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Geotechnical Assessment of Gully Erosion at Ankpa Area, North Central Nigeria

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Abstract: *An assessment of the geotechnical parameters as causative agents in the formation of gullies in Ankpa area of north central Nigeria is presented. Gully erosion is an environmental hazard that is ravaging the landscape of Ankpa and its environs. Geologically, Ankpa falls within the Anambra Basin which is linked with the development of the Niger Delta Miogeosyncline and the opening of the Benue trough and underlain by sandstone of the Ajali Formation. Geological field work was carried out to assess the causes and extent of the gully erosion menace using traverse method. Soil samples were collected from gully sites and trial pits dug at varying depths for geotechnical analyses. The test carried out includes; Sieve analysis,specific gravity test, natural moisture content, compaction tests and Atterberg' limit tests. Results from the sieve analysis; uniformity coefficient (Cu) ranges from 2.4 to 8.0 and coefficient of gradation (Cc) range from 0.5 to 2.3, these indicate that the soil from the gully sites and trial pits are within the medium to coarse grain range with very low percentages of silt/clay. Plasticity index carried out to compare plasticity characteristics of erosion prone areas and stable land revealed that the soils are non-cohesive and non-plastic ranging from 2.5% to 10.5% at both areas. The compaction test shows that the optimum moisture content (OMC) ranges from 11.5% to 15.5% while the maximum dry density (MDD) ranges from 1.90KN/m^3 to 1.94KN/m^3. The maximum dry density values are generally low which indicates that the soils are not compact but very loose. The study identified Ankpa gully erosion to be induced majorly by natural factors and some human activities. The natural factors that influence erosion in Ankpa and its environs include; the highly friable Ajali sandstone underlying the area of study as observed from the geotechnical tests, gently and steeply sloping locations, heavy rainfall and under-rated runoff. Human activities include: non-compliance to town planning regulations, poor land management, land clearing for cultivation, bush burning, lumbering and excavation.*

Keywords: *Geological Properties, Geotechnical analysis, Gully Erosion, Ajali Formation*

I. Introduction

The formation of gullies is one of the greatest environmental disasters in Nigeria especially Southeastern and part of North Central Nigeria. Large areas of agricultural lands are lost or have become unsuitable for settlement and cultivation due to gully erosion. There have been numerous attempts to curb gully erosion in these regions; especially through large-scale engineering projects, however, little has been discussed about the real causes of this menace and ways to prevent their onset or the use of community-based low-technology approaches to mitigate their development.

Gully erosion can be defined as the erosion of the soil by flowing water in a well-defined channel and it is readily observable in the field because of its striking morphological expression on the landscape (Obiefuna & Jibrin, 2012). Gully erosion occurs primarily as a result of rain drop impact, washing away by running water which creates rills that later develop into gullies. The different activities of man without regards to the conservational laws are manifested by the degrading of the soil by the process of weathering and erosion. Though gully erosion problems arise mainly from natural causes but their extent and severity are increasingly being attributed to man's ignorance and unintentional action (Enabor and Sagua, 1988).

The features responsible for the causes of erosion depend on the amount of land exposed, the slope of the land, the nature of the soil, method of land management, the intensity and duration of rainfall, Hudson (1973), stressed that soil erosion has damaging effects on land and agricultural production. Akpata and Atanu (1990), concluded that the increasingly deforestation which affects environmental conditions results from low level of awareness among the people, this generally causes soil erosion, and recommended environmental education and land use management.

Gully erosion is an environmental hazard that is ravaging the landscape of Ankpa and its environs. Dangers of this menace are discussed in many textbooks and scientific journals but few people understand its real impact on agriculture, infrastructure, and socio-economic aspect of both urban and rural development in Kogi State especially Ankpa area. In light of the above consideration, geotechnical test was conducted in the study area where erosion is adversely devastating the land with a view to providing the geological, hydrological and geotechnical parameters that contribute to the genesis and expansion of these gullies. These assessments will help in suggesting appropriate prevention and control measures.

II. Study Area

Ankpa is located in the NW quadrant of Ankpa sheet 269 on a scale of 1:25,000. The study area covers a land area of about 30km², from longitude 7° 36'E to 7° 39' E and latitude 07° 23' N to 07° 26' N as shown in figures 1 below. Ankpa lies on a gently undulating plateau bisected by the river Anambra which drains most of the area. Ankpa is located in the eastern part of Kogi State. The people are predominantly Igala speaking; farming and trading are the major occupations of the people.

The topographical map below indicates the location of the study area as curled from Ankpa sheet 269 on a large scale of 1:25,000.

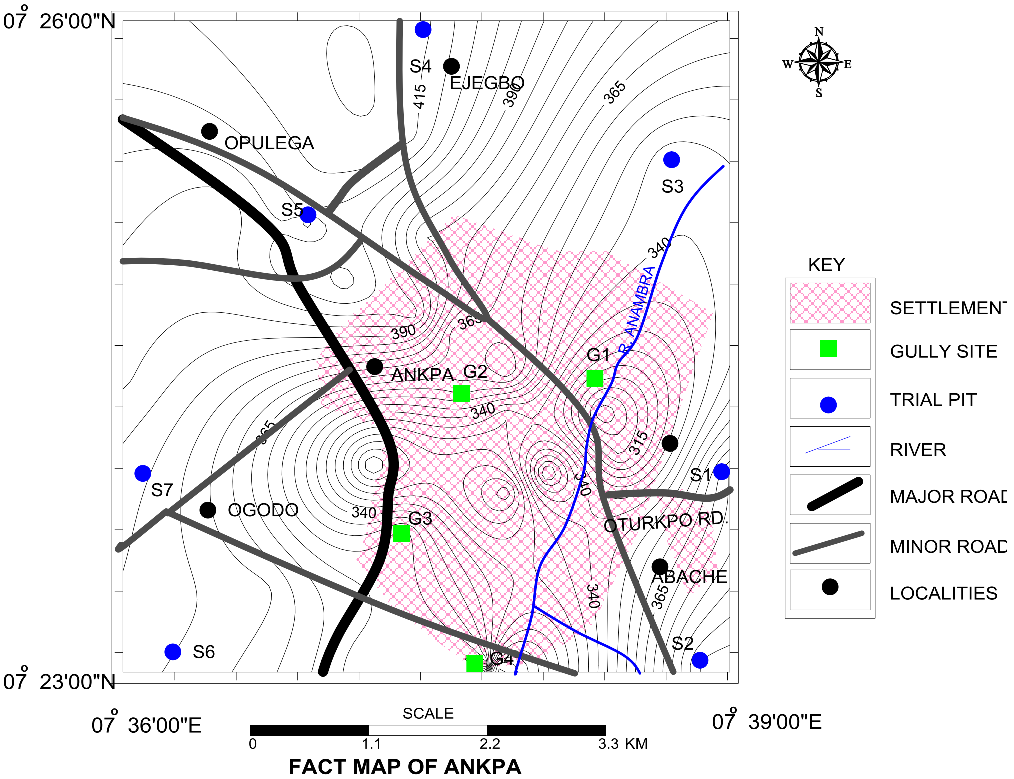

Figure 1: Topographical map of Ankpa area with gully sites and trial pit locations.
Source: Office of the Surveyor General of the Federation, 1987.

The relief map of Ankpa and its environs produced from the elevation and coordinates using surfer 8. This map presented in figure 2 below shows the undulating nature of the topography from the high elevations to the low. This explains how the topography influence gullies formation.

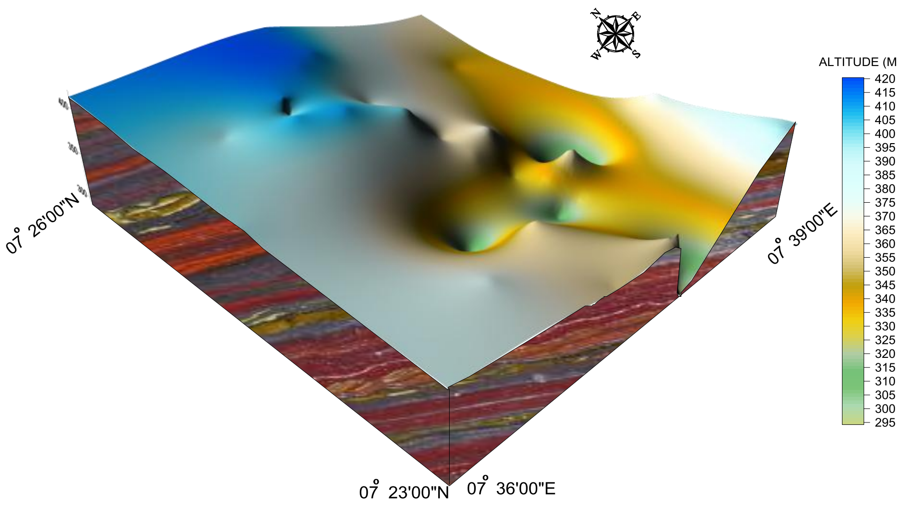

Figure 2: Relief map of Ankpa.

The topography is good for natural drainage with suitable gradients to the River Anambra which runs through the town. The climate of the area is essentially the same as that of the Middle Belt of Nigeria with high temperature and excessive humidity during the greater part of the year. The nearest meteorological station which has continuous records for a considerable period is at Lokoja, located on the western part of the project area and Makurdi. The meteorological data used in this research work is curled from those at the Nigeria Meteorological Agency Station in Lokoja. This is supported by the fact that areas in similar latitude experience similar meteorological conditions.

The Local Geology of the Area

The Geology shows that Ankpa falls within the Anambra basin whose genesis has been linked with the development of the Niger Delta Miogeosyncline and the opening of the Benue Trough, Murat (1972). Stratigraphically, Ankpa comprises of cyclic sedimentary sequence that started in the early Cretaceous time. Marine and fluviatile sediments comprising friable to poorly cemented sands, shales, clays and limestone were deposited, with occasional coal peat and thin discontinuous seams of lignite, Du Preez (1965). The sediments have been affected by the major Santonian folding and a minor Cenomanian folding and uplift, Murat (1972). The study area is typical of Ajali Formation or the false bedded sandstone, figure 3. The Ajali formation consists of thick friable poorly sorted sandstone, typically white in colour but sometimes iron-stained. Ajali sandstone is often overlain by a considerable thickness of red earthly sands, formed by the weathering and feruginization of the Formation.

Physiographically, the Anambra basin can be sub-divided into three main sub-basins (Ladipo, 1986):

i. The shallow and smaller Ankpa sub-basin to the north, which is separated from
ii. The deeper and longer southern Onitsha submarine basement feature, the Nsukka high land and
iii. The south-western extension of the sub-basin constituting the third arm, the Benin flank.

Geological map of Ankpa presented below indicates that Ankpa is underlain by the sandstone of the Ajali formation in the Anambra basin.

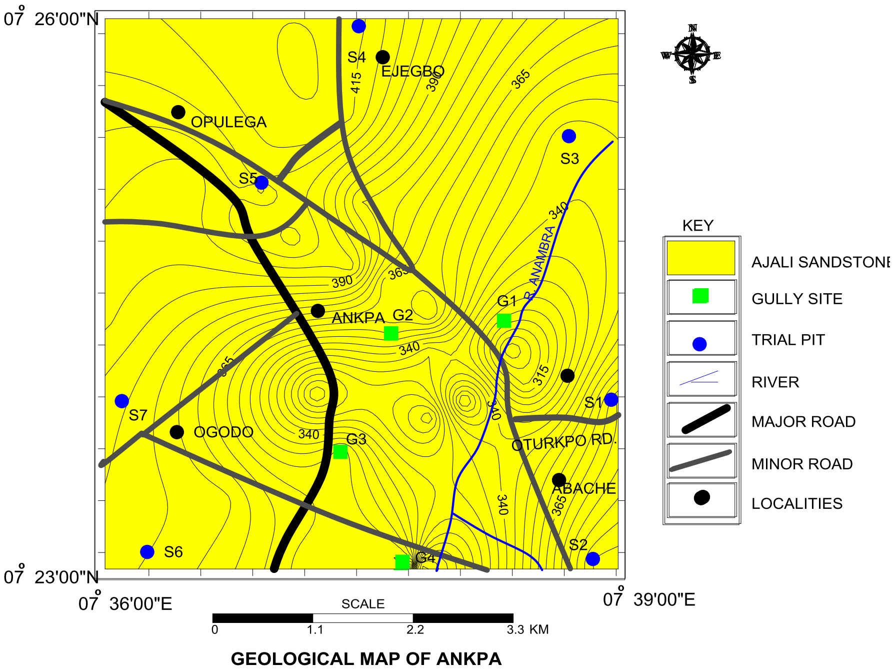

Figure 3: Geological map of Ankpa Area.

III. Material and Methods

Geological Field Work

Field work was conducted using transverse method to access gully sites and sample locations. About eleven (11) samples were collected at gully sites and from trial pits dug at 1m to 3.5m for geotechnical analysis in the laboratory. Each soil sample collected was observed in hand specimen and later stored in separate polythene bags and labeled accordingly for easy identification. The information recorded on each gully site includes; gully site location, elevation, longitude and latitude, width, and depth. The equipment used includes; Global Positioning System (GPS), topographical map, measuring tape, recording sheet, digital camera, hand trowel, shovel, and digger.

Laboratory Analyses

The samples collected from the field were analyzed using; sieve analysis, Atterberg' limits test, bulk and dry density, soil compaction test, specific gravity and natural moisture content determination. These analyses were carried out at the Civil Engineering Department laboratory of University of Agriculture, Makurdi.

Sieve analysis (grain size distribution)

The soil samples were oven-dried and then made ready for the grain-size analysis. The main equipments used are beam balance, mechanical sieve shaker, metal trays, set of sieve, and brush for cleaning the sieves. The sieves were arranged in order of reducing aperture. (300g each of the soil sample was used throughout the analysis). The air dried of the sample was necessary to reduce the moisture content and to facilitate easy passage of the grain through sieves. The set of sieves were shaken for 5 minutes for proper sieving of the soil sample. After this time, the material retained on each sieve was transferred in turn to the pan of a suitable balance on to a container. Any particle logged in the aperture of the sieve was removed with a brush. The mass of soil sample retained on each sieve was recorded against the sieve aperture size.

Particle size distribution curve

The result of mechanical analysis is generally presented on a semi-log graph known as particle size distribution curve. The particle diameters are plotted on the log scale and the corresponding percentage finer are plotted on the arithmetic scale. The general slope has the shape of the distribution and it is described by means of some constants such as effective sizes, uniformity coefficient, and coefficient of gradation. These terms are denoted as D_{10}, Cu, Cc, respectively.

Effective size

This is the diameter of the particle size distribution curve corresponding to 10% finer passing.

Uniformity coefficient

$$Cu = \frac{D_{60}}{D_{10}}$$

Where Cu = uniformity coefficient, D = effective sizes.

Coefficient of gradation

$$Cc = \frac{(D_{30})2}{D_{10}.D_{60}}$$

Where Cc = coefficient of gradation.
D = effective sizes.

Sorting coefficient

$$So = \left(\frac{(D_{75})}{(D_{25})}\right)^{1/2}$$

Where So = Sorting co
D = Effective si

Particle size distributio the range of particle size present in the soil as well as the manner in which size variation occurs. A coarse grained soil is described as well graded if there is no excess of particles in any size range and if no intermediate are lacking. A coarse grained soil is described as poorly graded.

a) A high proportion of the particles have size narrow limits.
b) Particles of both large and small sizes are present but with a relative low proportion of particles of intermediate size.

A Well graded sands have uniformity coefficient of Cu ≥ 6 and coefficient of gradation Cc = 1≤ Cc≤3 while poorly graded sands have uniformity coefficient of Cu < 6 and coefficient of gradation Cc = 1 >Cc>3
A graph of percentage finer passing against sieve sizes (particular diameter) to conventional scale is plotted. Flattened slopes show finer sands or poorly graded soils. A gentle slope shows intermediate sands while steep slope shows coarser sand soil well graded.

Calculations

$$\% \text{ retained on any sieve} = \frac{\text{wt of soil retained}}{\text{Total wt of sample}} \times 100$$

Determination of natural moisture content

Two cans of different sizes were used. The can numbers were recorded and then weighed to determine the weight of can. The cans were filled with the soil sample. The weight of can + wet sample was recorded. The samples were then oven dried for 24 hours at a temperature of 100°c. The sample was weighed to determine the dry weight of the sample. Water is an extremely important constituent of soils; the Engineers and the Geologists have assumed that soil has phases namely: the solid phase, liquid phase and gaseous phase. The solid phase is very stable while there is interchange in the liquid and gaseous phases occurring in the voids found in the soil.
The amount of water present in each sample to the amount of oven dried (105^0C) Samples calculated as weighed percentage is known as the natural moisture content of the soil. Therefore if natural moisture content is represented by W, it is given by the equation:

$$W = \frac{w1 - w_2}{w_2 - w_c} \times 100$$

Where w_1 = weight of container + moist soil
w_2 = weight of container + oven-dried soil
w_c = weight of container

Calculations for sample 1 are as shown in Table 4 and similar procedures were followed for all the samples.

Atterberg's limits test

Liquid Limit Test (LL)

A certain quantity of oven-dried soil sample was pulverized and sieved through 425µ (Micrometer) British Standard (B.S.) No. 40 sieve. The soil material was then mixed with water until a uniform paste was achieved and the paste was placed in the cup of the liquid limit device. The paste was smoothened and the grooving tool was drawn throughout the sample along the symmetrical axis of the cup, holding the tool perpendicular to the cup at the point of contact. The crack of the device was then turned and the number of blows necessary to close groove were noted. Care was taken to ensure that the groove was closed by a flow of the soil and not by slippage between the soil and the cup.

Plastic limit (PL)

The PL is defined as the moisture content in percentage at which the soil crumbles when rolled into threads of 3.2mm in diameter. The test is simple and is performed by repeatedly rolling an ellipsoidal soil mass by the finger on a glass plate. Some amount of the pulverized soil sample that was sieved through sieve B.S. No. 40 sieve was used for plastic limit test. The test soil thoroughly mixed with water and to such an extent of water content, which just allowed a thread of about 3.2mm to be rolled. The rolled sample was achieved on a glass plate and the process was repeated until a thread of about 3.2mm in diameter began to show signs of crumbling. Some of the crumbling materials were taken for water content determination, which when arranged, gives the plastic limit. Two of these determinations were obtained which were averaged to give the plastic limit.

Plastic index

This is the difference between the liquid and the plastic limit of any particularly disturbed sample (LL – PL).

Specific gravity

Soil sample which was air-dry weighed 150g after which it was filled with distilled water. The pycnometer with the water was weighed and then bottle was then emptied and dried. The oven dry samples was introduced into the bottle, the soil was stirred with a glass rod in order to allow trapped air to be released. Sufficient air-free distilled water was added so that the soil in the bottle is just covered then weighed.

The specific gravity is the ratio of the unit weight of soil particles to the unit weight of water at some known temperature (usually 40^0C) and range numerically from 2.60 to 2.80. Within this range, the lower values for the specific gravity are typical of sands. Values of the specific gravity outside the range of values given may occasionally be encountered in soils derived from parent materials that contained either unusually heavy minerals or light minerals.

$$\text{Specific gravity} = \frac{\text{Wt. of solid particles}}{\text{Wt. of an equal vol. of } H_2O}$$

Compaction test

Compaction tests are carried out with the aim of determining the moisture density relationships of soils. A number of methods have been developed for this purpose. These include the standard compaction method (also called proctor method), the modified (The American Association of State Highway and Transportation Officials) AASHTO method and the vibrating hammer methods. The method adopted for this work is the standard method due to its availability. This method was introduced by Proctor in 1933 and has since become the most widely used method of compaction test in the world (BS, 1377, 1967, Test II)

IV. Results and Discussion

Sieve analysis

The table below is the result of sieve analysis carried out in the laboratory on soil sample 1. The results of other samples from 2 to 11 will be discussed; certainly the tables and graphs of those samples are much to be display in this article.

Table 1 Sieve analysis for sample 1

Sieve size	Wt of soil retained (g)	Percentage Retained (%)	Cumulative percentage Passing (%)
1.4	0.2	0.08	100.0
1.0	2	0.04	98.4
6.3	27	0.08	97.0
5.0	7.0	10	93.0
3.35	16.4	3.0	88.4
2.36	39.9	17.3	85.0
1.70	30.8	15.1	81.0
1.18	15.0	13.4	65.0
850	8.5	22.5	50.0
600	0.4	3.7	21.5
425	40	2.6	8.3
300	13	0.1	5.1
Pan	0.3	1	4.0

A graph of percentage finer passing against sieve sizes (particular diameter) to conventional scale is plotted. Flattened slopes show finer sands or poorly graded soils. A gentle slope shows intermediate sands while steep slope shows coarser sand soil well graded. The graph below is the particle size graph for sample 1 showing coarser sand.

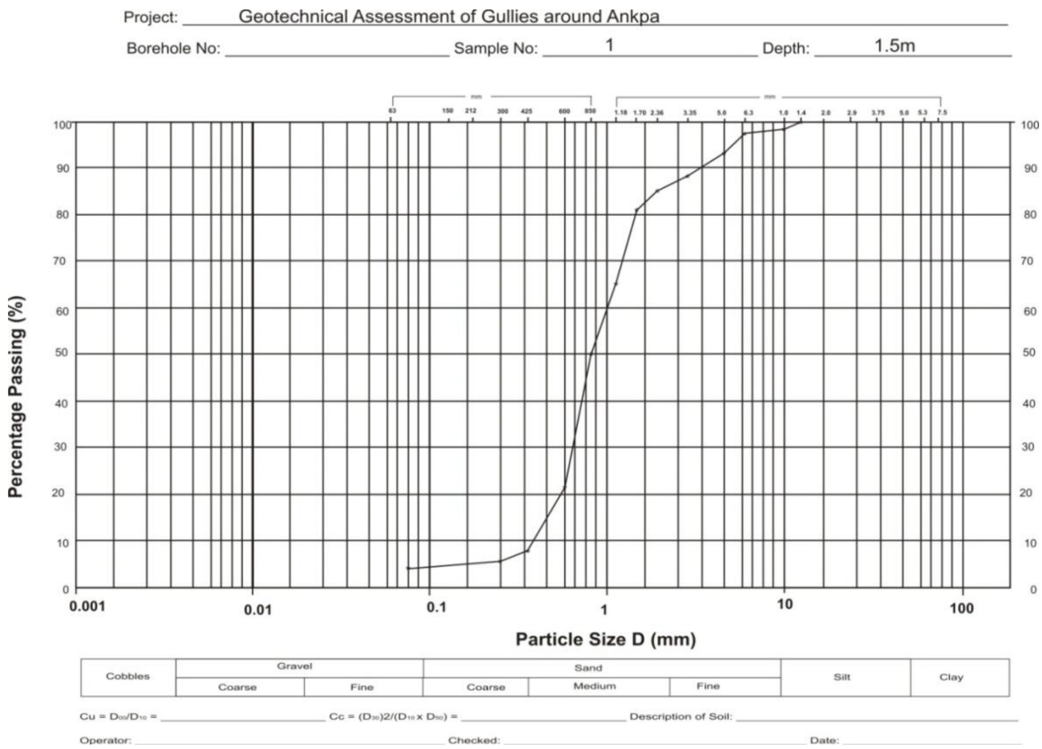

Figure 4: Particle size graph for sample 1

The general slope from the graph, figure 4, has the shape of the distribution and it is described by means of some constants such as effective sizes, uniformity coefficient, and coefficient of gradation. These terms are denoted as D10, Cu, Cc, respectively. The results explain the grade of the soil.

Uniformity Coefficient,

$$C_u = \frac{D_{60}}{D_{10}}$$

$$\frac{1}{0.42} = 2.4$$

$$C_u = 2.4$$

Coefficient of Curvature, C_c = $= \frac{(D_{30})^2}{D_{60}.\ D_{10}}$ $\frac{(0.6)^2}{(0.42 \times 1)}$

$$C_c = \frac{0.36}{0.42} = 1.0$$

$$C_c = 1.0$$

Sorting Coefficient, S_o = $\left\{\frac{(D_{75})}{(D_{25})}\right\}^{½}$

S_o = $\left[1.5 / 0.65\right]^{½}$ =

$S_o = \sqrt{2.3}$

$S_o = 1.5$

Determination of Atterberg's Limit

The table 2 is the result of Atterberg limit test; liquid limit and plastic limit for sample 1. Results of samples 2 to 11 will be discussed.

Table 2 Atterberg' limit test for sample 1

Test	Plastic limit		Liquid limit			
Container /No of Blows	118	101	112/12	214/22	72/32	81/42
Wt of cont + wet soil g	18.2	17.9	30.5	26.4	29.2	32.1
Wt of cont + dry soil g	18.0	17.7	27.7	24.6	27.0	29.8
Wt of Moisture g	0.2	0.2	2.8	1.8	2.2	3.3
Wt of Container	16.6	16.2	16.1	16.4	16.4	16.7
Wt of dry soil g	1.4	1.5	11.6	8.0	10.6	13.1
Moisture Content %	14.3	13.3	24.1	22.5	20.8	17.6

Figure 5 below shows Liquid Limit graph for sample 1. From the test results presented in table 2, a graph of moisture content against number of blows is plotted. The moisture content at 25 blows gives Liquid Limit.

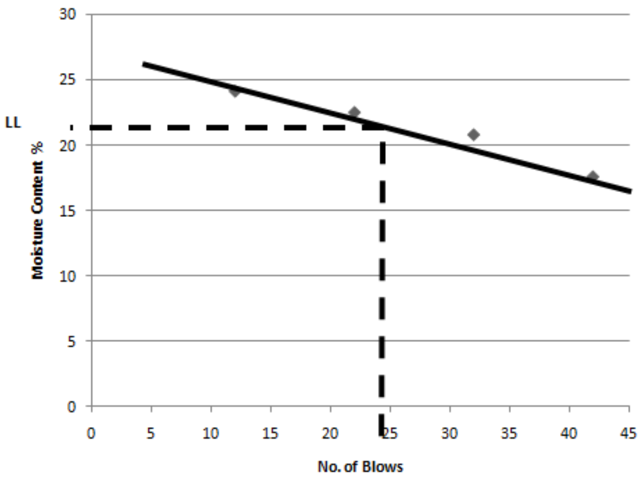

Figure 5: Liquid limit graph for sample 1.

Liquid limit (LL) =22.0
Plastic limit (PL) =13.8
Plasticity index (PI) PI=8.2

Specific gravity test results

The specific gravity is the ratio of the unit weight of soil particles to the unit weight of water at some known temperature (usually 40°C) and range numerically from 2.60 to 2.80. Within this range, the lower values for the specific gravity are typical of sands.

Depth of 1.5m sample (m)	**Sample 1**		**Sample 2**	
Soil specimen number	**1**	**2**	**1**	**2**
Mass of gas jar, plate, soil and water (M_3) g	118.4	120.2	119.2	120
Mass of gas jar, plate, and soil (M_2) g	49.2	51.0	50.3	51.3
Mass of gas jar, plate, and water (M_4) g	109.9	109.9	109.9	109.9
Mass of gas jar, and plate (m_1)	34.8	34.8	38.4	38.4
M_2-m_1 g	14.4	16.2	15.5	16.5
M_4-m_1 g	75.1	75.1	75.1	75.1
M_3-m_2 g	69.2	69.2	68.9	68.7
(M_4-m_1)-(M_3-m_2)	5.9	5.9	6.2	6.4
Specific gravity $Gs=(m_2-m_1)/[(m_4-m_1)-(m_3-m_2)]$	2.4	2.7	2.5	2.6
Average specific gravity	2.6		2.6	

Table 3: Specific gravity test for samples 1 and 2**.** Results of samples 3 to 11 will be discussed.

Soil compaction test

Compaction tests are carried out with the aim of determining the moisture density relationships of soils. The table 4, below is soil compaction test result for sample 1. Results of samples 2 to 11 will be discussed.

Table 4: Soil compaction test result for sample 1.

No. of procedures	**1**	**2**	**3**	**4**	**5**
Moisture can No.	129	58	91	72	63
Mass of cup + wet soil	81.0	79.0	84.0	85.3	83.4
Mass of cup + dry soil	77.2	73.7	76.7	76.3	73.1
Mass of water	3.8	5.3	7.3	9.0	10.3
Mass of cup, g	16.3	16.3	16.5	16.3	16.0
Mass of dry soil, g	60.9	57.4	60.2	60.0	57.1
Water content, w%	6.2	9.2	12.1	15.0	18.0

A graph of dry density against the water content obtained from the analysed data is plotted to obtain the maximum dry density (MDD) and optimum moisture content (OMC) as presented in figure 6 below. Soil compaction graphs of samples 2 to 11 will be discussed.

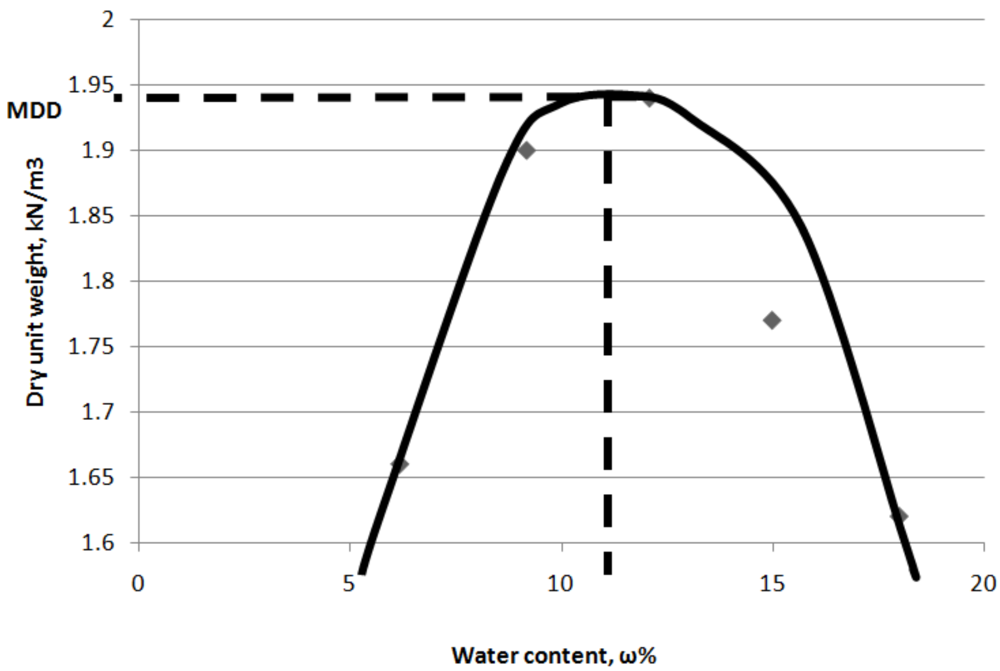

Figure 6: Soil compaction graph for sample 1.

Natural moisture content results

The amount of water present in each sample to the amount of oven dried (105̊C) samples calculated as weighed percentage is known as the natural moisture content of the soil**.** The table 5 below is the results of Natural Moisture Content test carried out on sample 1. Results of samples 3 to 11 will be discussed.

Table 5 Natural moisture content for samples 1 and 2

Sample No		**1**			**2**	
Depth of sample (m)		**1.5m**			**1.5m**	
Soil specimen number	1	2	3	1	2	3
Container No.	20	7	19	3	113	20
Mass of container + wet soil (g)	54.7	60.4	54.2	64.3	71.3	76.1
Mass of container + dry soil (g)	51.5	56.9	51.0	59.7	66.3	70.3
Mass of container (g)	15.8	16.4	16.9	15.8	16.4	15.8
Mass of dry soil (g)	35.7	40.5	34.1	43.9	49.9	54.6
Mass of moisture (g)	3.2	3.5	3.2	4.6	5.0	5.7
Moisture content (%)	9.0	8.6	9.4	10.5	10.0	10.4
Average moisture content (%)		9.0			10.3	

V. Discussion

Results of sieve analysis

According to the Unified Soil Classification (USC), a graph of percentage finer passing against sieve sizes (particular diameter) to conventional scale is plotted. Flattened slopes show finer sands or poorly graded soils. A gentle slope shows intermediate sands while steep slope shows coarser sand. The particle size graph (figure 4 above and that of sample 2), shows gentle to steep slopes. These infer intermediate to coarser sand. Well graded sands have uniformity coefficient of $Cu \geq 6$ and coefficient of gradation $Cc = 1 \leq Cc \leq 3$ while poorly graded sands have uniformity coefficient of $Cu < 6$ and coefficient of gradation $Cc = 1 > Cc > 3$. From the sieve analysis, uniformity coefficient (Cu) ranges from 2.4 to 8.0 and coefficient of gradation (Cc) ranging from 0.5 to 2.3 as shown in table 4. The results of the sieve analysis shows a grain size distribution ranging from medium to coarse well graded to poorly graded, poorly sorted sands with gentle to steep slopes. The absence of "fines" or silt/clay content indicates that the soils are non-plastic.

The table 5 below is the summary of sieve analysis results; uniformity coefficient and coefficient of gradation, calculated from the particle size graph (figure 4).

Table 5: Summary of sieve analyses results.

Sample No.	Cu	Cc
1	4.2	1.25
2	3.4	1.0
3	5.6	1.0
5	4.7	0.5
6	8.0	2.3
7	4.2	1.0
8	4.0	1.0
9	5.3	1.0
10	3.2	1.30
11	6.3	1.20

Results of Atterberg's Limit test.

The results of Atterberg's limit test are summarized in table 5 below. The liquid and plastic limits were used to obtain the plasticity index which is a measure of the plasticity of the soils, Onwemesi (1990). The values of the plastic index obtained range from 2.5% to 10.5% (table 6), this shows slight to low plasticity; (table 7), according to Burmister (1997).In the standard range of plastic limit of soil, according to Clayton and Juckes (1978), plastic limit of soil below 35% shows low plasticity (table 8). The results of plastic limit test presented in table 5 ranges from 10.95% to 18.05% <35%. Therefore the non-cohesive or the friable nature of the soils in the area account for the gully erosion problems because water flows through the soil with ease and move the soil particles down slope with increase in velocity of motion of the water**.** A plasticity chart was plotted, (figure 7). From the plasticity chart, all the soil samples from the various gully sites have their plots clustered within the low plastic range hence they are cohensionless**.**

Liquid limit, plastic limit and plasticity index for different samples obtained at various locations.

Table 6: summary of liquid limit, Plastic limit and the Plastic Index

Sample No.	Liquid Limit (%)	Plastic Limit (%)	Plastic Index (%)
1	22.0	13.8	8.2
2	25.1	16.8	8.3
3	24.0	16.4	7.6
4	23.0	13.8	9.2
5	17.8	10.49	10.5
6	21	10.95	6.55
7	16.0	10.49	5.51
8	24.5	14.35	10.5
9	23.0	18.05	4.95
10	17.0	12.65	4.35
11	19.5	16.95	2.55

The table 7 below is the plasticity indices corresponding to states of plasticity according to Burmister (1949). The values of the plastic index obtained range from 2.5% to 10.5% (table 5), this shows slight to low plasticity.

Table 7: Plasticity indices and corresponding states of plasticity

S/n	Plasticity index %	State of plasticity
1	0	Non plastic
2	1-5	Slight
3	5-10	Low
4	10-20	Medium
5	20-40	High
6	>40	Very High

Source: Burmister (1949).

The table 8 below is the standard range of plastic limits of soil according to Clayton and Juckes, (1978). From the plastic limit test results presented in table 5, the plastic limit range from 10.49% to 18.05%. The results are below 35% and hence the soil has low plasticity.

Table 8: Standard Range of Plastic Limits of Soil

Plastic limit of soil	Plasticity
Below 35%	Low plasticity
Between 35 – 50%	Intermediate plasticity
Above 50	% High plasticity

Source: Clayton and Juckes, (1978).

The figure 7 below is the plasticity chart, according to the American Society for testing and materials (ASTM D24B7). The Values of liquid limit and plasticity indices obtained from the Atterberg' limit tests are plotted. From the plasticity chart, all the soil samples from the various gully sites have their plots clustered within the low plasticity.

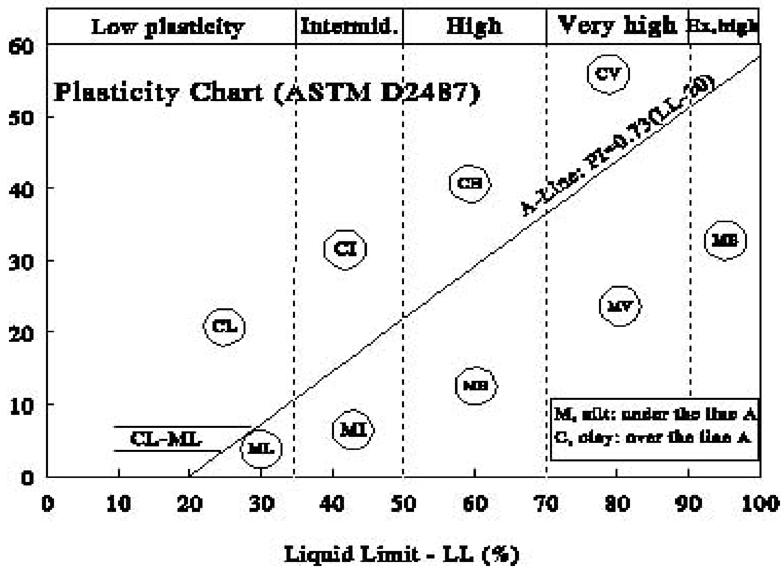

Figure: 7: Plasticity chart.

Source: American Society for testing and materials (ASTM D24B7)

Specific gravity test result

The specific gravity test is a measure of unit weight of a soil according to AASHTO. The results of specific gravity obtained from the analysis ranges from 2.5 to 2.7 (Table 9). This shows that the soil within Ankpa and environs are sandy and very light which makes them susceptible to surface runoff and hence erosion.

Table 9: Summary of specific gravity test results

Sample No.	Specific Gravity (SG)
1	2.6
2	2.6
3	2.7
4	2.7
5	2.6
6	2.5
7	2.6
8	2.5
9	2.6
10	2.7
11	2.5

Natural Moisture Content and Soil Compaction Test

The natural moisture content of a soil refers to the amount of water in the soil which is an indication of the drainage property of the soil. The results of the moisture content presented in table 9 indicates that the soil samples show relatively low moisture content value ranging from 0 to 10.7% this is because the soil are loose and hence cannot hold much water. Compaction test shows the maximum dry density (MMD) and the optimum moisture content (OMC) of the soil. One of the major reasons for carrying out compaction test on soil is to increase the soil strength and to prevent seepage of water through the soil. Hence both soil water content and the bulk density (dry density) affect soil strength, which will increase when the soil is compacted to a higher density and when the soil loose water, it dries and hardens.. The analysis shows that Ankpa and its environs have relatively weak and loose soil. This is responsible for failure of structures like drainages and culverts, therefore for construction of culverts and drainages, quantities of cementing materials like clay should be applied along construction zones to strengthen the soil. Though compaction test indicates the maximum dry density to which the soil may be compacted by a given force and it indicates when the soil is either drier or wetter than its optimum moisture content while compacting will be more difficult Brady and Weil, (1999). The porosity and water content of a rock also governs its comprehensive strength which decreases with an increase in porosity, since the water present in the rock will reduce the magnitude of internal friction of the rock, consequently decreasing its strength; the moisture content reduces the soil strength, Garg (2003).

The table below is the summary of natural moisture content and soil compaction test results for all the soil samples analysed.

Table 10: Natural moisture content and soil compaction test results

S/NO	MC%	MDDg/cm³	OMC%
1	9.0	1.94	11.5
2	10.3	1.93	12.3
3	9.0	1.94	15.5
4	10.7	1.92	12.0
5	8.6	1.90	14.0
6	10.7	1.90	11.5
7	9.0	1.94	12.0
8	10.7	1.93	12.8
9	9.2	1.90	14.0
10	7.0	1.93	12.1
11	8.5	1.94	11.9

VI. Conclusion

The results obtained in this investigation so far; (Atterberg, sieve, specific gravity and compaction test) show that the soils in the study area are cohensionless, not compact, and non-plastic, hence the menace of gully erosion. A highly exaggerated emphasis and predominance on engineering control measures involving construction of check-dams, bulldozing of earth materials, backfilling with soils and compacting, or construction of drainage or cut-off flood channels do not seem to be successful in checking gully incipient and extension or expansion in Ankpa and environs. Rather the engineering aspects of soil erosion control should be geared towards changing the slope characteristics of the area so that the amount and velocity of run-off are decreased drastically by adding considerable quantity of cementing materials like clay to the soil. Other soil stabilization techniques such as grouting, dewatering, construction of concrete ripraps and horizontal concrete terracing should be applied where pore pressures and seepage forces are high. The use of an integrated agronomic and engineering practice that will protect the soil and reduce run-off is also required. This will involve afforestation and tillage practices that lead to the use of agro-forestry practices which are based upon the development of the interface between the agricultural and forestry use of land.

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