten from pits without proper geotechnical study to determine their suitability as road fill material. This has consequently led to the loss of productive time on the highway, loss of life and properties, and finally leading to the repeated contracts to repair roads instead of channeling such fund to other sectors of the economy.

Some abandoned borrow pits threaten public safety due to the dangerous deep vertical walls that are prone to landslides after heavy rains that enhance saturation and liquefaction. In some places, abandoned borrow pits are filled with runoff water from adjoining water bodies and become ponds. More often children use the ponds as swimming pools, and many drown in the process. Borrow pits containing stagnant water also become breeding ground for vectors like mosquito and tsetse fly. Often abandoned borrow pits not containing water serve as dump sites for end of live vehicles. They are used for illegal dumping of wastes, and as hide-out for armed robbers and ritual killers. When these situations arise close to residential areas, major socio-environmental problems confront residents. When a borrow pit is progressively reclaimed during its active excavation, the problems mentioned above can be minimized.

Omosanya et al. (2011) recommended that a detailed environmental impact assessment be carried out before a borrow pit license can be obtained from the government, according to them a task force should be set up by government to indict operators and contractors that do not comply with borrow pit excavation regulation. Reclamation of the borrow pit should be placed under the task force mandate to borrow pit operator so that defaulters can be prosecuted. Berry and Pistocchi (2003) said that early response to the issue of abandoned borrow pit is to characterize the special features of the effects of unsustainable excavation. They further stated that both active and non-active borrow pits should have proper health, safety and environmental policies spelt out. Fencing of borrow pits to wade off roaming animals from falling into the pits is welcome (Ayodele et al., 2009; Nwachukwu et al., 2012). Clearing of vegetation for borrow pit and not restoring it to its original state is a distortion of ecosystem which can lead to the extinction of fauna and flora species. As a way of fostering meaningful professionalism, sustainable engineering practice in the excavation of borrow pit must come to bear.

Many scholars have worked on erosion processes, addressing effects and causes of erosion worldwide. Notwithstanding, none has addressed the issue of abandoned borrow pits and roadside excavation as important scenario. According to Pimentel et al. (2009)," Soil erosion is second only to population growth as a major environmental problem the world is facing." Erosion is termed accelerated when the rate of soil removal exceeds that of soil formation. The rate of soil formation at any point in time is governed by the factors of parent rock material, topography, climate and vegetation (Sabatini, 2002). For the most part, erosion which is the process of weathering and transport of sediment, soil, rock and other particles in the natural environment is caused by runoff water in the study area. Erosion causes land degradation in many forms and affect a full spectrum of natural environment (Akpokodje et al., 2010). Hudec et al. (2006) observed that the most affected gully erosion areas are underlain by unconsolidated to poorly consolidated sandy materials. The cleaner, more porous and weakly cemented sands are the most prone to gully advance, which increases directly with an increase in the proportion of grains, more than 1 mm in diameter.

Ezezika and Adetona (2011) concluded that community-based, low-technology land management practices and public awareness programs through workshops could halt the development of many gullies in the southeastern region of Nigeria. In this case, universities need to intensify effort towards sustainability studies on erosion, and report findings in the form of public seminars. Obiefuna and Adamu (2011) recognized geological and geotechnical parameters as main causative agents in the formation of gullies. The rate, degree, and energy of rainfall controls affect erosion. (Ellison, 2007) maintained that (Energy of rainfall: $E = 0.199 + 0.0873 \log I$) depends on duration, size and erosivity of precipitation, while Troeh et al. (1980) defined erosivity as: $Er = P \times E$. Where E = kinetic energy of the rainfall per mm of rain amount (MJ/ha mm). I = rainfall intensity (mm/h), or total kinetic energy of the rainfall, and P = quantity of precipitation (mm).

Geology of study area

The extensive thickness of inclined beds commonly exposed throughout the study area indicate the deltaic depositional environment composed of mixed sand, sandstone and a sequence of clay-shale. The relatively thin traverse bedded sediment overlying the fore set is the Ajali escarpment. It has been observed that significant sections of the Owerri – Okigwe expressway have broken down to the point that these sections have to be avoided by the use of detour, thereby increasing road accidents, and difficulties encountered by users of the road. This type of failure recognized by Akpokodje et al. (1985) and Uduji et al. (1994) is observed within sections of the road underlain by shale units, which naturally do not form a good road base material. Geologically, the region through which the highway runs has several shale formations (Figure 2) including Mamu (Upper Coal measure), Imo, Nkporo and Bende-Ameke of varying ages and degrees of weathering. Some of these shale units are exposed along the highway. Shale, by definition are fine-grained rocks that contain between 50 and 100% clay sized particles with clay mineral constituting at least 25% of the total rock volume. Shale when highly indurate may be used as construction materials. They are also known to possess a degree of intactness, continuity and strength because of their intermediate hardness.

METHODS OF STUDY

The field study involved identification of the three abandoned borrow pits along the Owerri-Okigwe highway. The elevations and coordinates of the pits were measured with GPS (Geographic information system) and recorded in a spread sheet. Geometry of the pit: the depth, overburden, surface and base diameter, and the angle of slope were duly measured and recorded.

Geotechnical measurements

The samples of soils close to the floor of the borrow pits were collected by triangulation at 1 m apart and 1 m below the topsoil layer. Also samples were collected at the slope 1 m above the floor

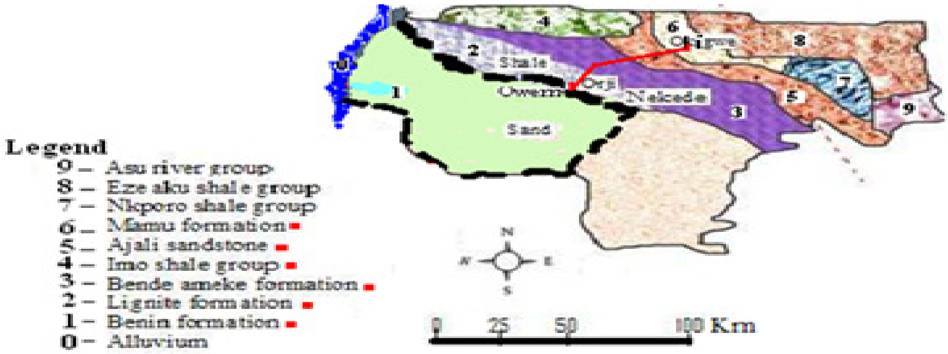

Figure 2. Showing geology map and formations underlying the study area on red square dots (Nwachukwu, 2010).

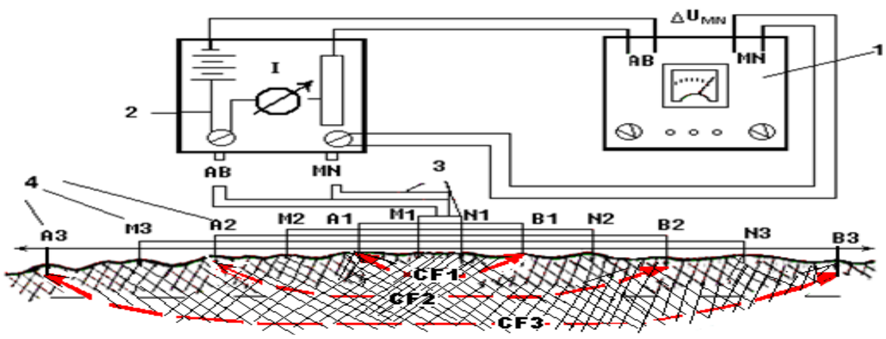

Figure 3. Schlumberger VES field arrangement.

of the pit and another 1 m below the surface of the pits. The samples collected were carefully kept in a brown polythene bag, labeled appropriately and sealed to prevent loss of moisture. At every point the topsoil was dug out at 1m below surface level before the samples were collected. Samples were taken to the laboratory where the under listed tests were carried out.

Grain or particle size analysis

This was conducted by wet sieving, to determine particle size distribution of the soil.

Atterberg limit test

The tests are based on the moisture content of the soil.

Direct shear test

The shear strength of a soil is its maximum resistivity to shearing stresses.

$\tau = \acute{C} + \sigma \tan \Phi$

Where $\acute{C}$ = effective cohesion; σ= effective stress; Φ = effective angle of shearing resistance.

Compaction test

The proctor compaction test is a laboratory method of determining the optimal moisture content (OMC) at which a given soil type will become dense and achieve its maximum dry density (MDD).

Factor of safety and probability of sliding

The classical approach used in designing open pit excavation is to consider the relationship between the capacity C (strength or resisting force) of the element and the demand D (stress or disturbing force). Factor of Safety is defined as: F = C/D and failure is assumed to occur when F is less than unity. Other parameters affecting safety and probability of sliding measured are sliding angle, overburden pressure, resisting force, water saturation, pit slope angle, and pit effective depth.

Geophysical application of vertical electric sounding (VES) method

VES application was necessary for determination of subsurface characteristics including lithologic variation, and depth and thickness of the various layers. This is constrained below a certain stipulated depth required prior to the construction of any civil engineering structure.

The Schlumberger field technique which is known as the vertical electrical sounding was applied (Figure 3). It is also known to be superior over other techniques in distinguishing vertical variation in

Figure 4. A. Road failure B. Surface about sliding C. Homes about sliding.

Figure 5. A: Borrow pit at Ihube B: Abandoned pit C: Roadside excavation.

resistivity, and field operations are faster. The professional assistance of the staff of GEOPROBE International Consultant Limited was employed for the use of their VES equipment (the allied associate Geophysical limited manufacturer of the Allied Ohmega instrument).

AGI 1D automatic analysis software was used to obtain the VES curves with number of layers constrained to the model curves. For literature demonstrating the field techniques of VES, we refer readers to Dobrin and Savit (1988) and Telford et al. (1990). The apparent resistivity (Ohm-m) at each measurement point was obtained by multiplying the field resistance by a geometric factor (Equations 1 and 2). In the VES, L is the current electrode spread (m), and I is the potential electrode spread (m). The apparent resistivity values were then applied in the AGI 1D automatic analysis to obtain the VES curves, with number of layers constrained to the model curve. VES traverses were run east to west, in the direction of regional strike.

Apparent resistivity $\rho a = K \times R$ (_-m) (1)

Where K = geometric factor; R = field resistance.
Equation (1) can be expressed as follows:

$$\rho a = \frac{\pi \left(\frac{L}{2}\right) 2 - \left(\frac{I}{2}\right) 2 \times R}{I}$$

Compass survey and GPS reading

A compass survey of the area was run. This was to define the limit of investigation and to produce a working base map. The elevations and coordinates of the study areas were measured using the E-trex GPS and recorded in a ruled sheet. Area of borrow pits investigated were determined through compass survey, and calculations accomplished by triangulation technique.

RESULTS

Result of direct measurements and visual assessments

Figure 4a-c, shows significant environmental hazards along sections of the highway under investigation. Figure 4a shows road failure that has for several years remained death trap to commuters. On top of one of the abandoned borrow pit at Owerri Okigwe highway is a high tension electric pole (Figure 4b). From the crest of the slope to the high tension pole is about 10 m. There is a thick vegetation cover of bamboo trees which have stabilized the soil from sliding. But that does not guarantee safety of the pole under heavy rains. The high tension pole poses a lot of environmental hazards to the residents and commuters. With increase in rainfall, infiltration will weaken the soil, creating tension cracks that become planes of failure. The hazard implications of landslide affecting high tension power lines are enormous and could lead to paralysis of industrial activities for communities in the affected areas. People may be electrocuted, resulting in mass death. Figure 4c shows some residential homes at the verge of sliding.

Figures 5a to c, are active and abandoned pits showing different soil texture. The sandy variegated color of

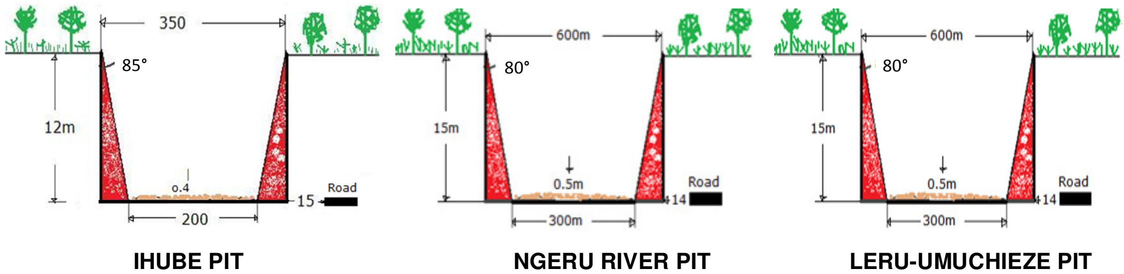

Figure 6. Geometry of the borrow pits.

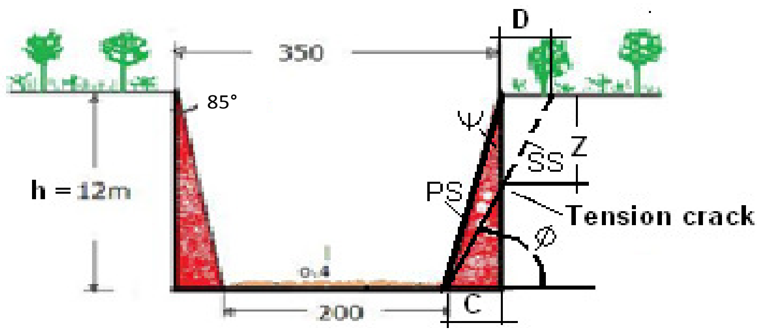

Figure 7. Analytical illustration of factor of safety and probability of sliding.

Figure 5a is typical of the Ajali sand Formation escarpment traversing the Okigwe-Enugu highway.

Figure 6 is a graphical illustration of the pits geometry from direct field measurements. The pit at Ihube, Limca company junction has the following coordinates and elevation North (05° 51' 802) East (07° 21' 360) and an elevation of 708ft. Ngeru River pit has the following coordinates: North (05° 45'. 904) East (07°14' 675) and elevation of 400ft. The third pit situated at Leru Umuchieze Umunneochie has the following coordinates: North (05° 45' 904) East (07° 14' 675) and an elevation of 708 ft. The 80° to 85° pit wall angle significantly indicate great tendency to sliding. Increased water saturation at peak of rain season creates planes of weakness where movement occurs often in form of slump.

Analyzing factor of safety and probability of sliding

The classical approach used in designing open pit excavation is to consider the relationship between force resisting sliding (C) possessed by the base rock and the overburden pressure (D) initiating sliding. The Factor of Safety (F) of the pits is defined as F = C/D (Figure 7) and failure is assumed to occur when F is less than unity.

For assurance of safety, C must be greater or at least equal to D. F is controlled by the following factors:

(i) Type of rock material constituting the overburden (Unit weight of rock).

(ii) Presence of trees increasing overburden pressure or tension.

(iii) Presence of external force such as buildings, machineries, vibration or seismic waves increasing tension.

(iv) Degree of water saturation (Unit weight of water).

If D is the distance of tension crack from pit crest, the less the distance, the greater is possibility of sliding.

If ϕ = Sliding angle; increases, C increases, and D reduces, thereby increasing safety factor, and reducing the probability of sliding. Other conditions are as follows:

SS = Sliding surface; established by tension crack is enhanced by water saturation, thereby increasing probability of sliding

Z = Effective depth of tension reduces with tension crack as angle of sliding increases, thereby reducing probability of sliding.

ψ = Pit slope angle (80 to 85°) when reduced, enhances slope stability.

h = Effective depth of pit affects pit slope angle and stability of slope.

Result of electrical resistivity measurement (VES)

Figures 8 to 10 show the VES curves as constrained to the specified number of geo-electric layers. The various layers are differentiated by color code, with lithology,

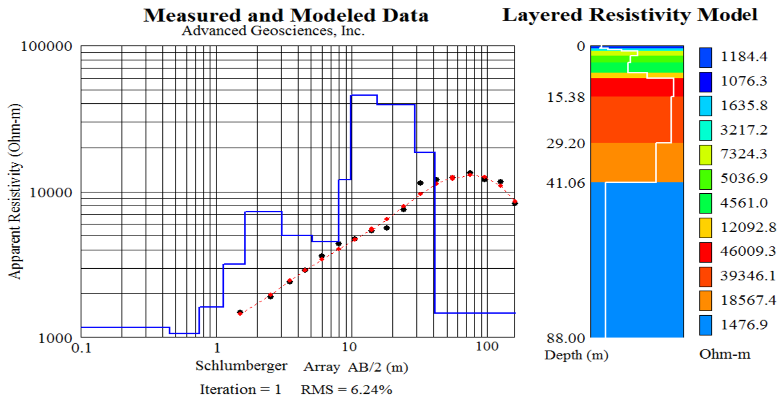

Figure 8. Ngelu River VES.

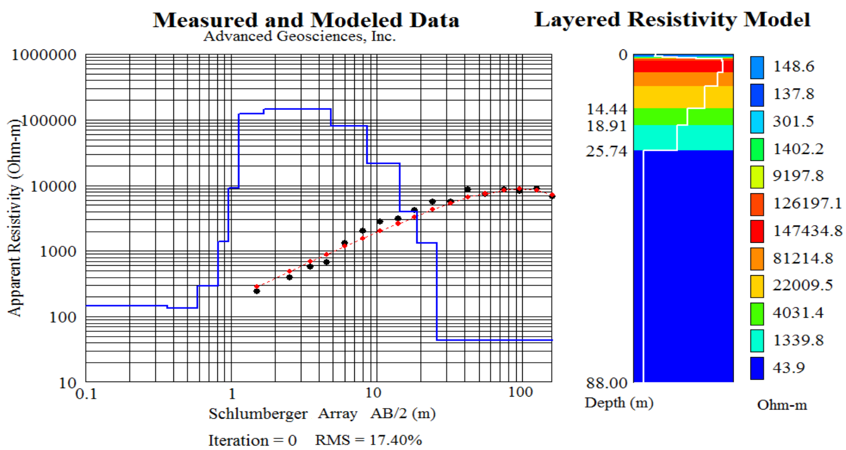

Figure 9. Ihube VES.

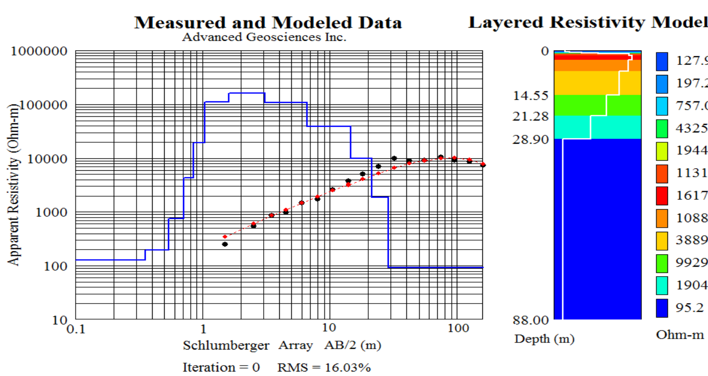

Figure 10. Leru Umuchieze Umunneochi VES.

resistivity values, and thickness properly described. The VES curves are produced using Advanced Geophysics Inc. (AGI) 1D Software. Analytical result revealed ten geo-electric layers at Ngelu (Table 1), nine at Ihube (Table 2), and nine at Leru as shown in Table 3. The VES results generally present the subsurface geology of the area as predominantly shale units, capable of causing frequent road failure. Generally, the VES result shows near surface lithology consisting of shale, siltstone, silty-sand and clay units to an average depth of 8 m. These

Table 1. Ngelu River VES 1 Result analysis.

Layer	Depth (m)	Resistivity (Ohm-m)	Lithology	Color
1	0.5	1184.4	Topsoil	Mixed Blue
2	0.7	1076.3	Sand	Blue
3	1.6	3217.2	Siltstone	Greenish Blue
4	5.1	5036.9	Shale	Green
5	8.0	4561.0	Shale	Green
6	9.8	12092.8	Sandstone	Yellow
7	15.38	46009.3	Shale-sandstone	Red
8	29.20	39346.1	Shale-Siltstone	Red
9	41.06	18567.4	Shale	Brown
10	88.00	1476.9	Clay-shale	Blue

Table 2. Ihube VES Result analysis.

Layer	Depth (m)	Resistivity (Ohm-m)	Lithology	Color
1	0.36	148.6	Topsoil	Mixed Blue
2	0.58	137.8	Sandy clay	Blue
3	0.95	1402.2	Silty sand	Green
4	4.85	147434.8	Shale-sandstone	Red
5	8.59	81214.8	Shale-sandstone	Off Red
6	14.44	22009.5	Shale	Yellow
7	18.91	4031.4	Siltstone	Green
8	25.74	1339.8	Silty sand	Greenish Blue
9	88.00	43.9	Clay-shale	Blue

Table 3. Interpretation of VES 3, showing 9 geo-electric layers.

Layer	Depth (m)	Resistivity (Ohm-m)	Lithology	Color
1	0.4	127.9	Topsoil	Mixed Blue
2	0.8	4325.0	Mixed Sand	Green
3	1.6	113173.1	Shale-sandstone	Red
4	3.1	161749.7	Shale-sandstone	Red
5	6.6	108853.6	Shale-sandstone	Off Red
6	14.55	38892.9	Shale	Yellow
7	21.28	9929.6	Siltstone	Green
8	28.90	1904.6	Clay-shale	Greenish Blue
9	88.00	95.2	Clay	Blue

materials are not suitable as base material for road construction. These materials have tendency to swell when wet, and to shrink when dry causing road failure irrespective of the quality of road fill material used.

Result of grain size distribution

Analysis of grain size distribution of the respective soil samples is shown in Figure 11. Ihube (Sample 1): 2.5% Gravel, 96.5% Sand while Silt and Clay is negligible. Ngeru (Sample 2): 3.3% Gravel, 94.3% Sand while Silt and Clay content is also negligible. Leru-Umuchieze (Sample 3): 7.7% Gravel, 57.7% Sand and Fines (Silt and Clay) is 34.1%. From the result it shows that the soil samples at Ihube and Ngelu crossing contain mainly sand, little gravel and no fines. The samples at Leru Umuchieze contain applicable quantities of Gravel, Sand and Fines.

Result of direct shear strength

Direct shear test (Figure 12) shows that the soil samples are cohesionless. This implies that they are easily eroded and can be transported from one location to another in

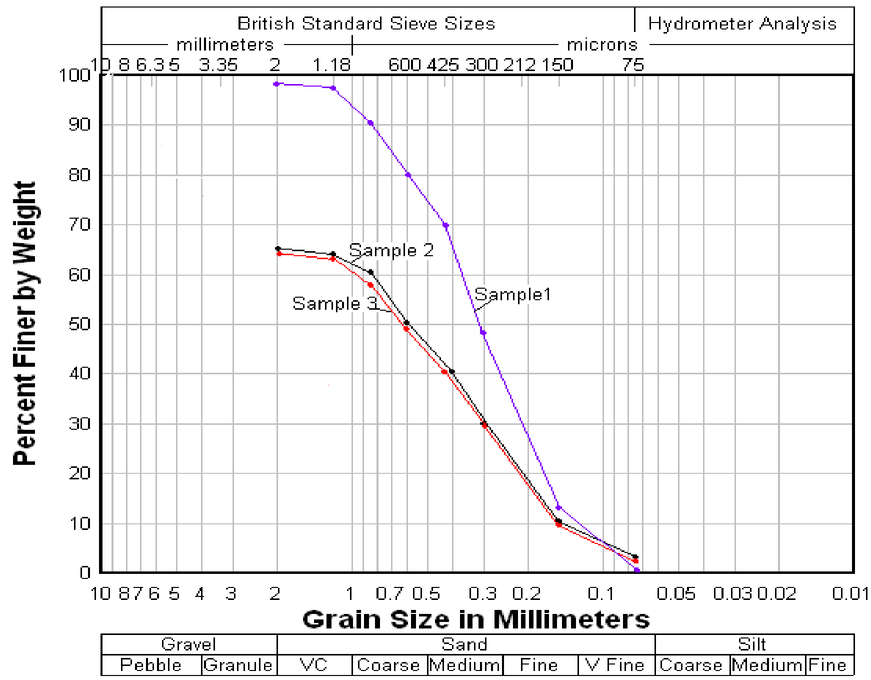

Figure 11. Grain size distribution curves of the three soil samples.

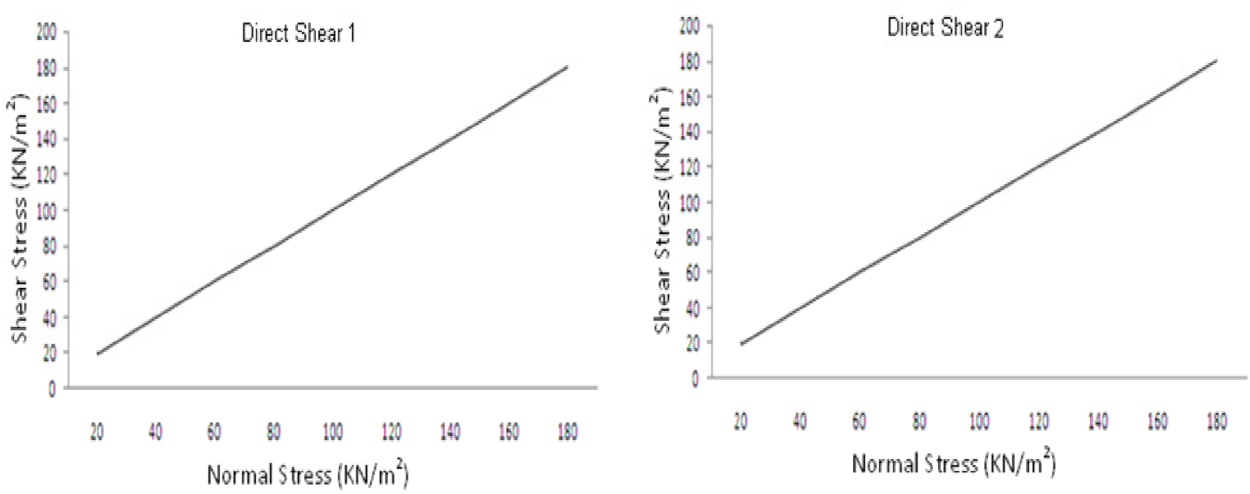

Figure 12. Shear stress verses Normal Stress.

the form of landslide and gully erosion. From the result, it shows that the soil structure in the study area is poor, accounting for the series of road failures.

Result of compaction test

Compaction test as given by Figure 13 on the three soil samples collected from the pit indicate that for Test 1 (Ihube): M.D.D = 2.05 Mg/m^3, O.M.C = 13.5%; Test 2 (Ngelu River): MDD = 2.0 Mg/m^3, O.M.C = 12.5%; Test 3 (Leru-Umuchieze): MDD = 2.1 Mg/m^3, O.M.C = 12.9%. From the result analysis it shows that all the soil samples collected at the different borrow pits sites were non plastic (NP). This means that the plasticity index of the soil is zero. It also means that the plastic and liquid limits

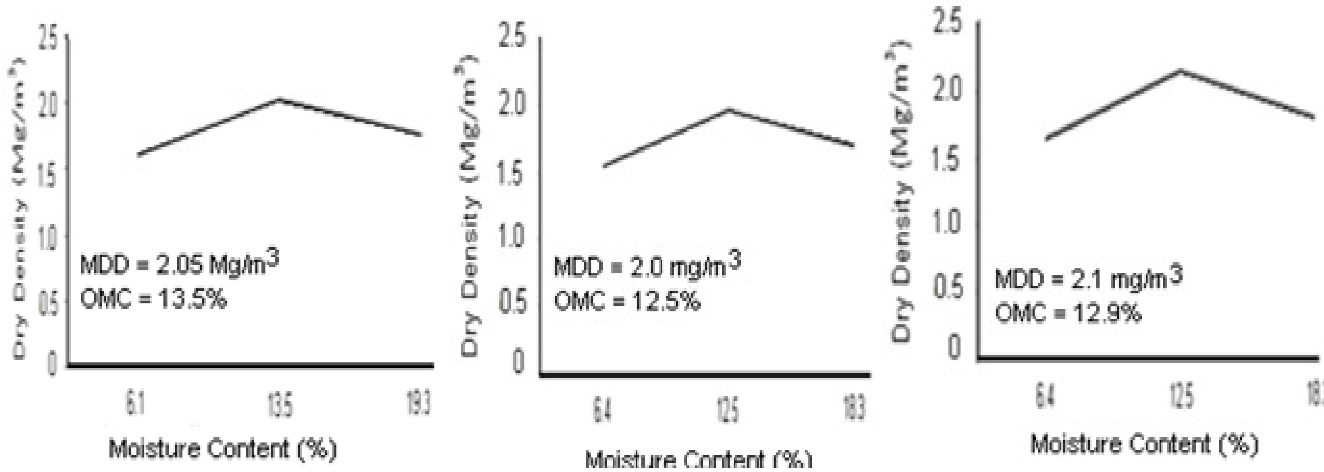

Figure 13. Graph of dry density vs. moisture content (%);

cannot be determined by standard procedure (Head 1984). Since the soils are non-plastic, they are likely to have higher permeability.

RESULT DISCUSSION

Environmental assessment

Borrow pits located near settlements are also a source of concern in terms of human health and safety. Such borrow pits could become breeding areas for mosquitoes during the rainy season should they become inundated with water. Other health and safety concerns could be to children who may use the collected water as play grounds and contract water borne diseases such as bilharzias or possibly drown. A few of the borrow pits are also too close to the roads such that they are a danger and could cause accidents to the motoring public. In the three abandoned pits investigated, there is clear evidence of unsustainable engineering practice. The areas under this study are classified as danger zones where no meaningful agricultural activities can be carried out. The animal and plant species within these areas are likely to face extinction due to lack of habitat. The areas are characterized by thick and dense vegetation typical of the tropical rainforest. The soil consists mostly of sand and shale. The presence of trees, shrubs and grasses is responsible for the dense vegetation within the areas. Some of the abandoned borrow pits have been turned into hid-outs of criminals.

Geologically, the region through which the highway runs, cut into the Ajali escarpment, and surrounded by shale units of varying ages and degrees of weathering. Some of them are exposed along the highway. The borrow pits produced soil used in constructing the highway. Particle size distribution confirmed the soil as predominantly sandy. Direct shear test indicated the soil as cohesionless. This can be confirmed by the poor consolidation of the soil particles. By these characteristics, the highway became susceptible to erosion, and to internal displacement of the soil. The anticipated embankment performance is between “poor and good” and highly prone to failure. Inhabitants of the community and the road users expressed their anxiety and worries over the current state of the highway. According to them the highway failure has resulted to delay in vehicular movement leading to increase in fuel consumption and waste of precious man hours on the highway. It also leads to frequent accidents, and repeated repair or maintenance of the same highway. Such funds could be used to strengthen other infrastructures.

Landslide

In the three sites under investigation, there were incidences of landslide, representing a serious environmental problem of the area. Landslide is described as a down slope movement of rock and soil along a slip surface. It is also associated with disturbance of the equilibrium which normally exists between stress and strength in materials resting on slopes and this relationship is dependent on factors like height, steepness of the slope, density, strength, and friction of the material on the slope. The geometry of the three pits revealed a slope angle between 80 to 85°. The slope is weakened by heavy rainfall between March and September each year. From the vertical electric sounding carried out, the area is composed mainly of shale. This shaliness is also responsible to the frequent road failure.

The accompanied landslides in the area lead to loss of hundreds of life and damage to properties. Inhabitants interviewed affirmed that since the abandoned borrow pits were not reclaimed; they have suffered unquantifiable loss of properties. Sliding angle, overburden stress, resisting force, water saturation, pit slope angle, and pit effective depths, aided the occurrence of landslides in the borrow pits.

Erosion

The soil characteristics and the geological set up of the study area have enhanced the occurrence of erosion activity. Egboka and Nwankwo (1985) upheld that hydrogeological and geotechnical parameters as causative agent in the initiation of erosion in the rain forest belt of Nigeria. Nwajide and Hogue (1979) identified topography, climate and soil characteristics as major causes of erosion. There are other man-made factors such as roadside excavation of borrow pits, as shown in Figure 5c. Absence of functional drainage systems make runoff to wash off the road. Stagnant pool of water in the borrow pits breed mosquitoes and tsetse fly. This causes persistent malaria and sleeping sickness in the area. Villagers interviewed reported that the runoff from the erosion comes in high volumes and velocities, and often drown some children in the abandoned borrow pits. Clearing of vegetation and stripping of soil from borrow pits causes erosion downhill, creating potholes, cutting off the road, and reducing soil fertility. The operation of heavy equipment along access roads and surrounding areas of the borrow pits leads to compaction of affected areas, thus disturbing the natural state of soils. There is also the possibility of leakage of petroleum products from the construction equipment into the ground which could initiate erosion processes.

Structural failure

Structural failure is initiated when the material is stressed beyond its bearing capacity, thereby causing fracture or deformation. It can also be related to man-made factors and geotechnical parameters. Residential buildings were found almost sliding into pit. Heavy duty equipments like bulldozers, pay loaders and trucks were used in excavation and loading at the pits, their vibration generate lateral waves to the surrounding structures. Accumulations of such waves weaken the foundation of structures in the vicinity of the study area. This could enhance water infiltration and saturation in the soil making the structure to collapse. Occupants of such buildings have abandoned the place for fear of the buildings collapse (Figure 4c). Close to the abandoned borrow pits are visible cracks and pot holes indicative of road failure (Figure 4d). This kind of road failure is in line with the observations of Akpokodge et al. (1985) and Uduji et al. (1994). Since the base material for the road is shale, the road portion is subjected to swelling during the rains and shrinking during the dry season. Abeyesekera et al. (1978) described laterite as notorious unpredictable material in which a number of failures have been reported involving settlement and shear failure of compacted laterite embankments.

CONCLUSION AND RECOMMENDATIONS

The issue of abandoned borrow pits is a major environmental problem for Government, road contractors, and host communities where abandoned borrow pits are found. Abandoned borrow pits causes landslides, gully erosion, road failure, and ground water contamination. Abandoned borrow pits show evidence of unsustainable engineering practices. There is urgent need to emphasize on sustainable soil excavation system in Nigeria. Firstly, there should be no road side excavation, and operators of borrow pits should get the necessary site approval from government ministries of environment before opening a borrow pit. Secondly, geotechnical assessment must be carried out to certify adequacy of a site, in terms of its soil characteristics to avoid cases of trial pits that leads to abandon borrow pits. To do this, the use of geophysics by surface resistivity measurement is applicable. Thirdly, the Federal Ministry of Environment through its relevant agencies like the Nigeria Environmental Regulatory Agency (NESREA) should set up a taskforce to enforce environmental regulations. Regulations may include locating a borrow pit not less than 200 m from the edge of a proposed or existing highway, and reclamation of borrow pits immediately excavation is completed. Abandoned borrow pit could be reclaimed for agriculture, or turned to recreational park. However, where operators and contractors fail to comply, they should be prosecuted. Reclamation cost can be reduced if integrated into the excavation cost. Highway engineering may allow expertise test of the soil in approved laboratories before the soil is excavated for road fill material to minimize failures.

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