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EVALUATION OF THE PRE-GROUTING AND POST-GROUTING ERODIBILITIES OF NANKA SAND GEOLOGIC UNIT CAUSING GULLY IN ANAMBRA STATE, NIGERIA

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ABSTRACT: *The study evaluated grouting using some selected Chemicals to ascertain if erodibility of the soil is being affected (lowered) by grouting and to what extent. The study adopted the laboratory research method in analyzing the samples collected from the selected gully erosion sites to determine their various erodibilities using an artificial rainfall simulator. To achieve this, the following steps were taken: to determine the erodibilities of the formation samples collected, to determine the relationship between pre-grouting and post-grouting erodibilities of the samples of the formation collected and to infer whether or not grouting reduces erodibility. The study postulated and tested the hypothesis: there is no significant difference between the pre-grouting and the post grouting erodibilities of the samples collected. It was found that there is reduced erodibility with the application of each grouting chemical. The erodibility before grouting was higher than the erodibility after grouting and the test of hypothesis showed that there is significant difference between the pre-grouting and post grouting erodibilities of samples collected. The study therefore recommended the adoption of chemical grouting as a control measure to gully erosion in the study area. The study went further to recommend that there should be an insitu study on the workability of the grouting chemicals as proven in the laboratory with cost-benefit analyses being done in order to compare this method with other available methods*.
KEYWORDS: gully erosion; grouting of Nanka sands, pre-grouting and post-grouting erodibilities.

INTRODUCTION

Gully erosion occurs virtually in many parts of Nigeria; but it is most devastating in the south-eastern states which includes Anambra, Imo, Enugu, and Abia; but with less effect in other areas like Auchi in Edo state (Izinyon*et al,* 2013). Anambra State is the most affected of all the states in Nigeria where Agulu, Nanka and Oko communities of the State are the worst hit (Ajaero and Mozie, 2011). Available literature has also clearly reiterated the fact that the underlying geology exerts a major control on gully development and, more often than not, the process is rock-type-dependent. as some rocks are more susceptible to erosion than the others (Abdulfatai *Et Al*, 2014).

A lot has been done in combating gully erosion and its associated negative effects in the south-eastern part of Nigeria (especially in Anambra State), but being a naturally occurring incident the problem still lingers. The main methods of controlling this menace as adopted in Anambra State are: bioremediation and the use of civil engineering / concrete works for channelization of surface runoffs being the main agent of erosion and stabilization of the surfaces prone to this menace. Majority of these structures are being undermined by the waters due to loose soil particles. In the bid to advance research in this area, the option of grouting was being explored in order to stabilize the underlying soils for a sustainable gully erosion remediation.

Statement of the Problem

Many lives have been lost as a result of the problem of gully erosion. Some either fell into these gullies and sustained various degrees of injury or died. Some instances have also been reported where people were drowned in some of the gully sites. According to Abdulfatai *et al* (2014), about 23 people have been reported in the past few years to have lost their lives in a single event of gullying activities in Ibori, Ugbalo, Ewu-Eguare, Idogalo and Oludide communities of Edo State, Nigeria. In Anambra, thousands of people have been displaced and evacuated from their homes following the gully incidences. In fact, the gully erosion in Oko and Nanka communities in Anambra State has created very deep gullies and wide craters, threatening to sweep away the homes of over 826 families as this channel is continuously expanding at an alarming rate (Abdulfatai *et al*, 2014).

From literature and the outcome of reconnaissance survey, it is clear that the main geologic unit responsible for gullying in Anambra State is the Nanka Sands which is a geologic unit occurring within the Ameki Formation of the stratigraphic sequence of the Southeastern Nigeria. It is a very loose and friable geologic unit (Onuoha and Onwuka, 2014). This work therefore compared the erodibilities the soils/rocks before grouting and after grouting using samples from gully erosion sites underlain by the Nanka Sands geologic formation.

Aim and Objectives

The aim of this study is to ascertain if erodibility of the soil is being affected (lowered) by grouting and to what extent. This is with the view of being able to decide whether or not grouting will be adopted in the study area as a measure of reducing soil erodibiity.

To achieve this aim, the following objectives were pursued:

1. to determine the erodibilities of the formation samples collected,
2. to determine the relationship between pre-grouting and post-grouting erodibilities of the samples of the formation collected and
3. to infer whether or not grouting reduces erodibility.

Hypothesis

The following hypothesis was postulated and tested:

H_0: There is no significant difference between the pre-grouting and the post grouting erodibilities of the samples collected.

LITERATURE REVIEW

Ojha and Shrestha, (2007) conducted a study on Bio-Engineering Measures for Stabilizing Cut-Slopes of Dipayal-Mellekh road, Far Western Nepal using field survey method. They found that grasses species such as Eulaliopsiss binata (Babiyo), Neyraudia reynaudiana (Dhonde), Cymbopogon microtheca (Khar), Saccharum pontaneum (Kans) and Thysanolaena maxima (Amliso), Arunduella nepalesis (Phurke) and Themeda species are suitable especially for slope stability.Simpson (2010) in his paper titled “Prevention and Control of Gullying Processes in Diverse Climatic Settings: Lessons for the age of global climate change” commented on

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cultural method (which he referred to as vegetative techniques) of erosion control. He said it has been found to be a cheap and effective method, for instance planting of plantain and banana on the floodplains have also been proven to be effective in controlling erosion.Obiadi *et al* (2010), opined that intensive afforestation program can be very effective in the control of gully erosion especially when well applied. This helps to protect the soil from the direct impact of raindrops and runoff as well as maintain the moisture content of the soil at responsible level during the dry season.

Izinyon *et al,* (2013) discussed the use of structural and non-structural approaches for the control and management of the Queen Ede gully in Benin City by evaluating and analyzing available geotechnical, hydrological, morphological, meteorological, bio-resources and other pertinent data relating to the site and subject matter. They recommended that the gully can be controlled and managed through a combination of structural and non-structural methods consisting of drop structures at the gully head, check dams at the bed and reshaping of the gully walls which are structural; and non-structural means through the planting of vetiver grass on the bed and reshaped walls of the gully as well as mounting of community awareness programmes to the gully menace through proper dumping of wastes and termination of drains. The reconnaissance survey of the study area shows that the major gully erosion control methods adopted in the area are bioremediation and use of civil engineering structures for channelization and these failed over time as they are being undermined by the flood waters due to the loose nature of the soils underlying the area, hence the need for a method of stabilization or increase in the soil resistance like grouting. Grouting earlier was rejected due to the toxic nature of the chemicals. Like in Japan, acrylamide grouts were banned in 1974 considering that it is a neurotoxic material and may be carcinogenic, but recently more environmental-friendly and less reactive chemicals like the silicates are being used. According to Reuben (2003), the modern era of chemical grouting began a half century ago, with the introduction of many new materials, and the significant modifications to the silicates.

Sina and Maassoumeh (2012) in their Review of soft soils stabilization by grouting and injection methods with different chemical binders, affirmed that soil stabilization has become one of the useful solutions to treat the soft soils to achieve the required engineering properties and specification so that structures can be placed safely without undergoing large settlements and can also be applied in erosion control, landslide management and to check issues like subsidence and differential settlement.

Study Area

The study area is Anambra State, located between latitudes 05^o 40’N and 07^0 10N’ and longitudes 06^o 35’E and 07^0 20’E, in the South-Eastern part of Nigeria (Onwuka, 2009). Boundaries are formed by Delta state to the west, Imo state and Rivers state to the south, Enugu state to the east and Kogi state to the north.

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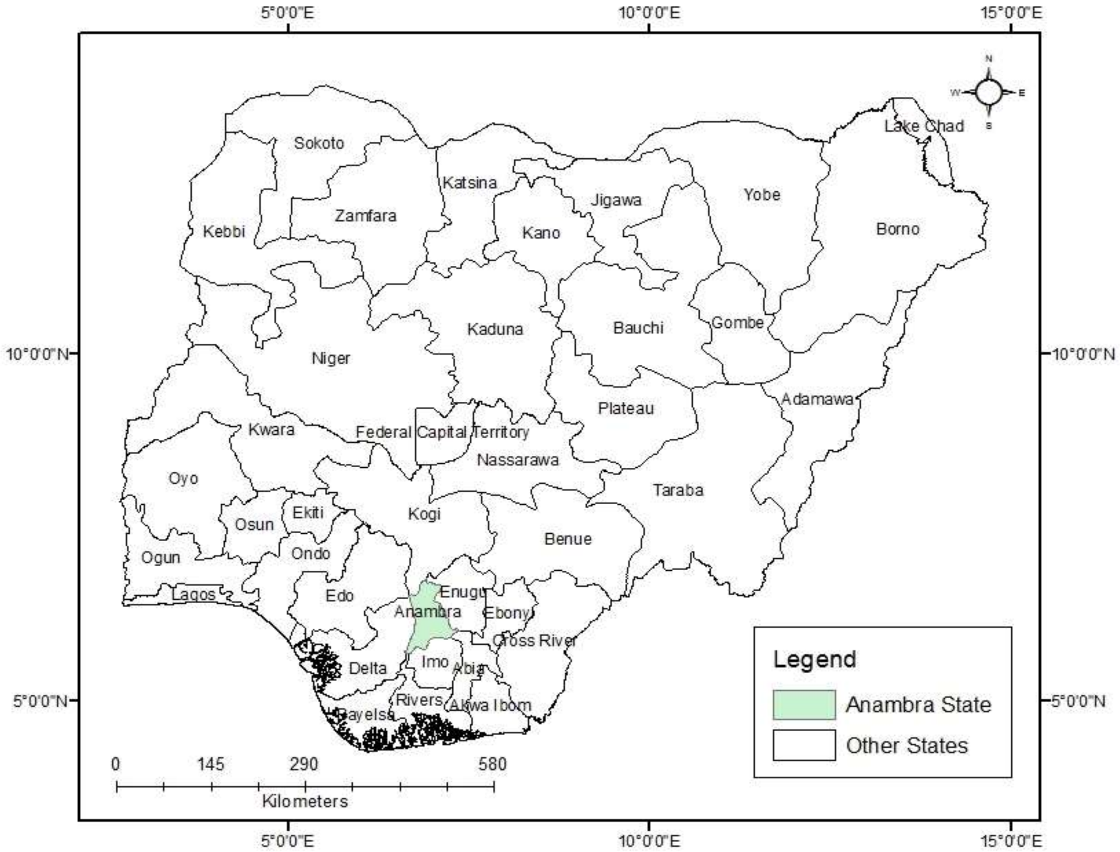

Fig. 1: Map of Nigeria Showing Anambra State (Source: National Geohazards, Awka, 2018).

Two climatic seasons exist in the study area, namely rainy season (March- October) and dry season (November- March). The annual rainfall of the area is about 2000mm. According to Onwuka (2009), the study area lies within the rain-forest belt of Nigeria. In the south, the area is bounded by mangrove swamp forest, and in the north, by savannah grassland. The rainy season is characterized by heavy down pours accompanied by thunder storms, heavy flooding, soil leaching, extensive sheet out wash, ground infiltration and percolation, (Afigbo, 1981; Egboka and Okpoko, 1984). Rainfall records of between 5. 87mm (at the beginning of rainy season) to 289.95mm (at the peak of rainy season are common). This increases the volume of water vapour in the atmosphere and eventually to leads high relative humidity, heavy thunder storms and high rainfall intensity except sometimes during the month of August when there is a noticeable drop in rainfall. This phenomenon is often referred as August break.

The dry season on the other hand begins when the dry continental northeastern wind blows from the Mediterranean sea across the sahara Desert down to southern Nigeria. It is characterized by extensive aridity and a lot of particulate and dust generation. The dry season is characterized by chilly and dry hamattan wind. There is equally a marked lowering of water table and intense leaf fall (Afigbo ,1981). Anambra state experiences high temperatures in the range of 27˚ - 28˚ C, which increase to a peak of about 35˚ C between February and April, the hottest period. The coolest periods occur from mid July through December to early January, coinciding with middle of the rainy season and the harmattan respectively.

METHODOLOGY

This study adopted the laboratory research method in analyzing the samples collected from the selected gully erosion sites to determine their various erodibilities.

Apparatus for Erodibility Test

Rainfall simulator was used to measure the erodibility of the various samples to be collected. The adoption of a rainfall simulator is based on the fact that the main agent of erosion acting in the area under study is water through rainfall.

Procedure

An artificial rainfall simulator was used, with a chamber that can take about 5kg of the disturbed sample subjected to equal degree of compaction will be exposed to the varied droplets of the artificial rainfall and the records of the soil loss taken. The various samples will be exposed to the droplets of varied ml per minutes to represent drizzle, raindrops and heavy rain; and the records taken. The slope of the chamber will also be varied and the soil loss also measured to establish the effect of topography change on the erodibilities of the soils. The various results will then be collated and analyzed.

DISCUSSION OF RESULTS/FINDINGS

Tables 1 to 4, Summarized the Analyses Result for the Erodibilities of the Soil Samples from the four Stations Before and After Grouting as follows:

Table 1: Results of Erodibilities for Station 1

FLOW RATE (ml/min)	ANGLE OF SLOPE (^{o})	Wt. of Soil Used (g)	Wt. of Soil Eroded Before Grt. (g)	Wt. of Soil Collected After Grouting (g).	
				Al, Fe, Silicate	Na. Silicate
60	25	2,000	190.55	47.78	59.12
	45	2,000	220.34	60.10	80.55
120	25	2,000	340.70	69.46	85.12
	45	2,000	420.45	102.12	121.15
180	25	2,000	501.12	98.11	141.90
	45	2,000	898.16	140.05	160.77

Source: Author's laboratory Analyses (2019).

Table 2: Result of Erodibilities for Station 2

FLOW RATE (ml/min)	ANGLE OF SLOPE (°)	Wt. of Soil Used (g)	Wt. of Soil Eroded Before Grt. (g)	Wt. of Soil Collected After Grouting (g).	
				Al, Fe, Silicate	Na. Silicate
60	25	2,000	207.90	33.26	55.80
	45	2,000	246.12	51.88	91.05
120	25	2,000	249.15	50.16	94.27
	45	2,000	460.18	91.16	136.66
180	25	2,000	620.17	102.81	134.95
	45	2,000	913.22	131.18	156.97

Source: Author's laboratory Analyses (2019).

Table 3: Result of Erodibilities for Station 3

FLOW RATE (ml/min)	ANGLE OF SLOPE (°)	Wt. of Soil Used (g)	Wt. of Soil Eroded Before Grt. (g)	Wt. of Soil Collected After Grouting (g).	
				Al, Fe, Silicate	Na. Silicate
60	25	2,000	202.10	60.03	54.96
	45	2,000	331.17	80.06	83.38
120	25	2,000	422.90	77.71	80.92
	45	2,000	846.67	93.12	123.16
180	25	2,000	803.81	101.24	126.13
	45	2,000	934.33	138.45	148.02

Source: Author's laboratory Analyses(2019).

Table 4: Result of Erodibilities for Station 4

FLOW RATE (ml/min)	ANGLE OF SLOPE (°)	Wt. of Soil Used (g)	Wt. of Soil Eroded Before Grt. (g)	Wt. of Soil Collected After Grouting (g).	
				Al, Fe, Silicate	Na. Silicate
60	25	2,000	311.06	44.42	62.00
	45	2,000	390.12	49.06	74.45
120	25	2,000	387.94	79.01	79.98
	45	2,000	709.05	100.06	91.00
180	25	2,000	901.11	94.01	124.33
	45	2,000	968.06	123.28	135.15

Source: Author's laboratory Analyses (2019).

From table 1 to table 4, three different follow rates were used (60,120, and 180ml/min) under two slope variations of 25^0 and 45^0 respectively. With a constant weight of soil. The higher the amount of soil collected, the higher the erodibility, and the lower the amount soil collected the lower the erodibility. The trend across the four stations as presented in the tables 1 to 4 above is such that there is reduced erodibility with the application of each grouting chemical.

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The trend also followed that with every increase in the slope and increase in the rate of flow (intensity of the artificial raindrops), there is subsequent increase in erodibility. This obeyed the natural law of slope and resistance. There were also very few cases where increase in the intensity of raindrops did not bring about increased erodibility. But at all points across the four stations after grouting with the two chemicals, increase in both topography and rainfall intensity yielded commensurate increase in the amount of soil eroded. It was also clear that the erodibility before grouting is far much higher than the erodibility after grouting.

Hypothesis: There is no significant difference between the pre-grouting and the post grouting erodibilities of the samples collected.

Statistical Tool: One sample T – Test

Reason for using one sample T – Test: one level of observation was collected; (that is the $AlFeSiO_4$ and $NaSiO_4$, as collected individually) from each station.

Decision Rule: Accept the null hypothesis if the p – value is greater than or equal to 0.05, otherwise reject it.

Degree of freedom: as contained in the results of the four stations.

Test proper: as contained in the results of the four stations

Decision and Reason for Decision: From the result of the four stations analyzed, it is clear that there is significant difference between the pre-grouting and post grouting erodibilities of samples collected.

CONCLUSION AND RECOMMENDATION

Conclusion

From the outcome of the analyses as shown in the tables 1 to 4 and the result of the test of hypothesis, the following conclusion were made:

1. There is significant difference in the pre-grouting and the post-grouting erodibility.
2. Furthermore, $AlFeSiO_4$ is a better grouting chemical since it has lower post-grouting averages compared to $NaSiO_4$ across the four stations.
3. The application of chemicals like $NaSiO_4$ and $AlFeSiO_4$ significantly reduces the erodibility of the soil provided other factors are constant.
4. Topography is a very critical factor in the growth of gullies on Nanka Sand geologic unit in Ameki formation of Anambra state (the study area) as can be seen in the erodibility test variation with varied angle of slope.

Recommendations

Sequel to the above findings and conclusion, the following recommendations were made:

1. The adoption of chemical grouting as a control measure to gully erosion should be done with utmost care and sensitivity, especially in the area of selecting the grouting chemicals as it has.

2. The study should be done in a larger scale and or site not in the laboratory to ascertain the feasibility of insitu chemical grouting as a control measure.
3. There should be a thorough cost-benefit analysis on this chemical method of gully erosion control.
4. There is need to analyze with other chemicals, silicates, fly ash, etc especially the fly ash which is already a waste from thermal plants and will form a ready raw material to be used for this process if proven.

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