Available online at www.elixirpublishers.com (Elixir International Journal)

Earth Science

ISSN: 2229-712X

Elixir Earth Science 161 (2021) 55919-55932

Geotechnical Investigations of Nekede Mechanic Village Gully, Owerri, Nigeria

Ikechukwu E. Nwosu
Department of Physics, Imo state University, P.M.B. 2000 Owerri, Nigeria.

ARTICLE INFO

Article history:
Received: 24 November 2021;
Received in revised form:
21 December 2021;
Accepted: 31 December 2021;

Keywords
Atterberg Limits,
Bulk Density,
Gully Erosion,
Plastic Limit,
Shear Strength,
Sieve Analysis.

ABSTRACT
This paper analysed the possibility of expansion of Nekede Mechanic-Village gully located in Imo State Nigeria using Geotechnical tests method. The gully site is located on longitude 7° 2' 6"E and latitude 5° 27' 46"N. The analysis of the Geotechnical tests showed that Site Areas 3 and 4 are structurally week and susceptible to erosion due to their poor Shear Strength and Bulk Density values – in addition to being Non-Plastic. In contrast, site areas 1 and 2 are relatively stable. Sites 3 and 4 are located close to residential areas thus demanding desperate attention from government agencies before the expanding gully wreaks havoc.

Introduction

Geotechnical materials are natural materials, and their properties are affected by various factors during their formation process, such as properties of their parent materials, weathering and erosion processes, transportation agents, and conditions of sedimentation (e.g., Vanmarcke 1977; Jaksa 1995; Phoon and Kulhawy 1999a; Baecher and Christian 2003; Mitchell and Soga 2005). Properties of geotechnical materials, therefore, vary spatially, which is usually known as "inherent spatial variability" (e.g., Vanmarcke 1977, 1983). In addition to inherent spatial variability of soils, various uncertainties are also incorporated into the estimated soil properties during geotechnical site characterization (e.g., Christian et al. 1994; Kulhawy 1996; Phoon and Kulhawy 1999a), including measurement errors arising from imperfect test equipments and/or procedural–operator errors.

Soil properties inherently vary from one location to another location in both horizontal and vertical directions. The soil property at the same elevation is frequently simplified and represented by a single variable (i.e., fully correlated along horizontal direction). Such simplification is usually considered reasonable to some degree for at least two reasons: (1) The soils at the same elevation went through similar geological processes. Therefore, the values of a soil property at different locations, but with the same elevation, are somewhat close to each other, and the correlation of the soil property at different locations in horizontal direction is much stronger than that in vertical direction (e.g., Phoon and Kulhawy,1999); (2) such simplification generally leads to conservative designs (e.g., Fenton and Griffith 2007; Klammler et al. 2010).

Gully erosion is a highly visible form of soil erosion or an antecedent of the removal of soil by running water that affects soil productivity, restricts land use and threaten roads fences. The issue of gully erosion in Mechanic Village Nekede (fig. 1) has remained intractable for over some years now and has done serious damage to the psychic of the local inhabitants of the area. The negative impact of gully has social, psychological, economic and health consequences. Many homes have been caused to relocate involuntarily: buildings are at the brink of collapsing into the gully. The gully has crippled communication in the affected areas as communities that were ordinary neigbours have suddenly become distant strangers. This has drastically affected social networks and interaction among indigenes of the affected communities.

Nîr (1983) indicated that urbanization affects erosion processes by removing vegetative cover, and also makes land impervious with layer of asphalt or concrete, thus altering drainage patterns, and increasing the amount of surface runoff and surface wind speeds. This increased runoff disrupts surrounding watersheds by changing the volume and rate of water flowing through them as reported by James (1995). Four primary types of erosion resulting from rainfall occur. They are splash erosion, rill erosion and gully erosion. Splash erosion is the first and least severe stage in the soil erosion process, this is followed by sheet erosion, then rill erosion and finally gully erosion which is the most severe as indicated by Zachar (1982); and Toy (2002).

Geology and Geomorphology of the Study Area

Nekede area is located in an area underlain by Benin Formation. The units are made up of sandy to gravelly sands without any shale or swelling clays. In general, Benin Formation spans from Miocene to Recent. It is the youngest of Niger Delta sediments. Its thickness is about 6,000ft, and very little hydrocarbon accumulation has been associated with the Benin Formation. The Benin Formation comprises the top part of the Niger Delta clastic wedge,

Tele: +234-8037729691
E-mail address: koonwosu2@yahoo.com

from the Benin-Onitsha area in the north to beyond the present coastline (Short and Stumble, 1967). The Benin formation consists of massive continental sands and gravels, it underlain gradationally by the delta front paralic lithofacies. The top of the formation is the recent sub aerially - exposed delta top surface and its base extend to a depth of 4600 feet. The base is defined by the youngest marine shale. Shallow parts of the formation are composed entirely of non-marine sand deposited in alluvial or upper coastal plain environments during progradation of the delta (Nwajide and Reijers, 1996). Although lack of preserved fauna inhibits accurate age dating, the age of the formation is estimated to range from Oligocene to Recent. Benin Formation covers the following areas: Benin City, Warri, Rivers State, Cross River State, Abia state (Part of Umuahia, and Aba), Imo State (some part of Aṅara, Amaimo, Ikeduru, Atta Village) it covers the entire owerri area with its outcrops at Ihiagwa behind Federal University of Technology Owerri.

The topography of the study area could generally be described as fairly steep with an average slope of about 8%; this is a continuous slope running from the upper reaches of the catchment (basin) down into the Nwokobo river valley. The drainage pattern is in agreement with the general topography of the study area, the entire study area is drained by the Imo River and its tributary, the Nwokobo River. Imo River is about 13km from the gully head which is some few meters from the Umueze-Eziala channels that convey run off into the gully which level expanded over the years. These drainage channels are fast gully fingers as some are currently up to 3m deep and about 4m wide.

The climate condition of the Mechanic Village Nekede study area is characterized by uniformly high temperature and a seasonal distribution of precipitation. A typical Wet and Dry season prevails in the area. The dry season (harmattan) runs through the months of October to March and the rainy season that begins in March and ends in October. The southwards moving Sahara air mass causes the dry season which is associated with extreme aridity, a dusty atmosphere, lowering of water levels and intense leaf fall. The rainy season follows the northward advance of maritime air from the Atlantic Ocean. July and August are usually the wettest periods of the rainy season.

The study area lies within the humid tropical rainforest belt of southeastern Nigeria and evidences of Sahara type vegetation. The dominant vegetation of the study area is the cashier trees planted by the colonial officials in a failed attempt to check and contain the gully expansion, many of these have been uprooted and ostensibly by the gullies. The surviving trees and remnants of the original rainforest can still be seen in the unaffected area within the stabilized gully areas and the river valley. Southeastern Nigeria is a typical gully erosion region in Nigeria. The presence of gully sites is one of the hazardous features that characterize Imo State as well as other states that adjoin it (Ofomata, 2008). A conservative assessment shows the distribution of known gully sites, in different stages of development as expressed in table 1. The studied gully has both active and dormant parts as shown in figures 3 and 2 respectively.

Materials and Methods

Sieve analysis consists of shaking the soil sample through a set of sieves that have progressively smaller openings. The sieves used for soil analysis are generally 203 mm in diameter. To conduct a sieve analysis, one must first oven-dry the soil and then break all lumps into small particles. The soil then is shaken through a stack of sieves with openings of decreasing size from top to bottom (a pan is placed below the stack). After the soil is shaken, the mass of soil retained on each sieve is determined. When cohesive soils are analyzed, breaking the lumps into individual particles may be difficult. In this case, the soil may be mixed with water to make a slurry and then washed through the sieves. Portions retained on each sieve are collected separately and oven-dried before the mass retained on each sieve is measured.

Albert Atterberg developed a method to describe the consistency of fine-grained soils with varying moisture contents. At very low moisture content, soil behaves more like a brittle solid. When the moisture content is very high, the soil and water may flow like a liquid. Hence, on an arbitrary basis, depending on the moisture content, the nature of soil behaviour can be broken down into four basic states: solid, semisolid, plastic, and liquid, as shown in Figure 4. The moisture content, in percent, at which the transition from solid to semisolid state takes place, is defined as the shrinkage limit (Dias, 2011).

The moisture content at the point of transition from semisolid to plastic state is the plastic limit, and from plastic to liquid state is the liquid limit. These limits are also known as Atterberg limits. The plastic limit is defined as the moisture content, in percent, at which the soil when rolled into threads of 3.2 mm in diameter, crumbles. The plastic limit is the lower limit of the plastic stage of soil. The test is simple and is performed by repeated rollings by hand of an ellipsoidal size soil mass on a ground glass plate The plasticity index (PI) is the difference between the liquid limit and plastic limit of a soil .

$$PI = LL - PL \qquad (1)$$

In this study, four sites around the Active and Dormant gullies were selected for geotechnical Soil test to ascertain the possibility of Gully extension towards roads and residential areas. These sites are shown in figure 5 as 1, 2, 3, and 4. The study was done in collaboration with Institute of Erosion Studies Federal University of Tech. Owerri.

Data Presentation and Discussion

The results of the geotechnical tests of the core samples obtained from sites 1, 2, 3 and 4 are presented in the following order; Sieve Analysis, Liquid limit and Plastic limit (where applicable), Shear Strength, and Bulk Density.

It is deducible from Sample 1 data that it is made up of slightly very fine gravelly medium sand with Liquid limit (LL) of 54.2% and Plasticity index (IP) of 24.1% which yields 30.1% as Plastic Limit on applying equation 1. The Shear Strength value is 192.3 KN/m^2 while the Bulk Density value obtained is 1.87 mg/m^3.

It can be inferred from Sample 2 data that it is made up of slightly very fine gravelly coarse sand with Liquid limit (LL) of 44.8% and Plasticity index (IP) of 16.2% which yields 28.6% as Plastic Limit on applying equation 1. The Shear Strength value is 98.9 KN/m^2 while the Bulk Density value obtained is 1.95 mg/m^3.

It can be inferred from Sample 3 data that it is made up of slightly very fine gravelly medium sand which is non-plastic. The Shear Strength value is 95 KN/m^2 while the Bulk Density value obtained is 1.79 mg/m^3.

It is evident from Sample 4 data that it is made up of slightly very fine gravelly medium sand which is non-plastic. The Shear Strength value is 110.58 KN/m^2 while the Bulk Density value obtained is 1.79 mg/m^3.

Conclusion

The shear strength of a soil mass is the internal resistance per unit area that the soil mass can offer to resist failure and sliding along any plane inside it. Engineers use the nature of shearing resistance in order to analyze soil stability problems such as bearing capacity, slope stability, and lateral pressure on earth-retaining structures. Comparatively, Bulk density is an indicator of soil compaction. Bulk density reflects the soil's ability to function for structural support, water and solute movement.

On comparing the Soil Types, Plastic Limits (where applicable), Shear Strengths, and Bulk Densities of core samples of 1,2,3,and 4; it is glaring that sites 1 and 2 are structurally stable since they are plastic, and have highest value of Shear Strength or Bulk Density. Sites 3 and 4 cannot be said to be stable from the data obtained in this study – a very troubling situation considering the fact that they are located close to residential areas (see Figure 5).

References

Baecher, G.B., and J.T. Christian (2003). Reliability and statistics in geotechnical engineering, 605 pp. Hoboken, New Jersey: Wiley.

Busby, J. P. and Peart, P. J (1997).Azimuthal resistivity and seismic measurements for the determination of fracture orientations.Geological Society, London, Engineering Geology Special Publications, 12, 273–281.

Christian, J.T., Ladd C.C., and Baecher G.B. (1994). Reliability applied to slope stability analysis. Journal of Geotechnical Engineering 120(12): 2180–2207.

Dias B. M., (2011).Fundamentals of Geotechnical Engineering. Paraninfo, Madrid Spain.

Fenton, G.A.,and Griffiths D.V. (2007).Reliability-based deep foundation design. In Probabilistic applications in geotechnical engineering, Geotechnical Special Publication No. 170, 1–12.

Igbokwe J.I., Ojiako J.C, and Nnodu V.C (2003) Monitoring Characterization and controlling of floodwater erosions using remote sensing techniques proceedings of the technical session of 38th annual conference of Geological Society of Nigeria

Jaksa, M.B. (1995). The Influence of Spatial Variability on the Geotechnical Design Properties of a Stiff, Overconsolidated Clay. Ph.D. thesis of the University of Adelaide

James W. (1995); Channel and habitat change downstream of urbanization. In Herricks, Edwin E. & Jenkins, Jackie R. Stormwater Runoff and Receiving Systems: Impact, Monitoring, and Assessment. CRC Press. 105.

Klammler, H., McVay M. , Horhota D., and Lai P. (2010). Influence of spatially variable side friction on single drilled shaft resistance and LRFD resistance factors. Journal of Geotechnical and Geoenvironmental Engineering 138(8): 1114–1123.

Kulhawy, F.H. and Mayne P.W. (1990).Manual on estimating soil properties for foundation design, Report EL 6800, 306 pp. Palo Alto: Electric Power Research Inst.

Mitchell, J.K., and Soga K. (2005).Fundamentals of soil behaviour. Hoboken, New Jersey: Wiley

Nîr Dov. (1983); Man, a Geomorphological Agent: An Introduction to Anthropic Geomorphology.Springer. 121–122.

Nwajide C. S and Reijers T. J. A. (1996); Sequence Architecture in outcrops: Example from the Anambra Basin, Nigeria. NEPE Bull. **11**/01, Nov. p. 23-32

Phoon, K.K., and Kulhawy F.H. (1999). Characterization of geotechnical variability. Canadian Geotechnical Journal 36(4): 612–624.

Short, K.C. and Stauble, (1967). A.J. Outline of geology of Niger delta. Bull.Am.Ass.Petrol.Geol. **54**, p. 761-779.

Toy T.J, Forster G.R, Renard K.G. (2002); Soil Erosion: Processes, Predicition, Measurement, and Control. John Wiley and Sons. 338:1. ISBN 978-0-471- 38369-7

Vanmarcke, E.H. (1977). Probabilistic modeling of soil profiles. Journal of Geotechnical Engineering 103(11): 1127–1246.

Vanmarcke, E.H. (1983). Random fields: analysis and synthesis. Cambridge: MIT Press.

Zachar D. (1982); Classification of soil erosion. Soil Erosion. Elsevier. 10:48.

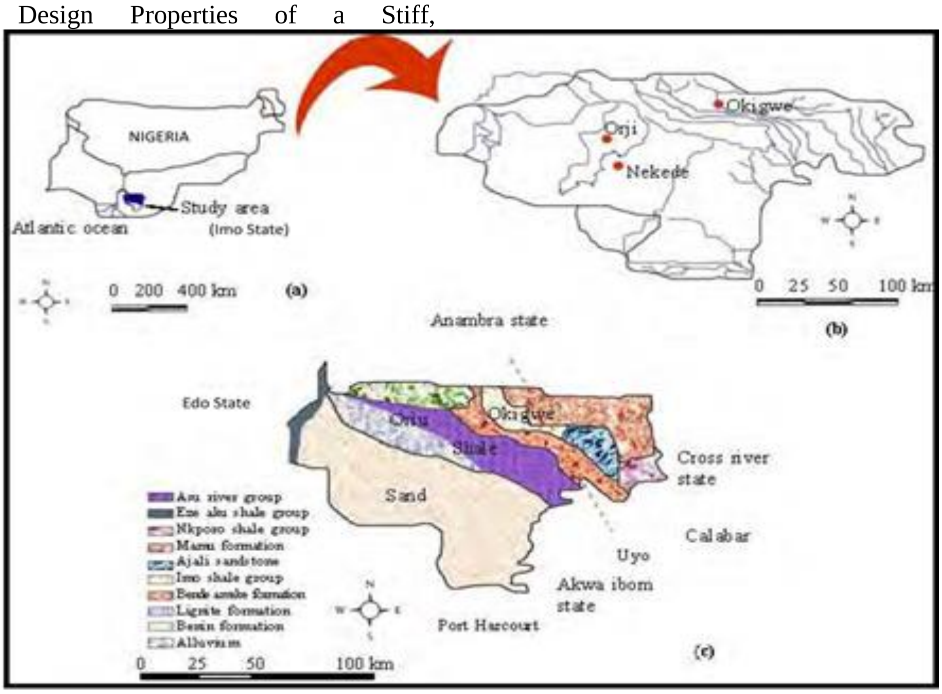

Fig 1. Map showing Location of the Study Area

Fig 2. Dormant Part of the Gulley

Fig.3. Extension of Active Part of the Gulley

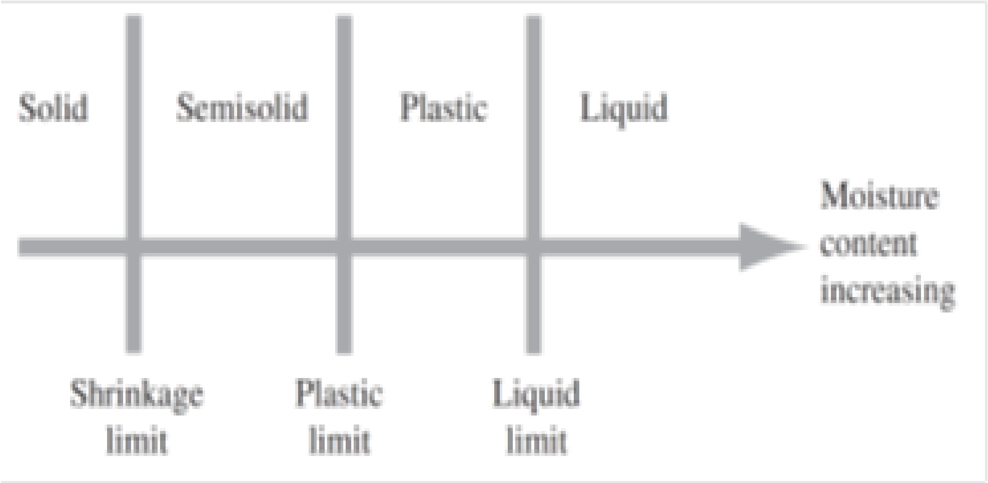

Fig 4. Atterberg Limits (B. M. Dias, 2011).

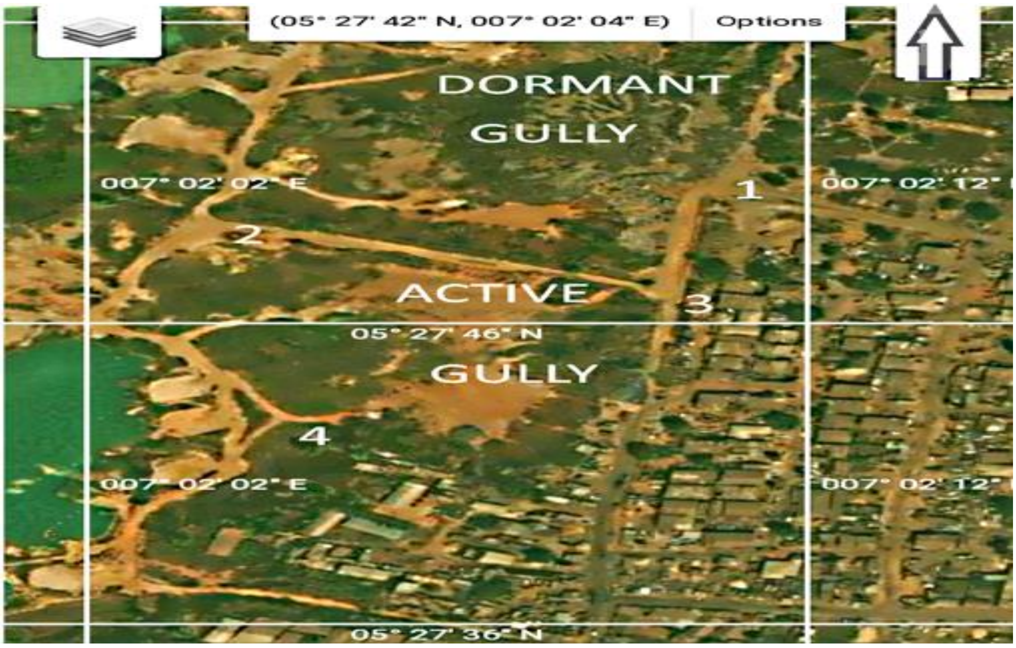

Fig 5 . Survey Map of the Study Area.

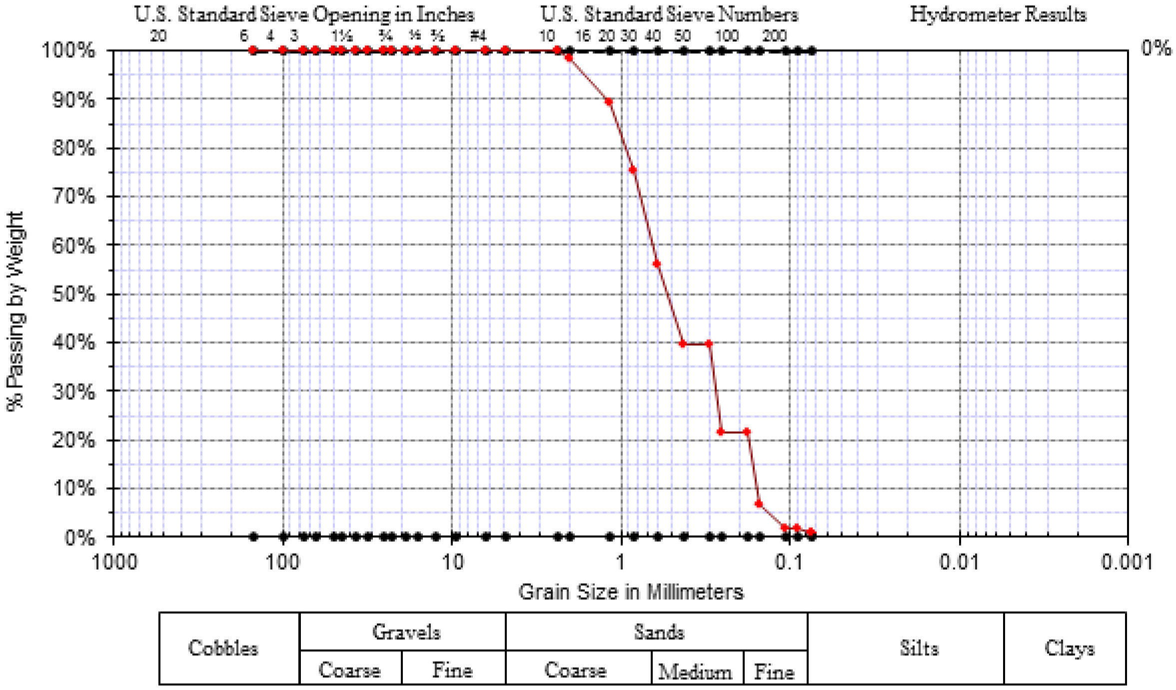

Fig 6. Sample 1 Sieve Analysis plot.

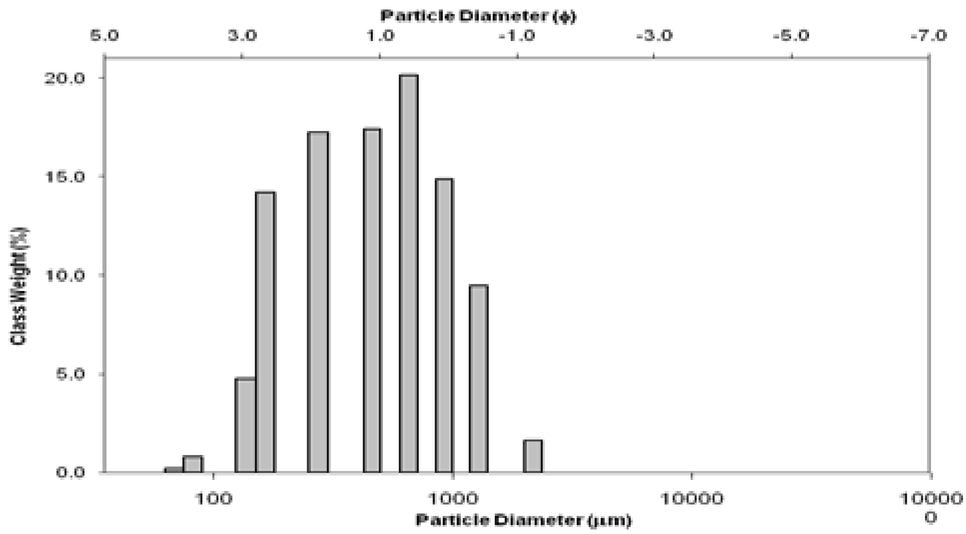

Fig 7. Sample 1 Sieve Analysis Bar chart.

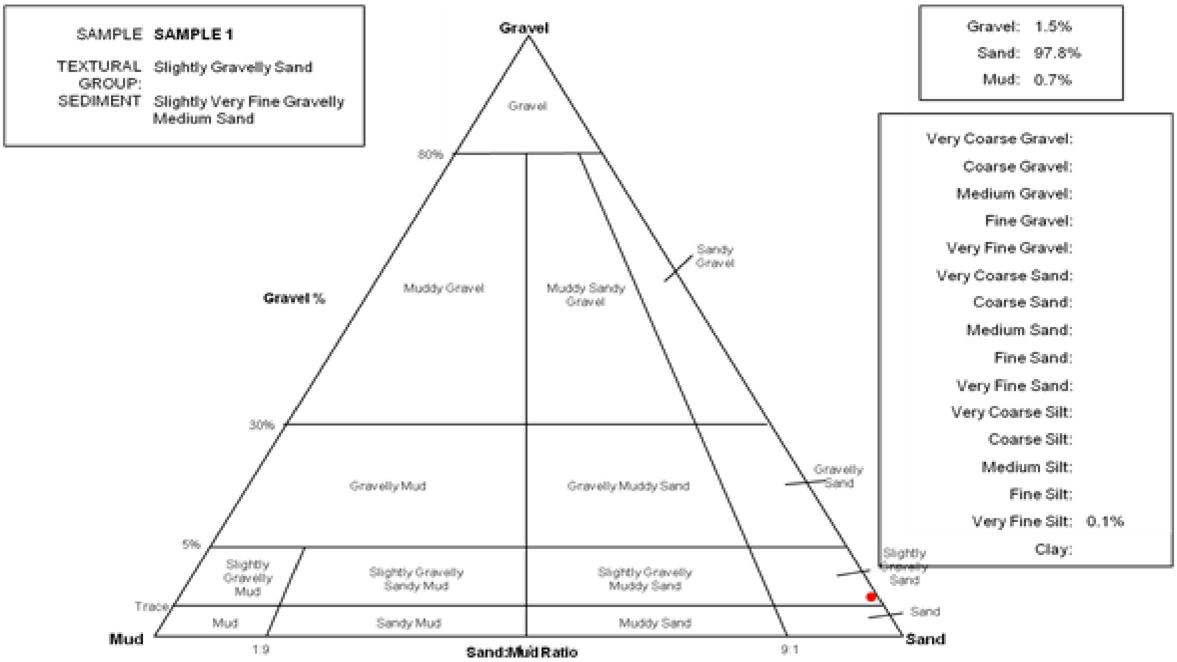

Fig 8. Sample 1 Textural Group Chart.

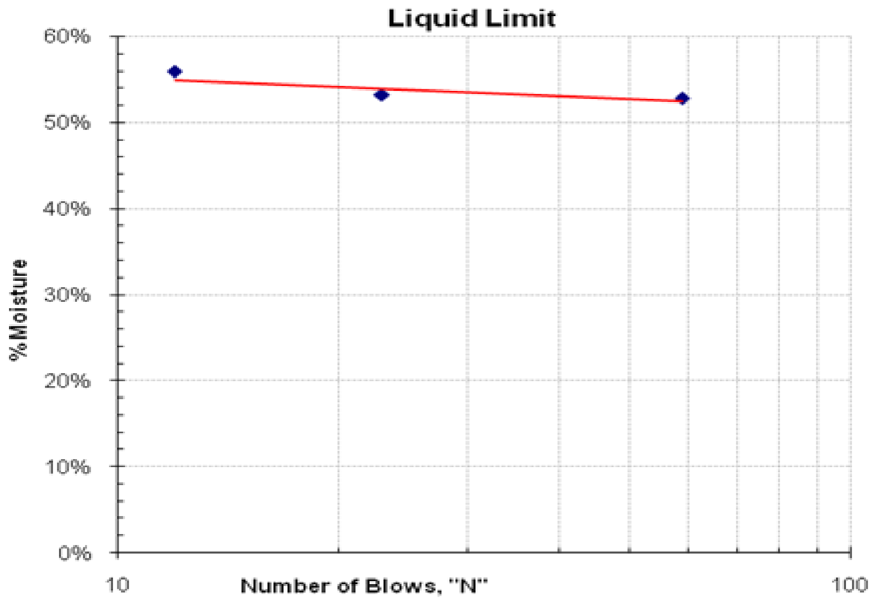

Fig 9. Sample 1 Liquid Limit Plot.

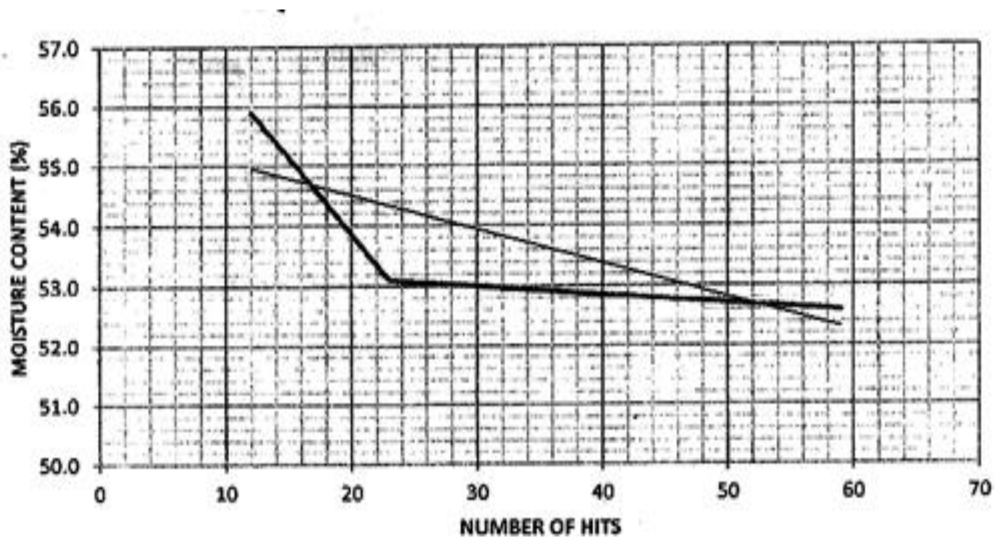

Fig 10. Sample 1 Liquid Limit Graph.

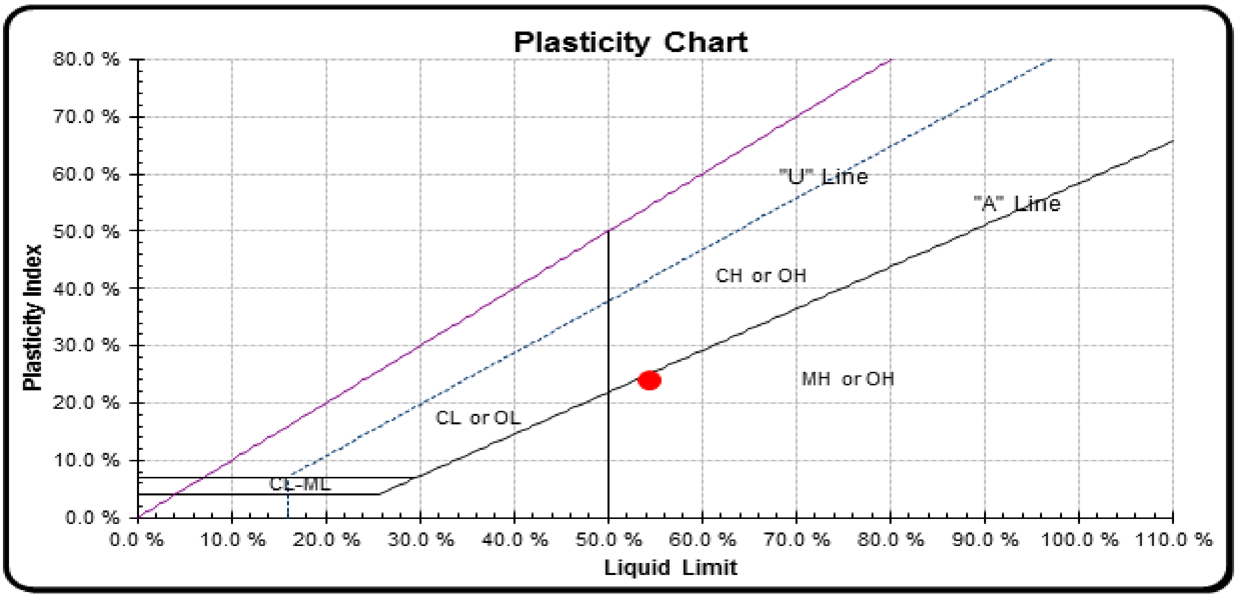

Fig 11. Sample 1 Liquid Limit Graph.

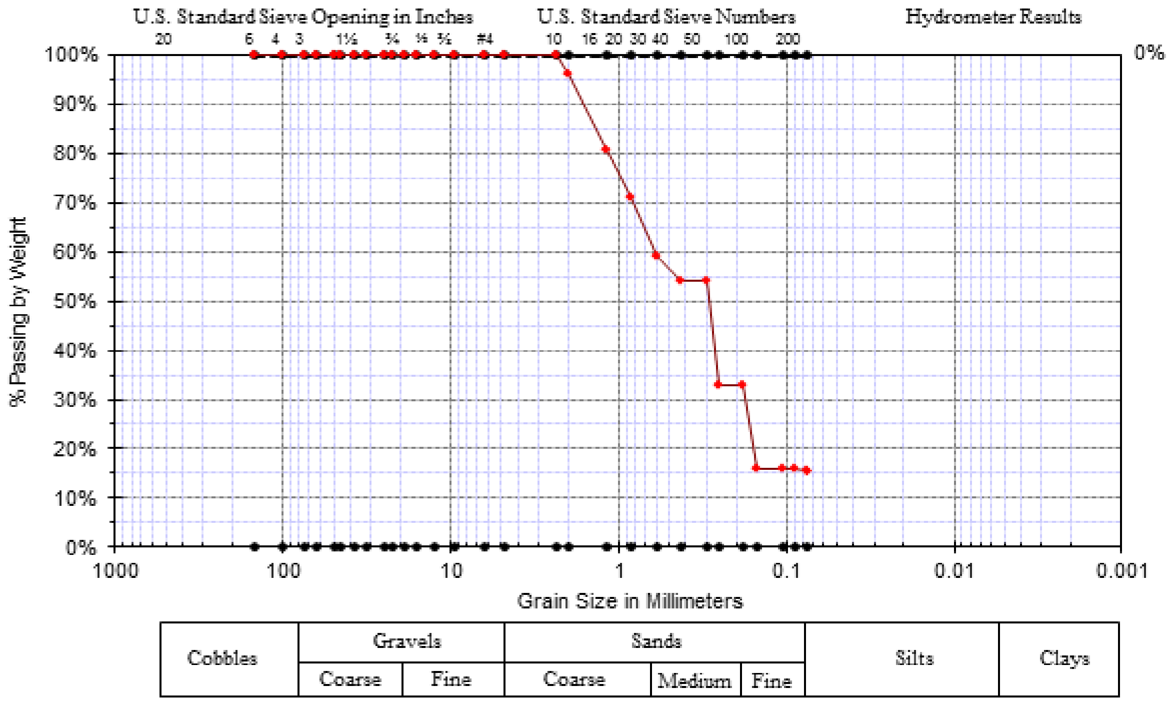

Fig 12. Sample 2 Sieve Analysis plot.

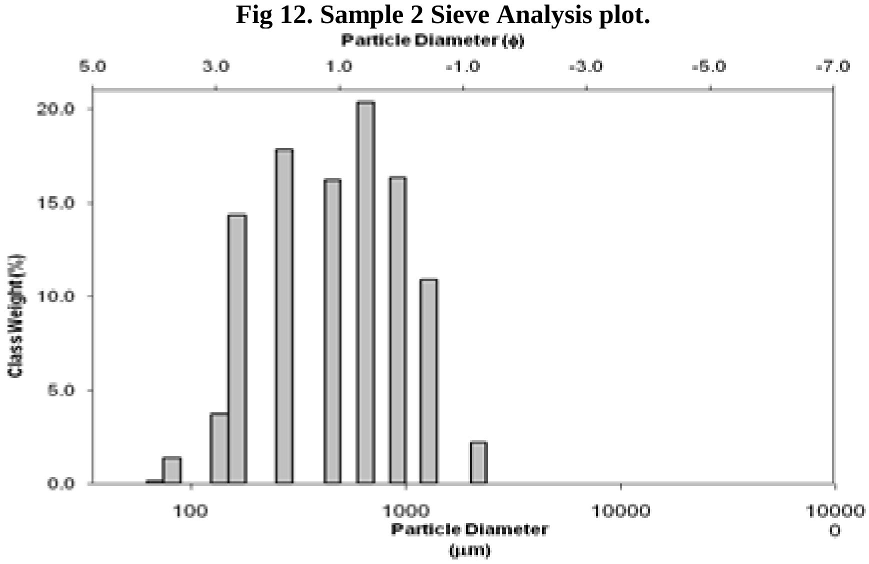

Fig 13. Sample 2 Sieve Analysis Bar chart.

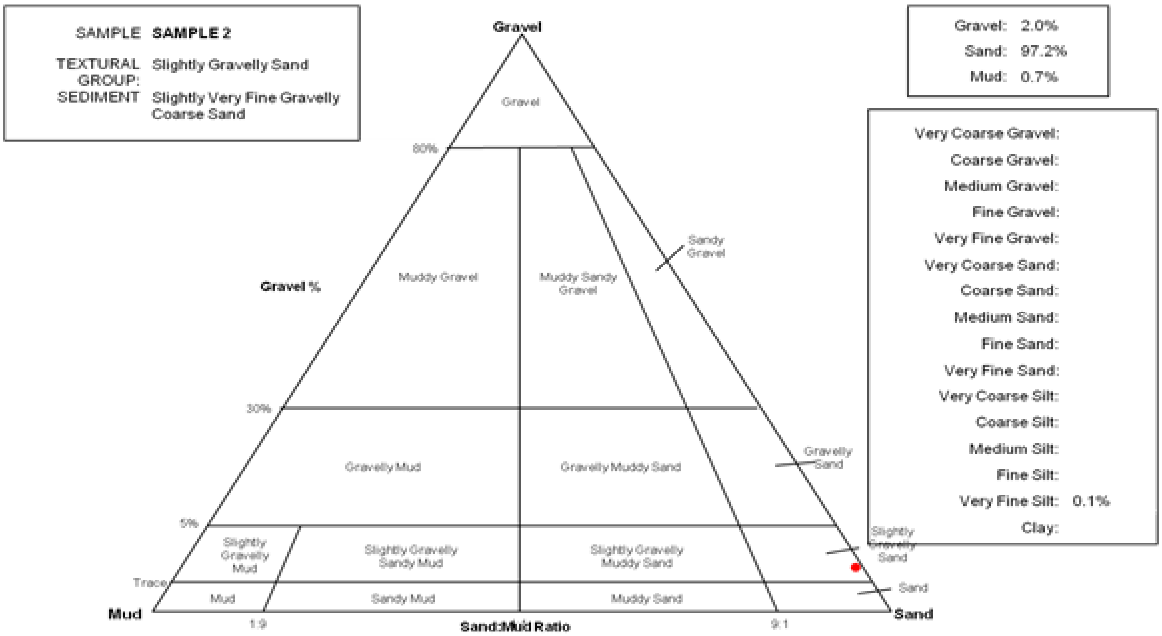

Fig 14. Sample 2 Textural Group Chart.

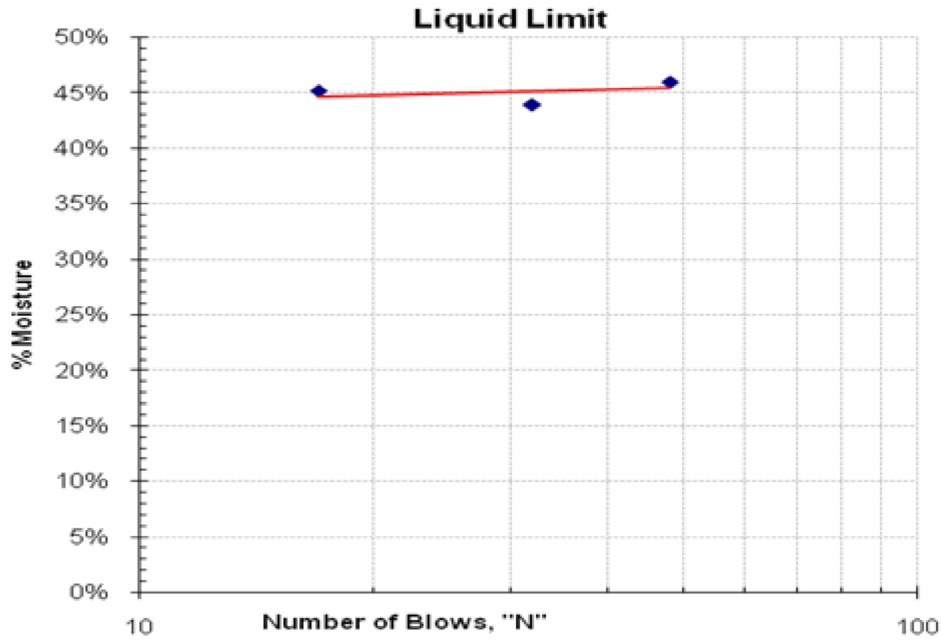

Fig 15. Sample 2 Liquid Limit Plot.

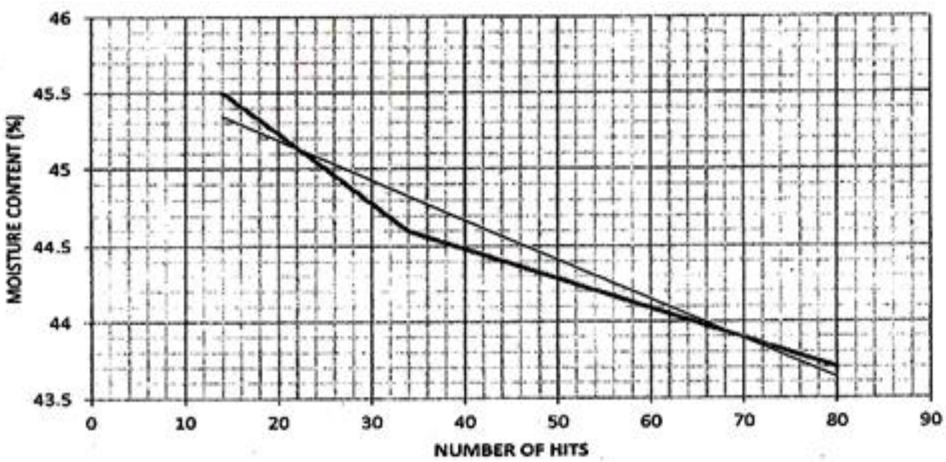

Fig 16. Sample 2 Liquid Limit Graph.

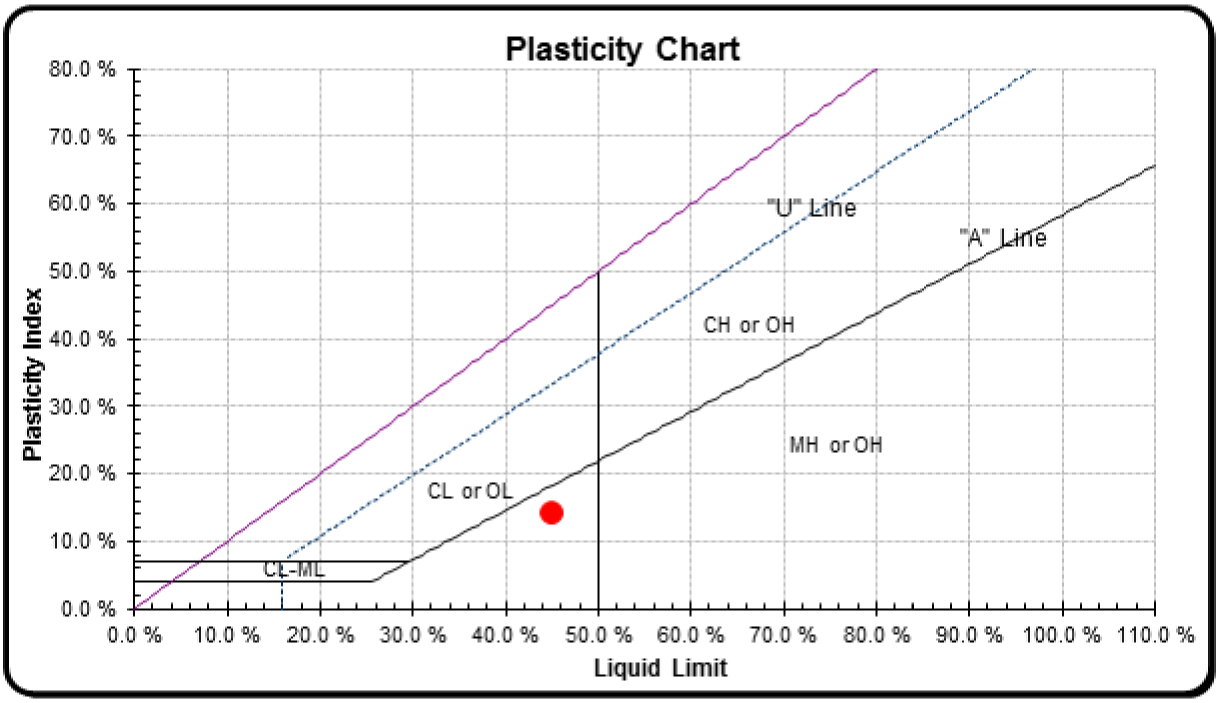

Fig 17. Sample 2 Liquid Limit Graph.

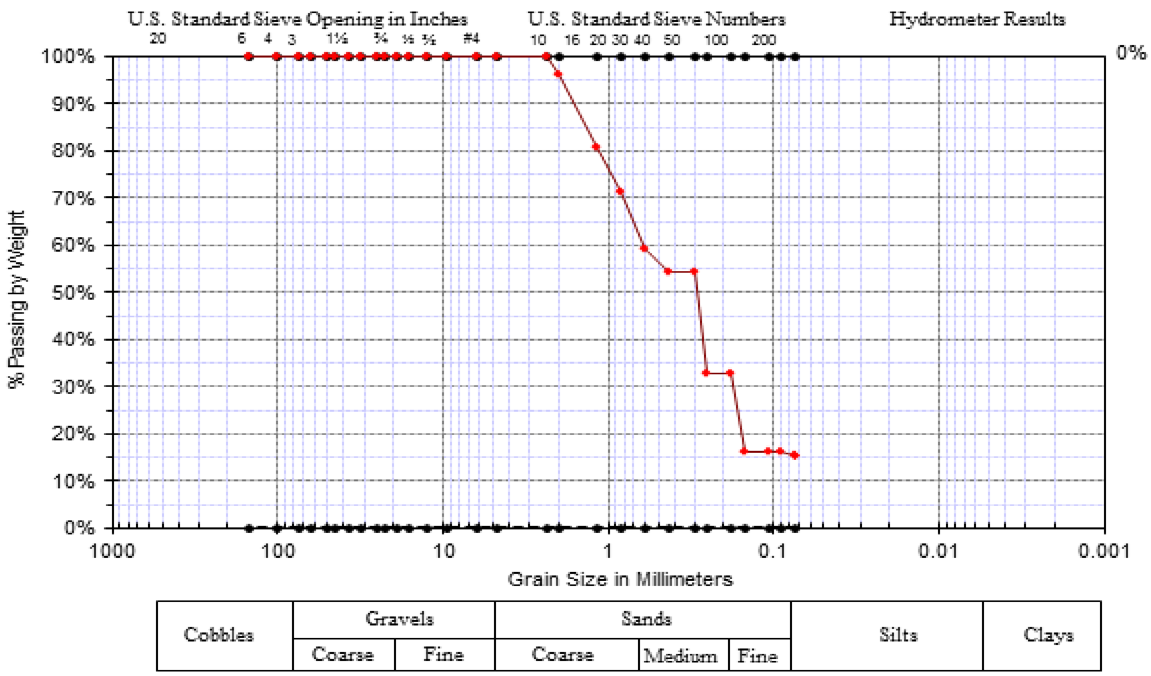

Fig 18. Sample 3 Sieve Analysis plot.

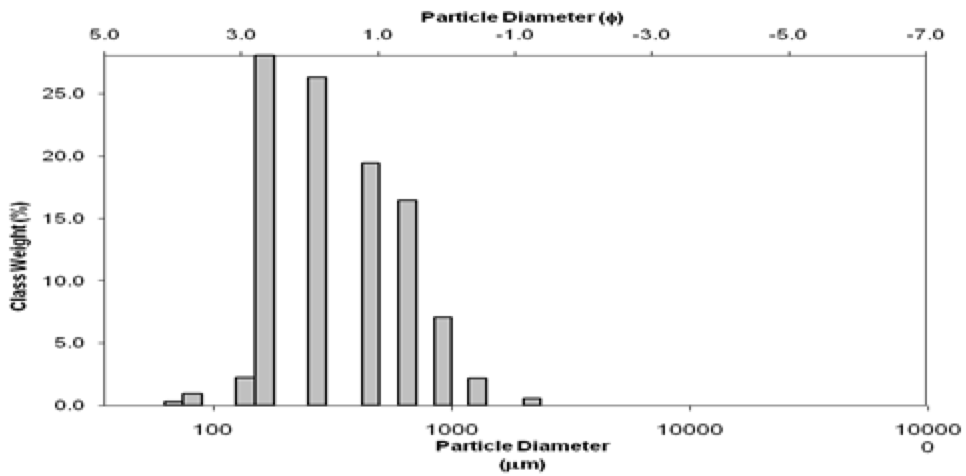

Fig 19. Sample 3 Sieve Analysis Bar chart.

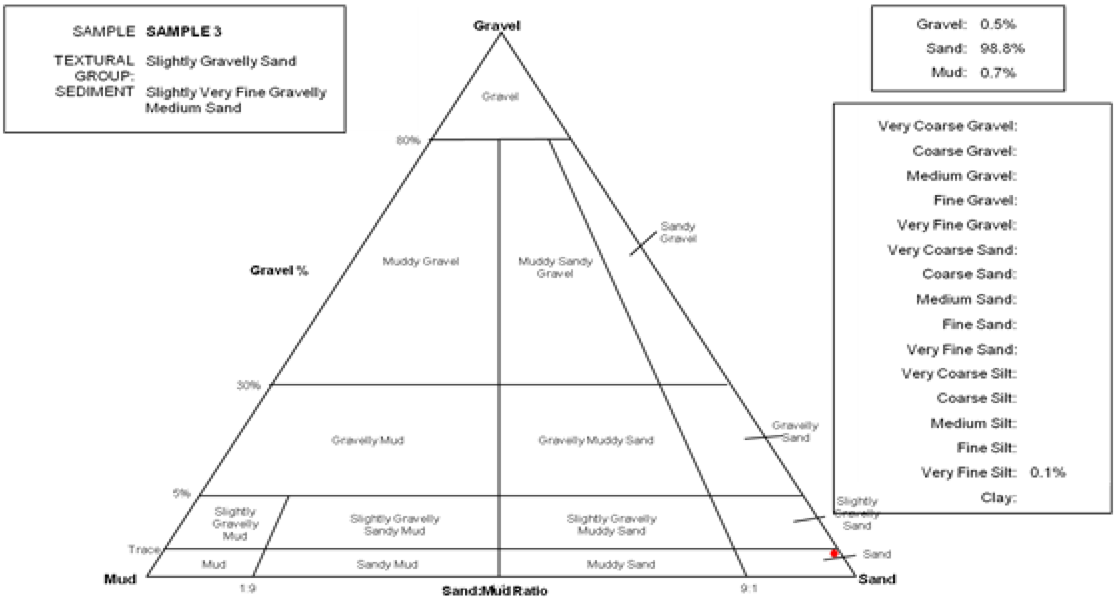

Fig 20. Sample 3 Textural Group Chart.

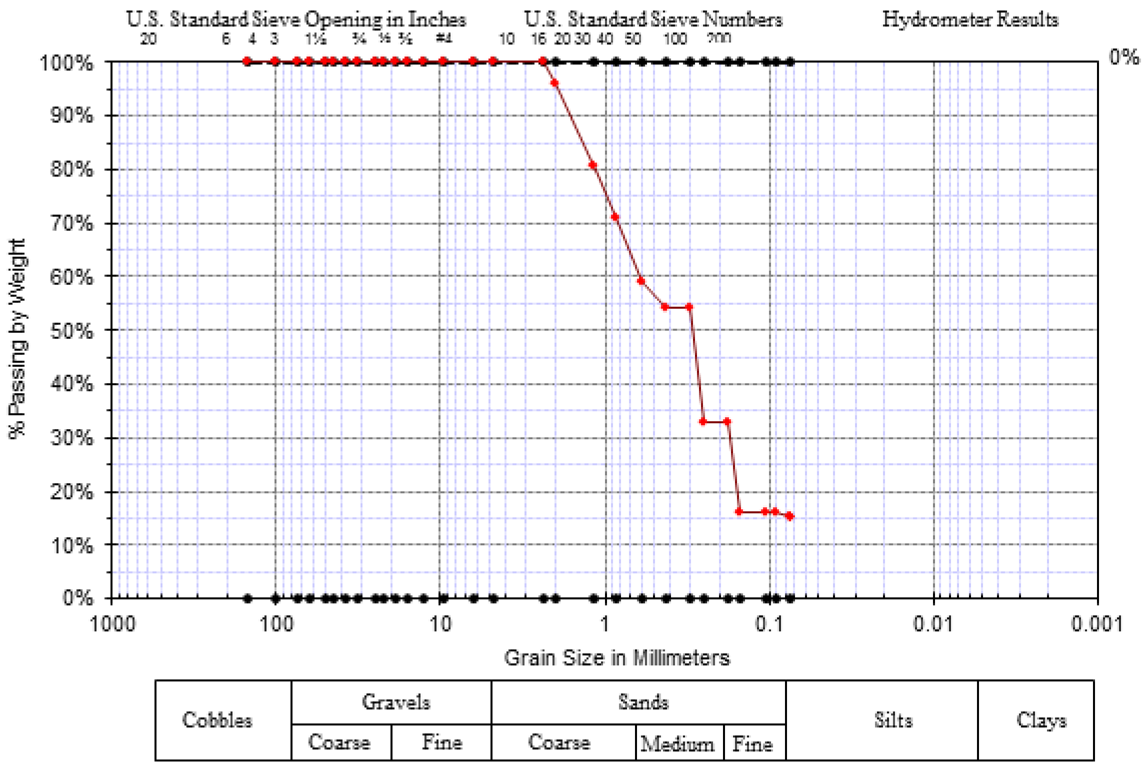

Fig 21. Sample 4 Sieve Analysis plot.

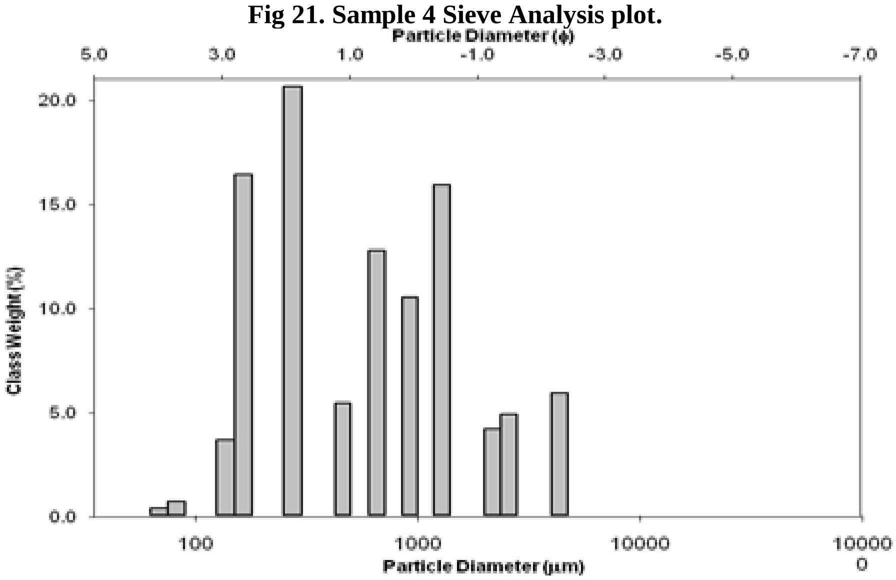

Fig 22. Sample 4 Sieve Analysis Bar chart.

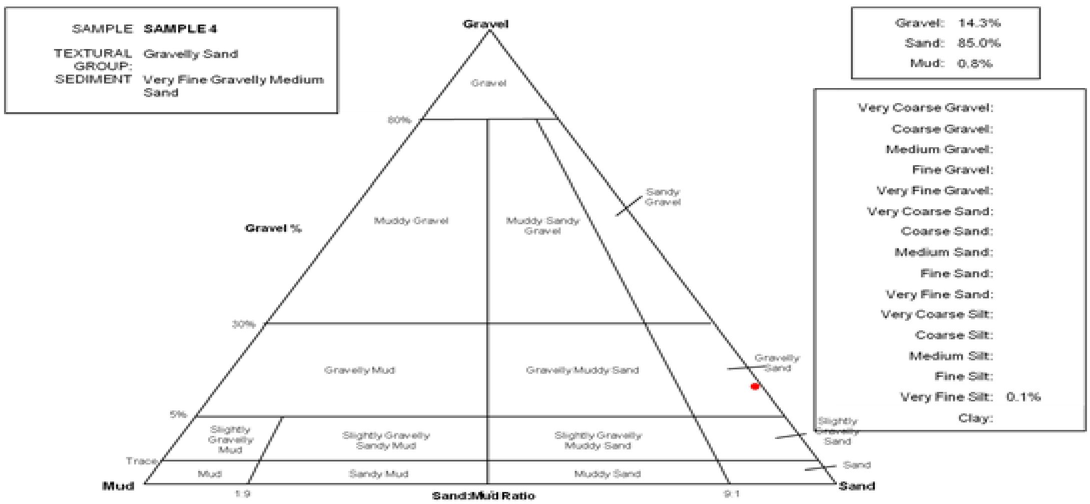

Fig.23. Sample 4 Textural Group Chart.

Table 1. Distribution of gully sites in southeastern Nigeria adopted from Igbokwe *et al* (2003).

S/N	State	No. of Gully Site	Stage	Control Measures
1	Anambra	700	Mostly active	Not successful
2	Abia	300	Some active/some dominant	Not successful
3	Ebonyi	250	Mostly minor gully sites	No records
4	Enugu	600	Some active/some dominant	Some successful and some not successful
5	Imo	450	Some active/some dominant	Some successful and some not successful

Table 2. Sample 1 Sieve Analysis Table.

Sieve Size (mm)	Soil Retained (g)	% Retained	% Passing
4	0.00	0.00	100.00
2.36	0.00	0.00	100.00
2	3.25	2.02	97.98
1.18	16.75	10.40	87.58
0.85	23.85	14.80	72.78
0.6	30.80	19.12	53.66
0.425	23.70	14.71	38.95
0.25	29.25	18.16	20.79
0.15	23.50	14.59	6.20
0.125	6.10	3.79	2.41
0.075	2.25	1.39	1.02
0.063	0.20	0.12	0.90
Pan	1.20	0.74	0.16

Table 3. Sample 1 Sample Statistics Table.

SAMPLE STATISTICS						
SIEVING ERROR:0.1%						
SAMPLE IDENTITY:SAMPLE 1				**ANALYST & DATE :**		
SAMPLE TYPE	**Poly modal, Poorly Sorted**			**TEXTURAL GROUP: Slightly Gravelly Sand :**		
SEDIMENT NAME: Slightly very fine Gravelly Medium Sand						
	μm		ϕ	GRAIN SIZE DISTRIBUTION		
MODE 1	655.0		0.616	GRAVEL :1.5%	COARESE SAND : 33.3%	
MODE 2	462.5		1.117	SAND :97.8%	MEDIUM SAND:34.3%	
MODE 3	275.0		1.868	MUD 0.:7%	FINE SAND: 19.8%	
D_{10}:	156.2		-0.261		V FINE SAND: 1.0%	
MEDIAN OR D_{50}:	471.7		1.084	V COARSE GRAVEL: 0.0%	V COARSE SILT: 0.1%	
D_{90}:	1198.2		2679	COARSE GRAVEL : 0.0%	COARSE SILT : 0.1%	
D_{90}/D_{10}:	7.673		-10.271	MEDIUM GRAVEL : 0.0%	MEDIUM SILT : 0.1%	
$D_{90} - D_{10}$:	1042.0		2940	FINE GRAVEL : 0.0%	FINE SILT:0.1%	
D_{75}/D_{25}:	2.736		3.917	V FINE GRAVEL : 1.5%	V FINE SILT: 0.1%	
$D_{75} - D_{25}$	449.3		1.452	V COARSE SAND : 9.3%	CLAY :0.1%	
METHOD OF MOMENTS					FOLK & WARD METHOD	
	Arithmetic μm	Geometric μm	Logarithmic ϕ	Geometric μm	Logarithmic ϕ	Description
MEAN (x):	566.2	429.1	1.221	421.0	1.248	Medium Sand
SORTING (σ):	403.1	2.240	1.163	2.55	1.109	Poorly Sorted
SKEW NESS (Sk):	1.308	-0.855	0.885	-0.140	0.140	Fine SK ewed
KURTOSIS (k)	5.285	5.737	5.737	0.909	0.909	Mesokurtic

Table 4. Sample 1 Shear Strength Table.

NORMAL STRESS (KN/m2)	SHEAR STRESS (KN/m2)
66.60	47.70
122.20	81.10
177.80	95.30
SHEAR STRENGTH 192.3KN/m2	

Table 5. Sample 1 Bulk Density Table .

WT.OF RING+ SAMPLE (g)	286.60
WT.OF RING (g)	103.50
VOLUME OF SAMPLE (cm3)	98.20
WT.OF SAMPLE (g)	183.10
BULK DENSITY (Mg/M3)	1.87

Table 6. Sample 2 Sieve Analysis Table.

Sieve Size (mm)	Soil Retained (g)	% Retained	% Passing
4	0.00	0.00	100.00
2.36	0.00	0.00	100.00
2	4.40	1.53	98.47
1.18	26.75	9.29	89.18
0.85	39.90	13.86	75.32
0.6	56.00	19.46	55.86
0.425	46.80	16.26	39.60
0.25	51.90	18.03	21.57
0.15	42.65	14.82	6.75
0.125	14.30	4.97	1.78
0.075	2.40	0.83	0.95
0.063	0.60	0.21	0.74
Pan	2.05	0.71	0.03

Table 7. Sample 2 Sample Statistics Table.

SAMPLE STATISTICS						
SIEVING ERROR:0.2%						
SAMPLE IDENTITY:SAMPLE 2				**ANALYST & DATE:**		
SAMPLE TYPE	**Poly modal, Poorly Sorted**			**TEXTURAL GROUP: Slightly Gravelly Sand**		
SEDIMENT NAME: Slightly very fine Gravelly Medium Sand						
	μm		ϕ	GRAIN SIZE DISTRIBUTION		
MODE 1	655.0		0.616	GRAVEL : 2.0%	COARESE SAND : 34.0%	
MODE 2	275.0		1.868	SAND : 97.2%	MEDIUM SAND: 32.9%	
MODE 3	925.0		0.117	MUD : 0.7%	FINE SAND: 18.4%	
D_{10}:	157.0		0.293		V FINE SAND: 1.5%	
MEDIAN OR D_{50}:	480.6		1.057	V COARSE GRAVEL: 0.0%	V COARSE SILT: 0.1%	
D_{90}:	1228.1		2.666	COARSE GRAVEL: 0.0%	COARSE SILT : 0.1%	
D_{90}/D_{10}:	7.795		-8.994	MEDIUM GRAVEL: 0.0%	MEDIUM SILT : 0.1%	
$D_{90}-D_{10}$:	1070.5		2.962	FINE GRAVEL: 0.0%	FINE SILT: 0.1%	
D_{75}/D_{25}:	3.377		9.750	V FINE GRAVEL: 2.0%	V FINE SILT: 0.1%	
$D_{75}-D_{25}$	610.2		1.739	V COARSE SAND : 10.4%	CLAY : 0.1%	
METHOD OF MOMENTS					FOLK & WARD METHOD	
	Arithmetic μm	Geometric μm	Logarithmic ϕ	Geometric μm	Logarithmic ϕ	Description
MEAN (x):	589.9	442.5	1.176	428.1	1.224	Medium Sand
SORTING (σ):	424.7	2.283	1.191	2.166	1.114	Poorly Sorted
SKEW NESS (Sk):	1.287	-0.907	0.907	-0.144	0.144	Fine SK ewed
KURTOSIS (k)	5.099	5.675	5.675	0-760	0.760	Platykurtic

Table 8. Sample 2 Shear Strength Table.

NORMAL STRESS (KN/m2)	SHEAR STRESS (KN/m2)
66.67	47.91
122.22	81.16
177.78	98.27
SHEAR STRENGTH 98.9KN/m2	

Table 9. Sample 2 Bulk Density Table.

WT.OF RING+ SAMPLE (g)	294.20
WT.OF RING (g)	103.50
VOLUME OF SAMPLE (cm3)	98.20
WT.OF SAMPLE (g)	190.70
BULK DENSITY (Mg/M3)	1.95

Table 10. Sample 3 Sieve Analysis Table.

Sieve Size (mm)	Soil Retained (g)	% Retained	% Passing
4	0.00	0.00	100.00
2.36	0.00	0.00	100.00
2	1.55	0.49	99.51
1.18	6.50	2.04	97.14
0.85	20.15	6.33	91.14
0.6	48.50	15.23	75.91
0.425	55.30	17.36	58.55
0.25	84.00	26.37	32.18
0.15	89.45	28.08	4.10
0.125	7.05	2.21	1.89
0.075	2.95	0.93	0.96
0.063	0.85	0.27	0.69
Pan	2.15	0.68	0.01

Table 11. Sample 3 Sample Statistics Table.

SAMPLE STATISTICS						
SIEVING ERROR:0.0%						
SAMPLE IDENTITY:SAMPLE 3				ANALYST & DATE:		
SAMPLE TYPE	Poly modal, Poorly Sorted			TEXTURAL GROUP: Slightly Gravelly Sand		
SEDIMENT NAME: Slightly very fine Gravelly Medium Sand						
	μ_m		ϕ	GRAIN SIZE DISTRIBUTION		
MODE 1	165.0		2.605	GRAVEL : 0.5%	COARESE SAND : 21.6%	
MODE 2	275.0		1.868	SAND : 98.8%	MEDIUM SAND: 43.7%	
MODE 3	462.5		1.117	MUD : 0.7%	FINE SAND: 30.3%	
D_{10}:	155.9		0.512		V FINE SAND: 1.2%	
MEDIAN OR D_{50}:	282.8		1.822	V COARSE GRAVEL: 0.0%	V COARSE SILT: 0.1%	
D_{90}:	701.1		2.682	COARSE GRAVEL: 0.0%	COARSE SILT : 0.1%	
D_{90}/D_{10}:	4.498		5.234	MEDIUM GRAVEL: 0.0%	MEDIUM SILT : 0.1%	
$D_{90}-D_{10}$:	545.2		2.169	FINE GRAVEL: 0.0%	FINE SILT: 0.1%	
D_{75}/D_{25}:	2.885		2.510	V FINE GRAVEL: 0.5%	V FINE SILT: 0.1%	
$D_{75}-D_{25}$	323.9		1.529	V COARSE SAND :2.0%	CLAY : 0.1%	
METHOD OF MOMENTS					FOLK & WARD METHOD	
	Arithmetic μ_m	Geometric μ_m	Logarithmic ϕ	Geometric μ_m	Logarithmic ϕ	Description
MEAN (x):	395.6	316.1	1.661	311.0	1.655	Medium Sand
SORTING (σ):	287.9	2.017	1.012	1.871	0.904	Moderately Sorted
SKEW NESS (Sk):	2.036	-0.665	0.665	0.258	-0.255	Coarse SK ewed
KURTOSIS (k)	2.959	6.787	6.787	0.707	0.707	Platykurtic

Table 12. Sample 3 Shear Strength Table.

NORMAL STRESS (KN/m2)	SHEAR STRESS (KN/m2)
66.67	21.10
122.22	56.67
177.78	94.40
SHEAR STRENGTH 95KN/m2	

Table 13. Sample 3 Bulk Density Table.

WT.OF RING+ SAMPLE (g)	279.50
WT.OF RING (g)	103.50
VOLUME OF SAMPLE (cm3)	98.20
WT.OF SAMPLE (g)	176.00
BULK DENSITY (Mg/M3)	1.79

Table 14. Sample 4 Sieve Analysis Table.

Sieve Size (mm)	Soil Retained (g)	% Retained	% Passing
4	13.65	5.69	94.31
2.36	11.20	4.67	89.64
2	9.30	3.88	85.76
1.18	36.80	15.35	70.41
0.85	23.00	9.60	60.81
0.6	29.00	12.10	48.74
0.425	11.58	4.94	43.77
0.25	50.90	21.23	22.54
0.15	40.40	16.85	9.69
0.125	8.90	3.71	1.98
0.075	1.60	0.67	1.31
0.063	0.70	0.29	1.05
Pan	1.80	0.15	0.27

Table 15. Sample 4 Sample Statistics Table.

SAMPLE STATISTICS						
SIEVING ERROR:0.3%						
SAMPLE IDENTITY: SAMPLE 4				ANALYST & DATE:		
SAMPLE TYPE	Poly modal, Poorly Sorted			TEXTURAL GROUP: Gravelly Sand		
SEDIMENT NAME: very fine Gravelly Medium Sand						
	μ_m		ϕ	GRAIN SIZE DISTRIBUTION		
MODE 1	270.0		1.868	GRAVEL :14.3%	COARESE SAND : 21.7%	
MODE 2	165.0		2.605	SAND : 85.0%	MEDIUM SAND: 26.2%	
MODE 3	655.0		0.616	MUD : 0.8%	FINE SAND: 20.6%	
D_{10}:	157.0		-1.259		V FINE SAND: 1.0%	
MEDIAN OR D_{50}:	612.0		0.708	V COARSE GRAVEL: 0.0%	V COARSE SILT: 0.1%	
D_{90}:	2394.1		2.666	COARSE GRAVEL: 0.0%	COARSE SILT : 0.1%	
D_{90}/D_{10}:	15.19		-2.117	MEDIUM GRAVEL: 0.0%	MEDIUM SILT : 0.1%	
$D_{90} - D_{10}$:	2236.5		3.925	FINE GRAVEL: 5.7%	FINE SILT: 0.1%	
D_{75}/D_{25}:	4.859		-6.271	V FINE GRAVEL: 8.6%	V FINE SILT: 0.1%	
$D_{75} - D_{25}$	987.1		2.281	V COARSE SAND :15.4%	CLAY : 0.1%	
METHOD OF MOMENTS					FOLK & WARD METHOD	
	Arithmetic μ_m	Geometric μ_m	Logarithmic ϕ	Geometric μ_m	Logarithmic ϕ	Description
MEAN (x):	937.5	539.7	0.590	620.9	0.941	Coarse sand
SORTING (σ):	1064.1	2.944	1.555	2.799	1.455	Poorly sorted
SKEW NESS (Sk):	2.015	-0.133	0.133	-0.044	0.044	symmetrical
KURTOSIS (k)	6.655	3.438	3.438	0.868	0.562	Platykurtic

Table 16. Sample 4 Shear Strength Table.

NORMAL STRESS (KN/m2)	SHEAR STRESS (KN/m2)
66.67	47.91
122.22	81.16
177.78	96.31
SHEAR STRENGTH 110.58KN/m2	

Table 17. Sample 4 Bulk Density Table.

WT.OF RING+ SAMPLE (g)	278.90
WT.OF RING (g)	103.50
VOLUME OF SAMPLE (cm3)	98.20
WT.OF SAMPLE (g)	175.40
BULK DENSITY (Mg/M3)	179