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GEOTECHNICAL ASPECTS OF A GULLY SITE AT OFEKATA II AUTONOMOUS COMMUNITY, AWO-OMAMMA, IMO STATE, SOUTHEASTERN NIGERIA

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ABSTRACT

There is a need to evaluate those factors that influence soil erosion and gullying in Southeastern Nigeria. This study analyzed some geotechnical aspects of soil in Ofekatta II autonomous community in Awo-omamma in Oru East Local Government Area, Imo State, Southeastern Nigeria which is facing erosion menace, to determine the soil parameters such as Atterberg limits, shear strength, grain size distribution, dry density, bulk and dry unit and the natural moisture content. To substantiate this, the Atterberg limits shows that soil is non-plastic and therefore friable and easily erodible. The grain size distribution data obtained showed clay (12%), silt (6%), sand (82%), and gravel (0%). The Bulk and Dry unit and the Natural Moisture Content show that the moisture content ranged from 11.2 to 14.4% while the dry density ranged from 18.3 to 20kg/m^3. The dry density values were generally low, signifying that the soil is not compact but loose and thus susceptible to erosion. The computation of the direct shear strength shows that the cohesion values ranged from 4-6 C (KN/m^2). These low values are a strong indication that the soil is cohesionless and can be eroded with ease when loose.

***KEYWORDS**: Gully, Erosion; Soil, Direct Shear Test, Atterberg Limit Test*

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INTRODUCTION

The formation of gullies has become one of the greatest environmental hazards facing many towns and villages in southeastern Nigeria. This region is fast becoming hazardous for human habitation. Hundreds of people are directly affected every year within towns and villages and have to be relocated, and yet the rate of increase in gully erosion has continued unabated with no suitable solution. (Adekalu et al., 2007; Okpala, 1990).

The economic cost of gully erosion in southeastern Nigeria is devastating. Gully erosions lead to great losses of land every year. Large sections of land have been destroyed in recent years in towns such as Ekwulobia, Nanka, Agulu,

Ozuitem, Oko in Aguata area, Isuikwuato, Orlu, and Nekedeto mention buta few. The impact is felt both in the developed and the undeveloped areas causing damages to properties and physical infrastructures, highways and sometimes leading to loss of life. (Egboka et al.,1990).

The Njaba River gully at Awo-omamma, Imo State,Southeastern Nigeria has a peculiar and very interesting origin and characteristics. Its genesis was spontaneous (Onu, 1998). A major failure suddenly occurred around the area a few years ago alongwith a linear zone following heavy rainfall. Slumping and land sliding followed. The impact of the gully on the environment was such that local newspapers reported the event like a volcanic eruption. This incident which has degraded the landform in the vicinity and caused great panic in the neighborhood has attracted the attention of geologists/earth scientists and various levels of government in Nigeria.

There is speculation that this sudden failure cannot be a chance occurrence. There must have been a pre-existing condition hitherto undetected which acted as a trigger for the spontaneous event that opened up the gully.

It was this exigency that prompted this study which is aimed at determining the geological and geotechnical factors leading to the formation, development, and expansion of the gully site in Ofekata II Autonomous community area of Awomama, Imo state, South Eastern Nigeria with a view of recommending appropriate control measures.

LOCATION AND GEOLOGY OF THE STUDY AREA

The study area is the gully erosion site at Ofekata II Autonomous community (Near GCC building), Latitude 05 40′N 446′ Longitude: 006 55′E 92 8′ Awo-Omamma, Imo state South-eastern Nigeria.(See figure 1) Awo-Omamma is a small community located about 33km North East of Owerri. The settlements/communities near the study area include Umuaka, Izombe, Ogbaku, Orodo, Okwudo, and Oteru. Etc.

The study area is made accessible by many major and secondary roads as well as footpaths and these facilitated the survey. The landscape is generally gently undulating with bush clad ridges, which separate the wide and shallow depressions running in the NW-SE direction. The average slope at the gully visited is about 0.022 southward. The area lies within the rain forest belt but the vegetation is that of Sudan savannah, the rain forest structures having been almost eliminated by human interference. Economic trees like the Iroko, gmelina, bamboo, rubber and oil palm pre-dominate.

Geologically, the study area is underlain by the coastal plain sands (Benin Formation) and bits of the Ogwashi/Asaba Formation from Eocene to Recent. (See figure 2) The opening of the South Atlantic Ocean initiated tectonism in the region of Southern Nigeria and led to the development of the Benue Trough (Wright, 1966; Nyong, 1995). The development of the Benue Trough provided the main structural control and framework for subsequent geologic evolution of Southeastern Nigeria.

The structure of the gully was evaluated, as the exposed soil profile can be seen due to the gully erosion and it was noticed that the topsoil is dark in color, followed by reddish lateritic sands. Rainfall varied from 1,990mm to 2,200mm. The hottest months are January to March, with the mean annual temperature above 20^{o}C. The influence of the harmattan lasts for about nine weeks (i.e from late December to late February). It has an average annual relative humidity of 75 percent which is highest during the rainy season when it rises to about 90 percent. The high temperature and humidity experienced in the state favor luxuriant plant growth, which ideally should produce the climax vegetation of the tropical rain forest. The area is drained by the Njaba and Awbana Rivers which are tributaries of the Orashi River.

So, therefore, the hydrology nature of the area is such the soil moisture content is easily saturated, and will not be able to absorb much rainwater and hence leads to a higher level of surface runoff.

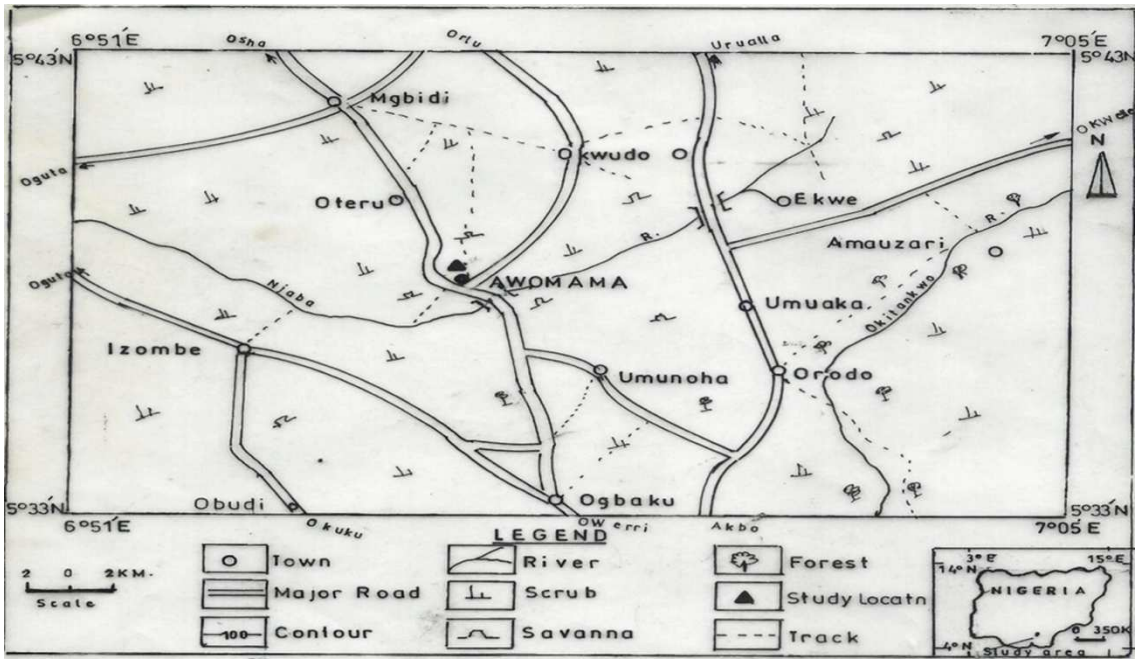

Figure 1: Location Map of Awo-Omamma (Ofekatta II)

Figure 2: GIS Map of Ofekatta II Autonomous Community

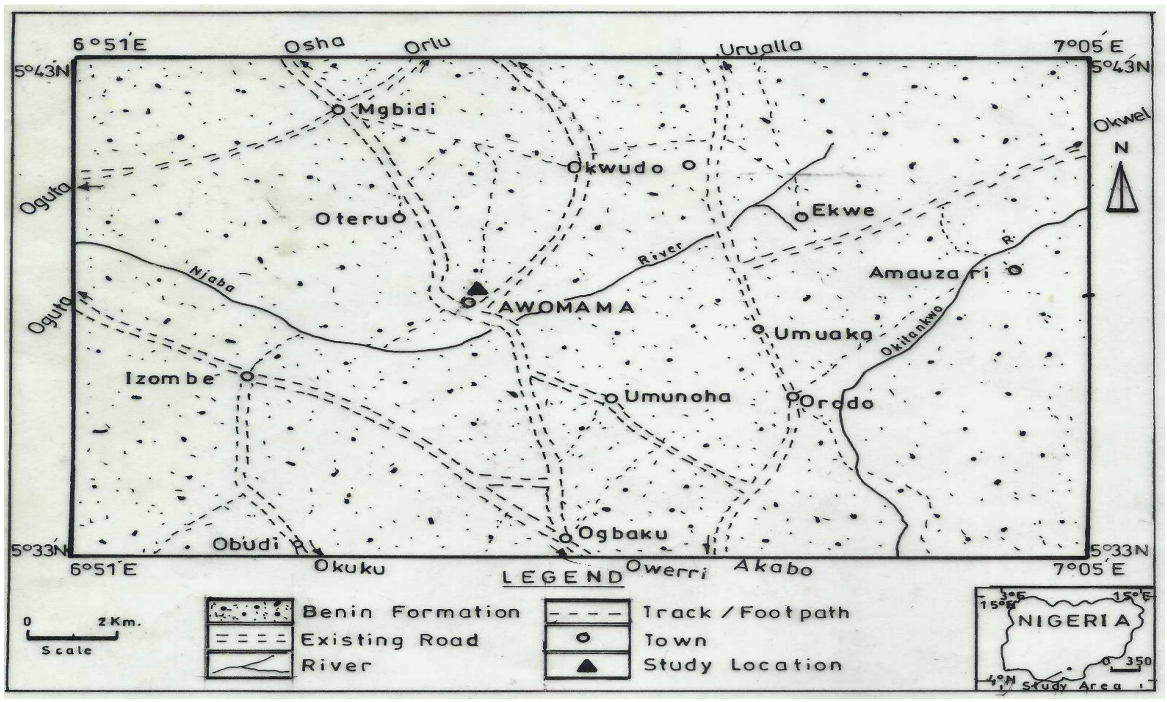

Figure 3: Geological Map of Oru East (Awo-Omamma)

METHODS OF INVESTIGATION

Undisturbed Samples were collected at three different depths ranging from top, middle and bottom of the gully site. Precautionary measures were taken to ensure that weathered soils were not collected along with fresh samples to ensure the reliability of the data.

The following tools and materials were used during the collection of samples: GPS - to geo-reference the sampling site; soil auger - to take a soil sample and; sample bags - for packing of the samples collected.

Geotechnical Investigation: The collected samples were also subjected to geotechnical investigation, and it was to obtain information on the physical properties of the soil around the site in order to proffer a solution to the gully menace. The list of geotechnical parameters carried out can be seen in the results and discussion.

Laboratory Investigation: The samples were subjected to the following laboratory tests: (a) Atterberg consistency limit (b) Moisture content determination (c) Bulk and dry unit weight determination (c) Grain size distribution and (d) Shear strength determination. These are needed for investigating the causes of distress aiding the gully erosion development and mitigating remedial measures.

RESULTS AND DISCUSSIONS

The location can be found using a GPS at Latitude 05 40′N 446′ Longitude: 006 55′E 92 8.′ (see figure 1). The gully erosion ran for 2.5km from the CGC building to the main road connecting the community to Onisha expressway. The depth of the gully is 2m with a width of 4m and at some point 3m along its path. The general trend of these gully system is NE, E-W, and SE with the NE trend dominating.

Meanwhile, it has been observed that the geotechnical properties of the soil in the area determine their susceptibility to gully erosion.

The liquid limit and plastic limit were used to obtain the plasticity index which is the difference between the liquid limit and the plastic limit (LL-PL=PI) and was used to measure the plasticity of the soil (Onwuemesi, 1990). This measurement showed 0%. This shows that the soils are non-plastic and friable. Based on the plasticity indices of the soil samples, they were classified and presented in Table 1.

Table 1: Classification of Soils Based on their Plasticity Index

S/N	Plasticity Index	Classification
1	Less than 1	Non plastic
2	1-7	Slightly plastic
3	7-17	Moderately plastic
4	17-35	Highly plastic
5	Over 35	Extremely plastic

It then follows that the relatively low cohesion or the friable nature of the soils in the area account for the gully erosion problem because water flows through the soils with ease and move the soil particles downslope with an increase in velocity of motion of the water.

Grain Size Distribution

Grain size analysis involves the division of rock samples by sieving into sized fractions. The result can be used to distinguish between sediments of different environment and to classify soils. Cumulative curves of the soil samples collected from the gully site were plotted. See results below.

The samples collected from different layers were subjected to grain size distribution involving (Hydrometer analysis method) and the summary of results are shown in Table 2.

Table 2: Grain Size Distrubution of the Samples

Soil Samples	Grain Size Distrubution
Top Sample	Clay 12% Silt 6% Sand 82% Gravel 0%
Middle Sample	Clay 12% Silt 6% Sand 82% Gravel 0%
Bottom Sample	Clay 12% Silt 7% Sand 81% Gravel 0%

Furthermore, the hydrometer analysis method was used for the sedimentation analysis of the top sample. The results of the analysis are presented in Table 3. For the wet sieving,

Wt of the sample before washing and drying = 60.0g

Wt of the sample after washing and drying = 45.6g

Therefore, Mass lost to washing (mass of fines) = 14.4g

% of fines = 24.0%

For the dry sieving of residue, mass = 45.6g

Table 3: Sedimentation Analysis by Hydrometer Analysis Method for the Top Sample

Sieve Size (mm)	Mass Retained (g)	Mass Passing (g)	% Passing
2.00	0.0	60.0	100.0
1.18	0.8	59.2	98.7
0.85	4.0	55.2	92.0
0.600	7.1	48.1	80.2
0.425	7.5	40.6	67.7
0.300	12.7	27.9	46.5
0.150	10.7	17.2	28.7
0.075	1.9	15.3	25.5
Pan	0.1	15.2	-

Additionally, hydrometer readings were obtained from the filtrate of the top sample and the results are presented in Table 4. The parameters are as follows: Initial mass of sample, M = 60g; Test temperature = 23.5 ^{o}C; Meniscus correction (Cm) = +0.5; Temperature correction (Mt) = +1.0; Dispersant correction (x) = 3.5; Specific gravity of particles (Gs) = 2.65 and; Viscosity of water ת = 0.8909 mPas

Table 4: Hydrometer Readings on Filtrate for Top Sample

Date	Time T (mins)	Hydrometer Reading (Rh^1)	True Reading (Rh)	Effective Depth H^R (mm)	Fully Corrected Reading (R)	Particle Diameter D (mm)	Percentage Finer than D.K (%)
26/10/2013	1	7.0	7.5	183.3	6.8	0.055	18.2
26/10/2013	13	6.5	7.0	185.3	6.3	0.015	16.9
26/10/2013	60	5.5	6.0	189.4	5.3	0.007	14.2
26/10/2013	120	5.0	5.5	191.5	4.8	0.005	12.9
27/10/2013	1440	5.0	5.5	191.5	4.8	0.0015	12.9

Again, the hydrometer analysis method was used for the sedimentation analysis of the middle sample. The results of the analysis are presented in Table 5. For the wet sieving,

Wt of the sample before washing and drying = 60.0g

Wt of the sample after washing and drying = 43.6g

Therefore, Mass lost to washing (mass of fines) = 16.4g

% of fines = 27.3%

For the dry sieving of residue, mass = 43.6g

Table 5: Sedimentation Analysis by Hydrometer Analysis Method For the Middle Sample

Sieve Size (Mm)	Mass Retained (G)	Mass Passing (G)	% Passing
2.00	0.0	60.0	100.0
1.18	1.0	59.0	98.3
0.85	4.1	54.9	91.5
0.600	7.3	47.6	79.3
0.425	7.6	40.0	66.7
0.300	10.2	29.8	49.7
0.150	11.2	18.6	31.0
0.075	2.0	16.6	27.7
Pan	0.2	16.4	-

The hydrometer readings were obtained from the filtrate of the top sample and the results are presented in Table 6. The parameters are as follows: Initial mass of sample, M = 60g; Test temperature = 23.5 ^{o}C; Meniscus correction (Cm) = +0.5; Temperature correction (Mt) = +1.0; Dispersant correction (x) = 3.5; Specific gravity of particles (Gs) = 2.65 and; Viscosity of water ת = 0.8909 mPas

Table 6: Hydrometer Readings on Filtrate for Middle Sample

Date	Time T (Mins)	Hydrometer Reading (Rh^1)	True Reading (Rh)	Effective Depth Hr (Mm)	Fully Corrected Reading (R)	Particle Diameter D (Mm)	Percentage Finer Than D.K (%)
26/10/2013	1	7.0	7.5	183.3	6.8	0.055	1.8.2
26/10/2013	13	6.5	7.0	185.3	6.3	0.015	16.9
26/10/2013	60	5.5	6.0	189.4	5.3	0.007	14.2
26/10/2013	120	5.0	5.5	191.5	4.8	0.005	12.9
27/10/2013	1440	5.0	5.5	191.5	4.8	0.0015	12.9

Also, the hydrometer analysis method was used for the sedimentation analysis of the bottom sample. The results of the analysis are presented in Table 7. For the wet sieving,

Wt of the sample before washing and drying = 60.0g

Wt of the sample after washing and drying = 44.8g

Therefore, Mass lost to washing (mass of fines) = 15.2g

% of fines = 25.3%

For the dry sieving of residue, mass = 44.8g

Table 7: Sedimentation Analysis By Hydrometer Analysis Method for Bottom Sample

Sieve Size (Mm)	Mass Retained (G)	Mass Passing (G)	% Passing
2.00	0.0	60.0	100.0
1.18	1.1	58.9	98.2
0.85	4.3	54.6	91.0
0.600	7.8	46.8	78.0
0.425	6.3	40.5	67.5
0.300	11.1	29.4	49.0
0.150	11.8	17.6	29.3
0.075	2.1	15.5	25.8
Pan	0.3	15.3	

For the bottom sample, the hydrometer readings were also obtained from the filtrates and the results are presented in Table 8. The parameters are as follows: Initial mass of sample, M = 60g; Test temperature = 23.5 ^{o}C; Meniscus correction (Cm) = +0.5; Temperature correction (Mt) = +1.0; Dispersant correction (x) = 3.5; Specific gravity of particles (Gs) = 2.65 and; Viscosity of water ת = 0.8909 mPas.

Table 8: Hydrometer Readings on Filtrate for Bottom Sample

Date	Time T (mins)	Hydrometer Reading (Rh^1)	True Reading (Rh)	Effective Depth Hr (mm)	Fully Corrected Reading (R)	Particle Diameter D (mm)	Percentage Finer than D.K (%)
26/10/2013	1	7.0	7.5	183.3	6.8	0.055	1.8.2
26/10/2013	13	6.5	7.0	185.3	6.3	0.015	16.9
26/10/2013	60	5.5	6.0	189.4	5.3	0.007	14.2
26/10/2013	120	5.0	5.5	191.5	4.8	0.005	12.9
27/10/2013	1440	5.0	5.5	191.5	4.8	0.0015	12.9

The results of sieve analysis presented in Fig. 3, 4, and 5 for the top, middle and bottom soil samples, respectively, show that the grain size distribution is predominantly sandy with a little amount of fines.

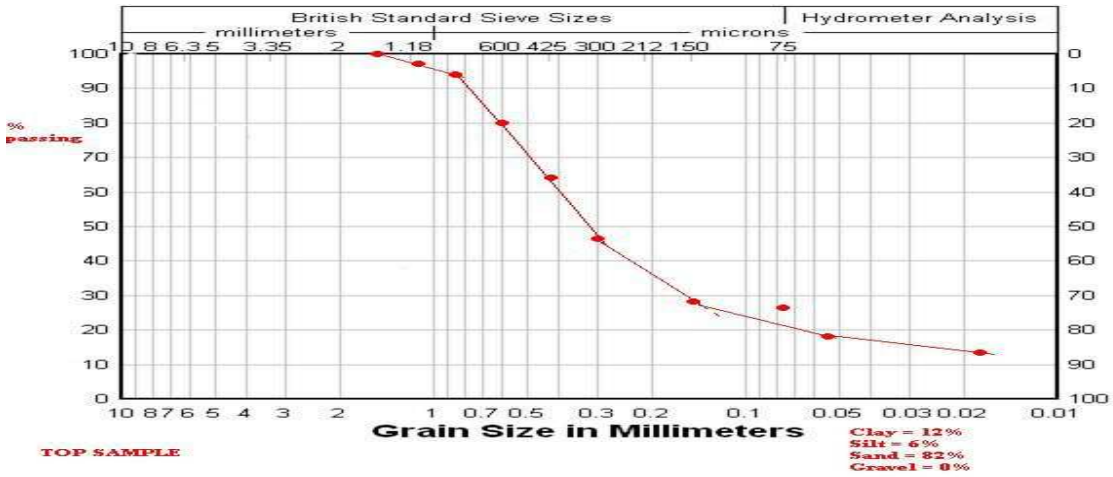

Figure 4: Sieve Analysis from Top Sample

Figure 5: Sieve Analysis for Middle Sample

Figure 6: Sieve Analysis for Bottom Sample

Natural Moisture Content Determination

The Bulk and Dry unit and the Natural Moisture Content of the top, middle and bottom soil samples show that the moisture content ranges from 11.2% to 14.4% while the dry density ranges from 18.3kg/m^3 to 20kg/m^3. The results of the natural moisture content of the three soil samples are presented in Table 9, while those for the bulk and dry unit weight are presented in Table 10

Table 9: Natural Moisture Content Determination

	TOP	MIDDLE	BOTTOM
Can identification number	35	20B	44
Wt of wet soil + can (g)	54.3	71.4	53.9
Wt of dry soil + can (g)	50.8	65.8	49.5
Wt of can (g)	19.6	17.6	19.0
Wt of dry soil (g)	31.2	48.2	30.5
Wt of water (g)	3.5	5.6	4.4
Water content w (%)	11.2	11.6	14.4

Table 10: Bulk and Dry Unit Weight (PB & PD)

	TOP	MIDDLE	BOTTOM
Wt of Ring + sample (g)	140.4	142.8	150.8
Wt of Ring (g)	60.7	60.7	60.7
Wt of sample (g)	79.7	82.1	90.1
Volume of sample cm^3	39.3	39.3	39.3
Bulk unit wt (Pb) (Mg/m^3)	2.03	2.09	2.29
Dry unit wt (Pd) (Mg/m^3)	1.83	1.87	2.00
Dry unit wt (Pd) (KN/m^3)	18.3	18.7	20.0

The maximum dry density values are generally low signifying that the soil is not compact but loose and thus susceptible to erosion.

Direct Shear Test Determination

This is used for the determination of the consolidated drained (or undrained) shear strength of soils. The test is performed by deforming a specimen at a controlled rate on or near a single shear plane. The dimensions of samples are as follows: Length of sample (L) = 60mm; Width of sample (W) = 60mm; Height of the sample (H) = 20mm; Area of sample A, = L x w = 3600mm^2 = 0.0036m^2; Volume of sample, V, = L x W x H = 7200mm^3. The results for the normal and shear

stress computations of the samples are presented in Tables 11 and 12, respectively, while those for the shear strength are presented in Table 13.

Table 11: Normal Stress (Δ) Computation for the Samples

Load (kg)	Load (KN) (1) ÷100	Area (m^2)	(KN/m^2) (2)÷(3)
24	0.24	0.0036	66.7
44	0.44	0.0036	122.2
64	0.64	0.0036	177.8

Table 12: Shear Stress (ד) Computation

Sample	Load(kg)	Max H.R	(3) x 0.002 (mm)	(4) x 0.88 (KN)	(5) ÷A (KN/m^2)
TOP	24	96	0.1923	0.1692	47.0
	44	170	0.341	0.2295	83.1
	64	228	0.456	0.4013	111.5
MIDDLE	24	96	0.345	0.169	47.0
	44	172	0.42	0.3035	84.3
	64	210	0.1972	0.3696	102.7
BOTTOM	24	99	0.1972	0.17352	48.2
	44	174	0.348	0.306	85
	64	236	0.472	0.4154	115.4

Table 13: Shear Strength Computation

Sample	C(KN/m^2)	Ø (^{0})	δn (KN/m^2)	דKN/m^2
TOP	5	26	177.8	91.7
MIDDLE	4	27	177.8	94.6
BOTTOM	6	30	177.8	108.7

The shear stress versus normal stress plots (direct shear strength) for the soil samples are presented in Figure 6.

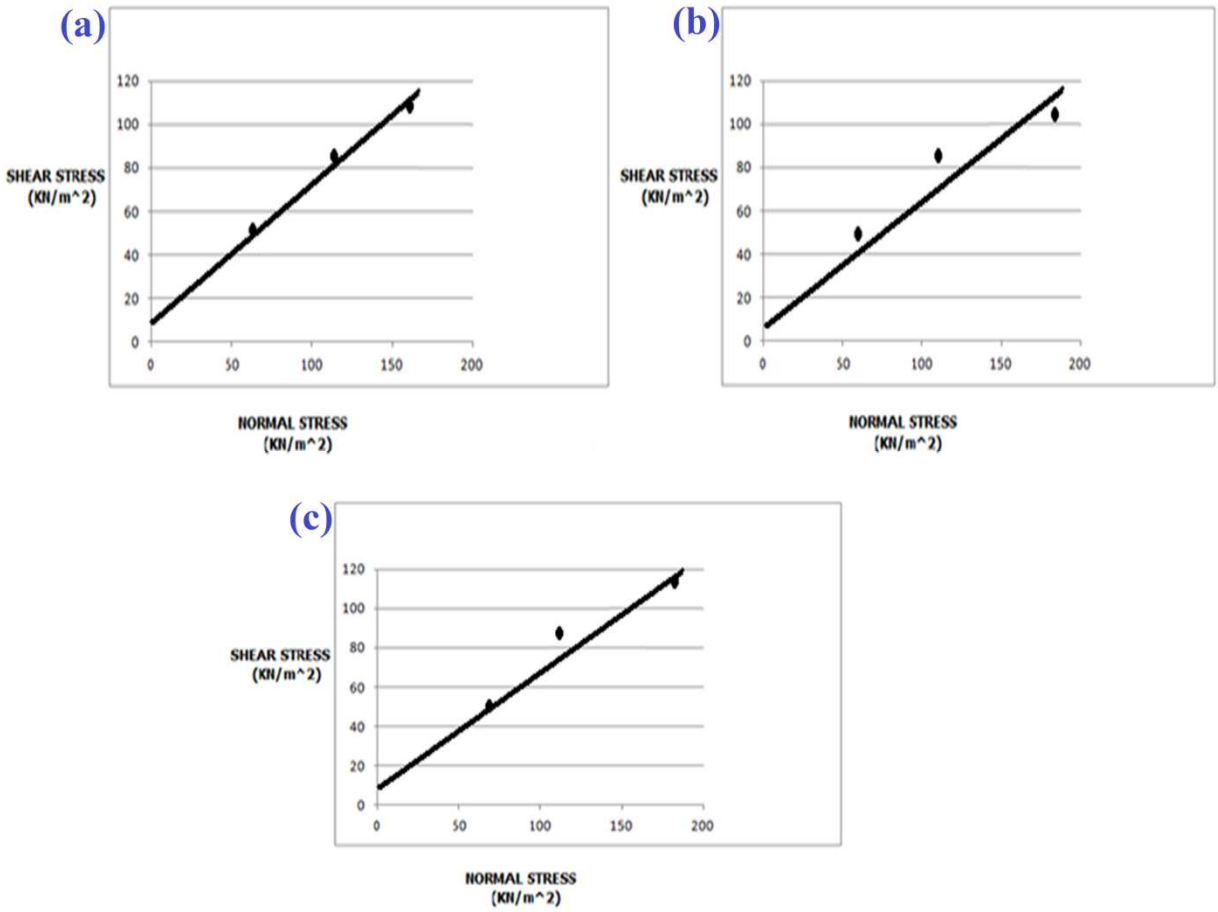

Figure 7: Shear Stress versus Normal Stress Plots for the (A) Top (B) Middle and (C) Bottom Soil Samples

CONCLUSIONS

Soil erosion in the form of gullies is very common in southeastern Nigeria. This study has shown the influence of geology, man and soil it-self on gully development and soil erosion in general. Past works on the estimation of potential soil erosion hazard in the region indicate that more than 1.6% of the entire land area has been devastated by gullies. The inherent characteristics of the local soils to a large extent promote the spread of soil erosion especially the gully type in the region.

It can be observed in the study area, that the people of Ofekata II autonomous community are mainly farmers, and artisans, etc. these classes of people do not understand that they are the ones encouraging the gully development. The government of the state has a portion of the blame too as they pay lip service to the drainage and proper sanitary disposal needs of the people in the area, houses are on the verge of collapse, to be roads are no longer there, and the villagers have to construct a make-shift bridge with lumbered trees, bags of sand and few cement blocks. This is dangerous as it can collapse at any given time due to the friable nature of the soil during heavy rainfall.

With the laboratory test results obtained, the gully is still in its early stages and can be curbed.

RECOMMENDATIONS

The problems of erosion, gullies, and landslides in the Southeast can be successfully tackled and solved by Nigerians if they sincerely decide to do so. The following suggestions and recommendations that can be handled singly or in groups, depending on availability of funds and materials, are humbly presented for your consideration and actions:

Construction of Drainages

There is every need to construct drainages as the communities do not have any to channel rain and surface water to streams or an outlet. The non-existence of drainages has aided in the gully development as the surface runoff after heavy downpour flood the area, destroy their farmlands and reduces the shear strength of the soil and hence encourages erosion.

Soil Conservative Measures

The use of vegetation has been acknowledged to prevent or reduce erosion through soil conservation. It was on this basis that, most Eastern Nigerian Government planted the cashew trees in the various parts of the region (Nanka, Agulu, Onitsha, Okigwe, Akwudor, Amucha, etc). The planting of bamboo trees in Ofekatta II autonomous community will help to control erosion as it has been noticed that most other trees can be dislodged from the roots. This explains the common use of bamboo tree by rural dwellers to control erosion. (UNEP 2011)

Government Activities in Erosion Prevention

A commission should be set up to monitor, report and proffer immediate solutions to Soil and Gully Erosion, and should be established by a Bill from the National Assembly. A special annual allocation or subvention of consolidated funds should be made and, possibly, budgeted for, for the next five years to the established commission to handle erosion and flood problems; the first assignment of the commission shall be to put aside one day every year that shall be declared an EROSION DAY for an annual appraisal of issues and problems of erosion nationwide.

More detailed studies and investigations should be carried out to produce maps, designs, cost, and reports on gully erosion sites for remedial work and control; Officials of the Presidency and members of the National Assembly should urgently carry out guided tours to the gully erosion-affected areas in South Eastern Nigeria so that they can see and appreciate the enormity of the ecological problems and become properly-guided in taking decisions on possible funding and assistance.

The uncontrolled felling of trees and clearing of bushes and forests, excessive bush burning, uncontrolled grazing of lands by cows and goats, etc. should be stopped. The Federal Ministry of Works and Housing must be made to change their planning, design and construction methods and techniques in gully erosion-prone areas since their present methods are erosion-causative and highly destructive. There is a great need to change the farming methods in the erosion-prone areas; The Ministry of Agriculture (Federal/State/LGA) should provide the necessary directives to the communities concerned.

Massive publicity (Press, radio, TV, etc.) should be embarked upon within and outside Nigeria in order to show the world-at-large the erosion problems in order to attract financial assistance. Erosion and flood control programmes and assignments must be worked out through involvement of people, individuals, communities, and LGAs of the affected areas through people-participation-in-projects-philosophy such that people can take an active part in gully erosion control projects. The World Bank, IMF, UNDP, UNEP, UNESCO, FAO, UNICEF, WMO, etc should be invited to assist in the

funding of projects on erosion control problems either in cash or through the provision of engineering or agricultural materials. A Panel of Inquiry should be carried out to establish how ecological funds for the Southeastern States were used to ensure judicious spending of the funds and promotes transparency.

This investigation was carried out in accordance with accepted geotechnical engineering practice. The conclusion and recommendation reached in the thesis are based on the data obtained from soil borings and test performed. It is not anticipated that the soil conditions will vary significantly from those described. However, should the soil conditions during any remedial works vary, it would be necessary to evaluate the engineering significance of such variations, which could result in further investigation and supplemental recommendations.

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