NIPES Journal of Science and Technology Research 4(2) 2022 pp.318 - 323 pISSN-2682-5821, eISSN-2682-5821

NIPES

Journal of Science and Technology Research

Journal homepage: www.nipesjournals.org.ng

Geotechnical characterization of Soil susceptibility to Gully Erosion, Capitol, University of Benin, Benin City,Edo State, Nigeria

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Article Info

Keywords: *geotechnical evaluation, soil susceptibility, erosion, gullies, moisture*

Received 07 May 2022
Revised 18 May 2022
Accepted 29 May 2022
Available online 25 June 2022

doi Crossref NIPES JOURNALS

https://doi.org/10.37933/nipes.e/4.2.2022.31

https://nipesjournals.org.ng

Abstract

A geotechnical evaluation and assessment of soil susceptibility to erosion were carried out in Capitol gully, University of Benin, Nigeria. Soil samples were collected with a hand auger from three (3) sampling points in the study area at a depth of 1m. The geotechnical properties of the soil samples analyzed in the Civil Engineering Laboratory, University of Benin were Sieve analysis, Atterberg limits, Compaction, Moisture content, and Shear strength according to BS 1377: part 1-9, 1990. Results of Sieve analysis indicates that percent passing 75mm sieve across sampling points 1,2 and 3 ranged from 9.4% -55% . The liquid limit values are 0.00%, 42.42% and 33.27%, while the plasticity index values are 0.00%, 25.44% and 19.98% for sampling points 1, 2 and 3 respectively. The value of specific gravity ranged from 2.59 to 2.34, maximum dry density (MDD) values ranged 1.64 - 1.75 mg/m^3, and optimum moisture content (OMC) ranged 11.20% - 16.5% for sampling points 1.2.and 3 respectively. The result of the shear strength characteristics across the three (3) sampling points showed that cohesion C, ranged from 8.0kN/m^2 - 20.93kN/m^2 and angle of internal angle of friction, (Φ) ranged from 13° - 23.81° respectively. The study confirmed that most soils at the sampling locations were non cohesive comprising mainly of loose sands with minimal amount of silt/clay present; indicating that the physical characteristics of the soils is likely responsible for its vulnerability to erosion and a contributing factor to the formation of Gullies in the Capitol, University of Benin, Nigeria. The poorly laterized soils observed in the study area could also be attributed low specific gravity in the area.

1.0 Introduction

Soil is formed as a result of weathering of rocks. It is a product of the interference of man on rocks through human activities. Soil erosion therefore is the process by which soil particles are detached from rock materials and transported from one place to another through an agent such as wind, water, and landslide wearing away and moving the surface constituents of the earth [1]. This loss of topsoil from farm land may be reflected in reducing crop yield potential, lowering of surface water quality and drainage network. Hence a good study of soil erodibility will enhance optimum agricultural yield and provide insightful measures that can effectively mitigate geo environmental hazards such as gully erosion [2]. Although erosion is a natural phenomenon, human interference on natural systems has created erosion that is much higher than the average geological erosion rate. Humans have often caused accelerated erosion by our manipulation of the soil for agriculture or construction use [3]. When soils are left bare even for a short period, the soils can be picked up and moved. These bare soils are exposed to the energy from raindrops and winds. The finer particles of the soil are eroded first, taking with them most of the natural fertility and production potential of the soil.

Gully erosion can be defined as the displacement of soil or soft rock by a waterbed with high enough velocity to separate and move soil particles. Gullies are formed when there is a decrease in soil resistance to agents of erosion or an increase in the erosive forces acting on the land surface. Gullies can be naturally or anthropogenicaly induced, or a combination of both factors. The underlying geology of the location and the severity of accompanied surface processes play a key role in its formation. Gullies are fundamental geo-hazards and it's a potent threat to environmental sustainability [4]. It is a highly visible form of soil erosion that affects soil productivity, restrict land use and can threaten road, fences and buildings. Environmental hazards associated with abandoned gullies in Nigeria are on the rise and a major concern to citizens, government and the environmental geologist [5]. Many states in Nigeria are currently under the threat of this phenomenal process, South- Eastern part of the country being the most affected. The development of gullies at the Capitol, University of Benin poses existential threat to both students and staffs due to the dangerous deep vertical walls that are prone to landslides after heavy rains. This gully may become a reservoir of stagnant water where various microorganisms can incubate and produce toxins. Abandoned gullies not containing water are used for illegal dumping of waste, and as a hideout for armed robbers [6]. Gully erosion mainly results to land degradation that affects not only the ecological balance existing among plants and animals but also a significant threat to human life. Their development decreases the extent of agricultural land, farm productivity by incision into the land, and depletes soil resources, which can thus decrease crop yields. Although it is a natural disaster, poor construction materials, inadequate maintenance of surface drainage systems, uncontrolled livestock access and over cropping, has contributed to the gully problem [4].

Available literatures have also clearly reiterated the fact that the underlying geology exerts a major role in gully development and more often than not, the process of gully formation is soil type dependent because some soils are more susceptible to erosion than others. It is therefore imperative to characterize the geotechnical properties of the underlying geology of capitol gully, with a view to ascertain its susceptibility and vulnerability to the development of gully erosion in the area.

2. Methodology

2.1 Description of study area

The study area is at Capitol is located in the University of Benin, Ugbowo Campus, Benin city. The area extends from Benin-Lagos road in the West to the Benin Auchi road to the North in Ovia North East Local Government Area of Edo State. The study area lies between latitude N06˚25'16.8" to N06˚25'16.9"and longitude E05˚28'17.8'' to E05˚38'20.9''. The western sector slopes at between 3-8% (average slope of 4%) into Ikpoba River which receives sediments from the gully area. On this same sector (western), the slope breaks just behind the Capitol. From this point, runoff due to change in gradient accelerates into Ikpoba River, [7].

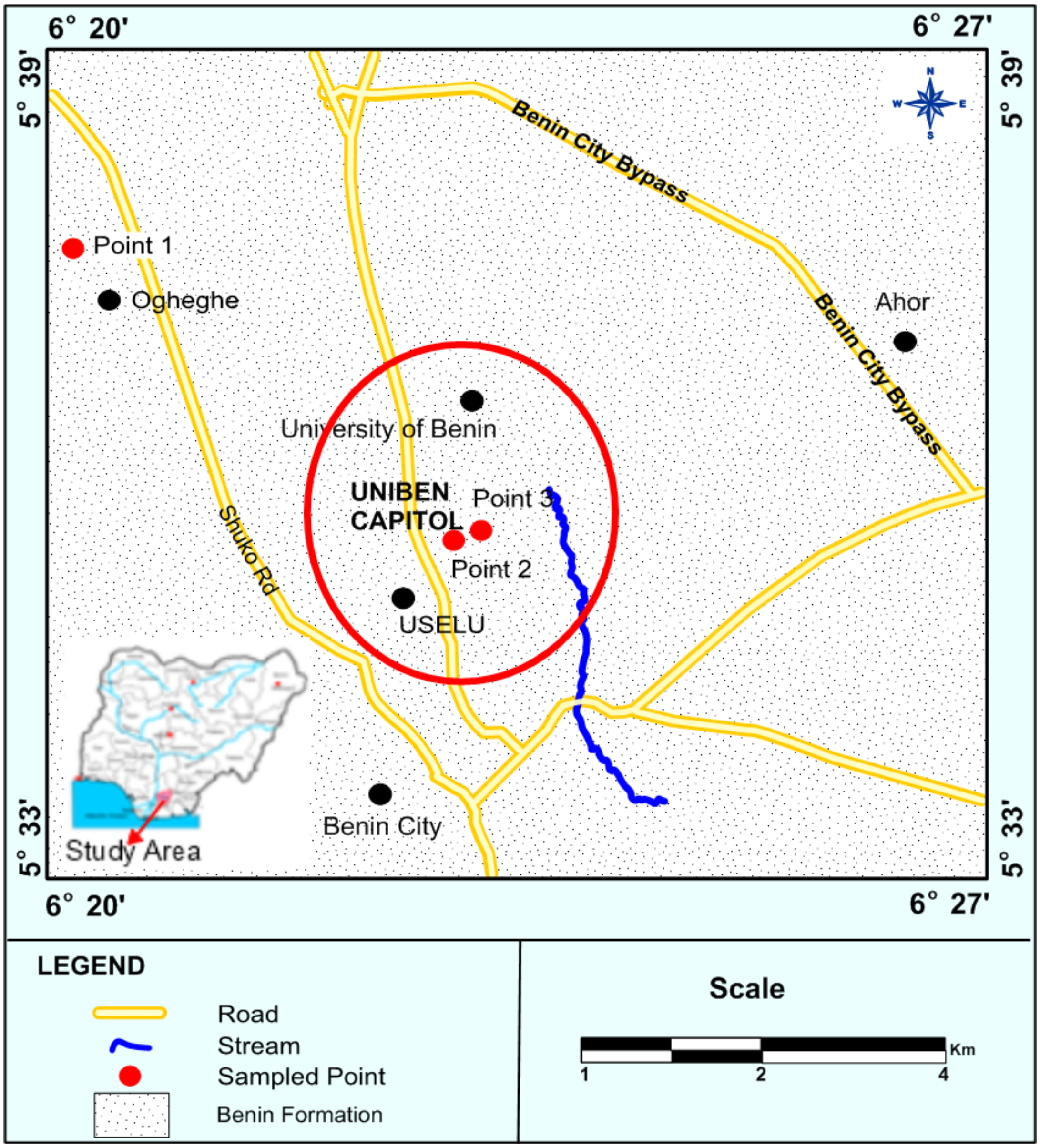

Figure 1: Study area of Capitol, University of Benin

2.2 Sample collection and Analysis

2.2.1. Global positioning survey

A hand held Global positioning system was used to obtain field coordinates of the area. A map was thereafter produced by imputing the coordinates in a GIS software.

2.2.2. Collection of samples:

Three (3) soil samples were collected at depths of 1m each which is disturbed samples. The samples obtained using a hand auger at a specified distance of 100m apart in order to ensure there is no variability in the soil profile were put inside a black polyethene nylon bag and taken to the civil engineering laboratory, University of Benin.

2.3. Sampling Techniques

The geotechnical investigations carried out includes particle size analysis, atterberg limits, specific gravity, compaction, shear strenght**.** All the laboratory tests were performed in compliance with British standard specification [8]. The geotechnical tests carried out to determine the susceptibility of soils obtained from capitol to erosion using the [9] standard methods as it relates to specification for roads and bridges.

3. Results and Discussion

3.1 Particle size distribution

The results of sieve analysis, reveals that percentage passing sieve 75micron ranges from 9.4 to 55 percent, with the highest value being at sampling point 3 as shown in Table 4.1. This implies that the predominant aggregate is sand with obvious presence of fine material such as silt and clay. The low amount of fine in sampling point 1 is indicates the lack of clay size materials which would have cemented the sand particles. Hence the study area contains insufficient binding materials and therefore suggests high susceptibility of the soil material to erosion.

The high amount of fines in sampling point 2 and 3 could be attributed to intense weathering of the underlying geology of the area. Such areas having weak unconsolidated sandy formations are also usually very susceptible to erosion [10].

Table 1: Summary of Result of particle size distribution

Sampling Points	**Site**	**Depth (m)**	**PERCENTAGE PASSING SIEVE NO**			
			1.18mm	**0.425mm**	**0.212mm**	**0.075mm**
1	Capitol Gully	1.0m	96.1	73.4	26.7	9.4
2		1.0m	95.8	75	49	35
3		1.0m	98	92	73	55

3.2 Atterberg and Consistency determination

The values of the liquid limit and plastic limit ranges from 42.42% to 17.03% for sampling point 2, and 33.27% to 13.29% for point 3, while sampling point1 recorded no values. The plasticity index for sampling points 2 and 3 were 25.39% and 19.98% respectively as indicated in Table 2. Sampling Point 1 has zero plasticity index indicating that the soil was non plastic. The value of plasticity index at sampling point 1 indicates that the soil is relatively unstable over a wide range of moisture content. This low value could also be attributed to low amount of fine fractions in the samples and indicates that the soil may change from one state of consistency to another with minimum change in water content [11]. [12] stated that a soil is non plastic(sand) if it has a plasticity index of zero, moderately plastic (silty clay) if it has a plasticity index between 7-17, and highly plastic if its plasticity index is greater than 17. Hence sampling points 2 and 3 are highly plastic. [13] Specified liquid limit of ≤ 30% and Plasticity index of ≤ 13% as soils suitable for construction of civil engineering structures. Therefore, soils from sampling locations 2 and 3 are unsuitable as construction materials and are therefore prone to gully erosion which may bring about changes in land use.

Table 2: Summary of results of Atterberg limit determination

Sampling Points	Site	Depth (m)	LL (%)	PL(%)	PI (%)
1	Capitol Gully	1.0	0.00	Non-Plastic	0.00
2		1.0	42.42	17.03	25.44
3		1.0	33.27	13.29	19.98

3.3 Specific gravity

The study area comprises a mixture of sand and clayey mineral aggregates with specific gravity ranging from 2.48 to 2.52 as shown in Table 3. According to a research work carried out by [14] the specific gravity of lateritic soil should be within the range of 2.60 to 3.40 and the specific gravity of clay should range from 2.2 to 2.6. The result however depicts that the study area falls within the clay range and were poorly laterized. Laterites in soils are usually very valuable for construction and building of engineering structures as they become hard when exposed to air [15]. The study area which contains no laterite would consists of weak, unconsolidated formations that are easily erodible.

Table 3: Summary of the results of specific gravity

Sampling points	Site	Depth (m)	Specific Gravity
1	Capitol Gully	1.0	2.59
2		1.0	2.47
3		1.0	2.34

3.4 Compaction tests

The maximum dry density as indicated in Table 4 ranges from 1.75 to 1.64, with sample one having the highest value, while the optimum moisture content ranges from 11.20 to 16.5 with sample three having the highest value. The low values of MDD imply that the soils are generally not compacted and are loosely bound. These values are within the range classified as low by [16] Loose soils are generally more easily erodible than compacted soils, hence the study area is highly prone to soil erosion.
The result of the moisture content test also shows low values of moisture content for the sampling points evaluated. This low moisture content of the subsurface soil leads to high capacity for water retention during rainfall. It eventually causes breakdown of the grain to grain forces that existed in the soil [17].

Table 4: Summary of compaction test results

Sampling Points	**Site**	**Depth (m)**	**MDD (g/ cm^3)**	**OMC (%)**
1	Capitol Gully	1.0m	1.75	11.20
2		1.0m	1.72	16.1
3		1.0m	1.64	16.5

3.5 Shear strength determination

The results of shear strength parameters as presented in Table 5 revealed that the values of cohesion (C) range from 8.07 to 20.93kN/m² while the degree of friction varies from 13.0 to 23.81 across the sampling points. 65kpa Cohesion (C) and 26° angle of friction has been classified as the average values that would offer resistance to surface run off [18]. These results typify a dearth in cementing and binding materials. It can be deduced therefore that the soils would offer little or no resistance to both surface water and ground water. Thus, could be the reason for gully development in the area.

Table 5: Results of shear strength determination

Sampling Poin ts	**Site**	**Depth (m)**	**Cohesion (kN/m^2)**	**ϕ(deg)**
1	Capitol Gully	1m	8.07	13.0
2		1m	20.93	22.00
3		1m	10.00	23.81

4.0. Conclusion

The engineering aspect 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. From the results and analysis, it was observed that the soil sample comprised mainly of sands and more fines with low and high plasticity. According to AASHTO soil classification system, the soil can be classified as A-7-5 soil. Findings also revealed that the soils were poorly laterized and could offer minimal resistance to flowing water. The shear strength of the soils around capitol is a contributor to the development of incipient gully in the area due to its low bearing capacity. Hence in conclusion, the gully in the

University of Benin capitol is probably due to the poorly laterized nature of the soils and the low amount of the degree of friction of the soils.

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