IMPACT OF SOIL PROPERTIES AND FLOW VELOCITY ON RIVER BANK EROSION IN NAGAON DISTRICT ACROSS TWO SEASONS

A Dissertation submitted in
Partial Fulfilment of the Requirement for the Award of the Degree of

MASTERS OF TECHNOLOGY
In
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DECLARATION

I hereby declare that the work presented in the dissertation “IMPACT OF SOIL PROPERTIES AND FLOW VELOCITY ON RIVER BANK EROSION IN NAGAON DISTRICT ACROSS TWO SEASONS”in partial fulfillment of the requirement for the award of the degree of “MASTER OF TECHNOLOGY” in Civil Engineering (with specialization in Water Resource Engineering), submitted in the Department of Civil Engineering, Assam Engineering College, Jalukbari, Guwahati – 13 under Assam Science & Technology University, is a real record of my work carried out in the said college under the supervision of Dr. PANKAJ GOSWAMI, Professor, Department of Civil Engineering, Assam Engineering College, Jalukbari, Guwahati – 13.

Do hereby declare that this project report is solemnly done by me and is my effort and that no part of it has been plagiarized without citation.

Date: KISHOR RAJKHOWA

This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

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CERTIFICATE

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ABSTRACT

Riverbank erosion is a complex process. Various hydraulic and geotechnical factors influence the process of bank erosion. In this study, the problem is considered from geotechnical point of view. An attempt has been made to determine the effect of soil properties on river bank erosion by field observation and laboratory tests. The bank materials along the river kolong and Kapili with erosion potentiality have been investigated. After analyzing the experimental results it was found that majority of the erodible river banks was made up of poorly graded soil with silt, low clay content, weak erosion resistant strength, highly permeable with low or no plasticity and low liquid limit. It is expected that such type of study will help in providing certain inevitable baseline information for various channel management practices for extremely flood prone areas

Keywords: Bank erosion, soil properties, eroded and less eroded sites, laboratory tests etc

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CHAPTER 1

INTRODUCTION

1.1 RIVER BANK EROSION

River bank erosion is a process commonly associated with migrating meandering streams or laterally shifting streams. Migrating streams tend to erode the banks and widen the channels by undercutting the bank having the eroded materials is then washed away by the flow. The composition and characteristics of the bank materials and presence of vegetative cover determine the erosion rate. The deposition within the river bed and banks causing sandbars are the reason behind intense braiding of the channel. Bank erosion is termed to be a function or hydraulic character of flow and properties of bank materials. High moisture content, low proportion of clay and good sorting of bank make the bank highly susceptible to erosion by the river.

Bank line erosion in the banks of Brahmaputra-Barak Rivers of Assam is due to high flood discharge in the river, bed slope and composition of the bed and bank materials. Bank erosion causes lateral widening which is a significant geomorphic process in a river of large lateral dimension like Brahmaputra. The lateral widening which occurs is generally caused by erosion and deposition around the banks.

1.2 Factors responsible for bank erosion:

The salient hydraulic and bank material factors responsible for bank erosion of the Brahmaputra River system are:

- Rate of rise and fall of river water level,
- Number and position of major channel active during flood stage
- Angle at which the flow channel approaches the bank line
- Amount of scour and deposition that occurs during flood
- Variability of cohesive soil in bank material composition,
- Formation and movement of large bed forms,
- Intensity of bank slumping, and

- Progression of abandoned river courses to present-day channel.

1.3 Cause of failure of river banks

Sediment gets into the river not only from the catchment area but is also contributed by erosion of its banks. Cause of failure of river banks can be any of the following singly or in combination**.**

- Underwater erosion along the toe of bank during the falling stage of the river
- Direct erosion of the river bank.
- Sloughing of saturated bank caused by rapid drawdown
- Liquefaction of saturated silty and sandy bank material.
- Erosion due to seepage from banks at low river discharge.
- Scour along waterline due to wind or wave wash of passing vessels.

1.4 Effects of river bank erosion

River bank erosion is not only associated with the threat that it possesses towards life, infrastructure and agricultural land located near the river bank, but also is an significant threat towards the habitat in and around the riverine ecology. Due to the river bank erosion and channel migration, the Assam valley portion of the Brahmaputra River has lost approximately 7.4% of its land area during its recent history of observations. The river bank erosion has caused major human and economic disasters than the annual flooding. The extensive bank erosion in the basin has lead to numerous social and economic consequences loss of agricultural land (loss of livelihood), loss of housing and other essential infrastructure, displacement and involuntary migration promoting native-migrant contest over limited resources, ethnic tensions, distrust and political instability and civil strife in the basin. High human intrusion (massive encroachments and deforestation) on the natural landscape of the basin (State Plan Division, 2003), resulting in heavy siltation in recent times has also made worse the extent of bank erosion in the basin.

1.5 Effects of soil parameters on river bank erosion

The soil properties which are likely to influence erosion are soil water content, soil unit weight, soil plasticity index, soil undrained shear stress, soil void ratio, soil mean grain size, soil percent passing, soil clay minerals, soil P", soil temperature, water temperature, water salinity, water P" soil swell, soil permeability, specific gravity etc.

The fine sand and silty nature of the river bank material and the unstable bank line along the most part of the river create a highly favorable environment for bank erosion The bank materials in the Brahmaputra are highly susceptible to erosion by the river due to their high moisture content, low clay content and poorly graded fine sand and silt.

Fig 1.1:Photo shows erosion of river kolong and kopili in (a) Rahachoki (b) Borchung and (c) Jorabari

1.6 OBJECTIVES OF THE STUDY

The objective of the project study is given below:

- To study the effect of soil parameters and flow velocity across the dry and wet season and its impact on the erosion of the river Kolong and Koplili in Nagaon district.
- Comparative analysis of the effect of the soil parameters across the two seasons.

CHAPTER 2

LITERATURE REVIEW

GENERAL

A literature review has been compiled to study the impact of soil properties and flow velocity on river bank erosion in nagaon district across two seasons. This consists of various research paper, Thesis and Journal carried out by some student, investigators/Researchers and published in various national and international journals, magazines and websites.

Jennifer G. Duan (2005) stated a probabilistic approach to calculate rate of bank erosion. Bank erosion occurs due to two processes i.e., basal erosion due to fluvial hydraulic force and bank failure under the influence of gravity. The frequency of bank failure is correlated to the frequency of flooding; therefore, bank failure frequently occurs in recessing limb of a storm hydrograph. This approach is applicable for cohesive bank material of planar bank failure. Limitation of this study is lack of field data, so further research needs to done considering theimpact of flood hydrographs. evolution of tension crack with basal erosion, bank material saturation prior to bank erosion and time period to wash away failed bank material. This paperindicates that the rate of bank erosion is a function of the hydraulic forces, bank geometry, bank material cohesion and frequency of failure.

Mahabaleshwara et al. (2013) have conducted a case study on soil erosion and its impact on sedimentation and floods by considering various relevant cases and also give some of the potential remedial measures. For this they used GIS (Geographical Information System) and Remote sensing tool to give a Digital representation of the hydrological variables like soil erosion and sedimentation. The Universal Soil Loss Equation (USLE) (Wischmeier & Smith, 1978) has also been used for estimation of on-site erosion rates.

$S_{am} = C\ P0.6\ ^{Fe\ 1.7}S\ ^{0.25}\ D_d\ ^{0.10}\ (P_{max} / P)\ 0.19$

$F_e = (0.8\ F_A + 0.6\ F_G + 0.3\ F_F + 0.1\ F_W) / A$

S_{am} = Mean annual sediment yield in cm C = Coefficient depending on the geographical location of the catchment P = Average annual rainfall in cm, A = Catchment area in km^2 S = Land slope D_d = Drainage density in km/km^2 P_{max} = Average max monthly rainfall in cm F_e = Erosion factor F_A = Area of arable land in the catchment F_G = Area occupied by the grass and$_c$scrub F_W = Area of waste land F_F = Forested area.They concluded that Erosion of soil from the catchments involves the process of detachment of soil from the soil surface and its transport by rainfall and runoff. Deposition of detached material takes place when the transport capacity of flow is smaller than the quantity of materialbeing transported. And also, they found that the main cause for the erosion is due to deforestation, lithological characteristics of the soil of particular area, improper treatment of catchment and other anthropogenic activities etc. For preventing further negative impacts suitable erosion controlling measures are to be implemented so that reservoirs can be maintained with their storage capacity and damages due to floods can be minimized.

Goswami P.et al (2016) have studied the effect of soil properties on river bank erosion in lower assam region. The bank materials along the river Gangadhar, Tipkat, Gaurang, Champamati (or Champabati), Puthimari (north bank tributary of the mighty Brahmaputra River) and Palashbari with erosion potentiality have been investigated. After analyzing the experimental results, it was found that majority of the erodible river banks was made up of poorly graded soil with silt, low clay content, weak erosion resistant strength, highly permeable with low or no plasticity and low liquid limit. It is expected that such type of study will help in providing certain inevitable baseline information for various channel management practices for extremelyflood prone areas.

Talukdar et al. (2018) have studied role of Critical Shear Stress and Erodibility of Soil in Stream Bank Erosion in Lower Assam Region of River Brahmaputra. The span of the river Assam it is about 700 km. The depth of the river differs from just few meters to 120 m in certainsites with mean depth of about 38 m in rainy season. The breadth of the river is also changingjust more than 1 km to around 10 km. The nature of the river Brahmaputra is vast and unpredictable in terms of migration and channel cutting and creating wonderful havoc by eroding its banks to the people living near its sides. The critical shear stress is determined on the base of clay and silt content as suggested by Torres and Julian (2006) and on the basis of clay content only as suggested by Beasly and Smerdon (1961). In both methods the value of critical shear stress was found much in all safe and erosion free locations than all other vulnerable areas without any exception. They summarized that the value of critical shear stress and coefficient of erodibility of soil are two significant parameters to measure the weakness oferosion in lower Assam region of Brahmaputr

Wolman, in 1959 showed that serious erosion of cohesive banks takes place through the loosening or detachment of aggregates by sub-aerial or sub-aqueous processes. If the bank is poorly drained, positive pore water pressures act to reduce the effective cohesion and weaken the soil. In extreme cases, loss of strength may be complete, leading to bank failure by liquefaction. The most favorable conditions for high pore pressures occur in saturated banks following heavy and prolonged precipitation, snowmelt, and/or rapid drawdown in the channel. Where the soil surface is exposed, surface processes of raindrop impact and overland flow may also be important.

Coleman (1969) have showed that The bank formation and rate of recession are controlled by the fluvial processes, whereas the mechanism of bank failure is determined by the engineering properties of the soils. Shear failures in the upper bank materials appear to be by far the most widespread mode of bank failure. This may be caused either by undercutting the upper bank materials by strong currents during the high flows or by over steepening of the bank slopes. Overhanging cantilevered blocks are produced during the undercutting which leads to eventual falls and over steepening causes steep slopes due to migration of thalweg closer to the bank during the falling stages.

Das Luna Moni (2020) has carried out a study to understand the pattern of change of sedimentload in the Jiadhol River of the Brahmaputra valley. A Sediment rating curve has also been derived to establish an empirical relationship between Discharge and Sediment load of the river. The study shows that fast siltation occurs in the riverbed during the rainy season while the river is dry for half of the year. Due to this rapid siltation, the carrying capacity of the Jiadhol river decreases overtime and as a result of this frequent overflow of the river during monsoon season occur along with frequent breaching of bridges is a common fact in the foothills of Jiadhol river.

Debnath et al. (2023) have assessed the changes in the Brahmaputra River planform using theGIS-based Digital Shoreline Analysis System (DSAS) and relates it with the changing LULC of the floodplain evaluated using the CA-Markov model. This study involves the future channel of the Brahmaputra River and its flood plain's future LULC were forecasted to pinpoint the erosion-vulnerable zone. For this they used forty-eight years (1973-2021) of remotely sensed data to estimate the rate of Bankline migration. The result from this study shows that the river'serosion-accretion rate was higher in early times than in more recent ones. The left and right banks' average shifting rates between 1973 and 1988 were 55.44 m/y and 56.79 m/ y, respectively, while they were 17.25 m/y and 48.49 m/y from 2011 to 2021.The Brahmaputra River's left bank had more erosion than the right, which suggests that the river is moving left (Southward) direction and also they found that Zones A (Lower course) and B (Middle course)of this river course got adversely affected than zone C (Upper course).According to their predicted results, the left bank, has the average rate of erosion and deposition w and 79.50 m/y, respectively, is anticipated to be more vulnerable to bank erosion than the rightbank. The left bank's average rate of erosion was 111.22 m/y. The study also evaluates river channel dynamics and the LULC study in locations where infrastructure and settlements wereat risk from channel migration.

DUTTA et al. (2005) Study on the erosion deposition process around majuli island.He found that Annual monsoons and flooding exacerbate erosion, especially during high-flow periods when water velocity and sediment-carrying capacity increase.Deposition is observed primarily along the northern banks, but it is insufficient to compensate for the land lost to erosion.The sediment deposited often shifts with changing water flow patterns, contributing to instability.

CHAPTER 3

DESCRIPTION OF THE STUDY AREA

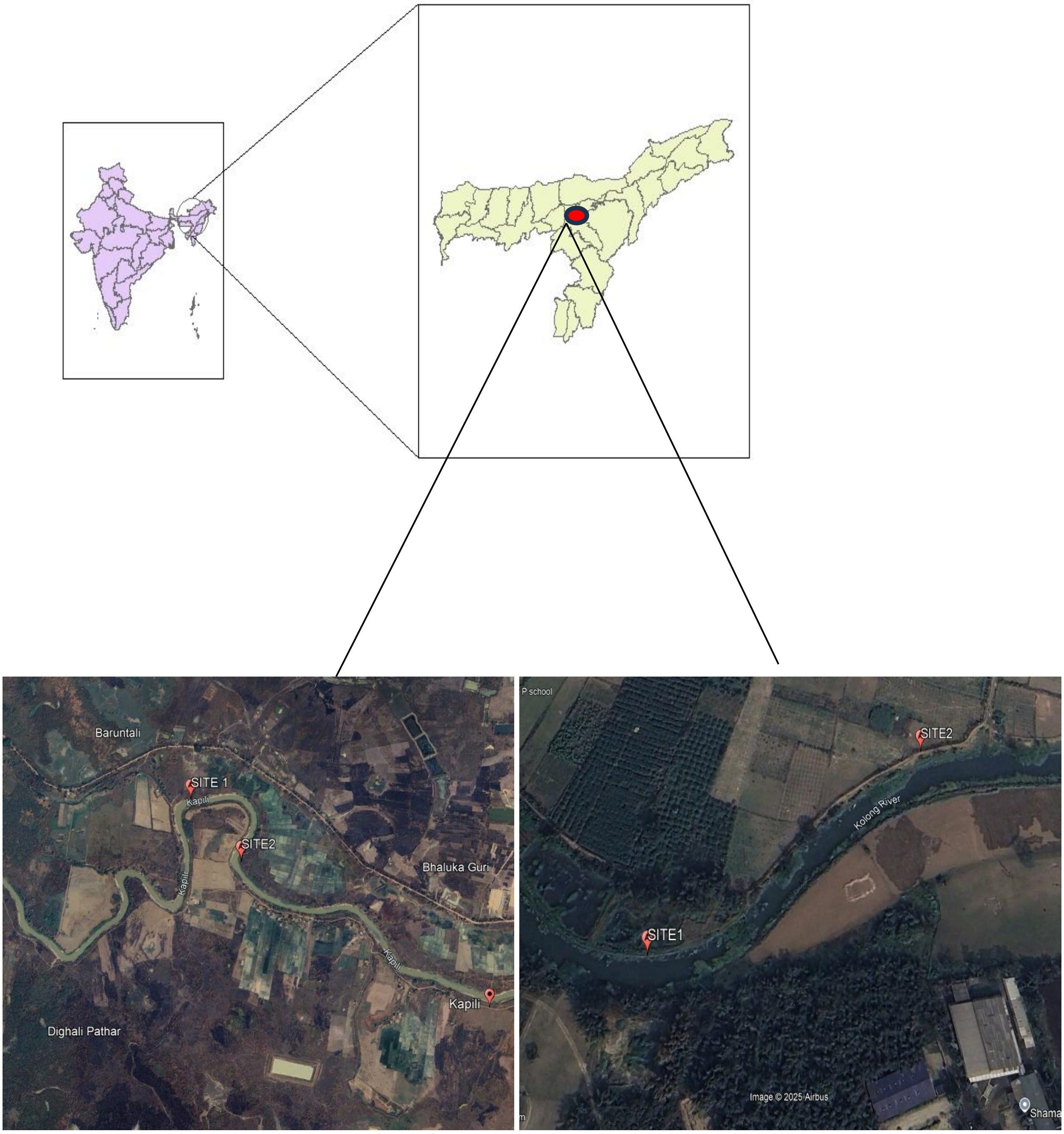
3.1 INTRODUCTION

The Study of sampling point of Kolong and Kapili River are discussed in this chapter.

3.2 STUDY AREA

The study area of this project focuses on Kolong and Kapili River which are lies between at latitude 26 ° 21′0" and longitude 26 ° 21′0" and latitude 26 ° 21′0" and longitude 26 ° 21′0"respectively as shown in the figure 3.1 and Along with four different locations from which samples were collected. The Kolong River is a distributary of the Brahmaputra, originating near the town of Jakhalabandha. It meanders through Nagaon district and remerges into the Brahmaputra at Kajoli Choki. Historically significant and central to the livelihoods of local communities, the Kolong faces challenges such as siltation and seasonal water flow variation.

The Kapili River another tributary of the Brahmaputra, originates in the Meghalaya plateau and flows through the Karbi Anglong and Nagaon districts. Known for its steep gradients and lateritic terrain in the upper catchments, the Kapili River basin provides a diverse range of soil types.



(a) (b)

Fig 3.1:photo shows the study area of(a)Kapili river(b)Kolong river

CHAPTER 4

METHODOLOGY

The project work is divided into two phase including dry season and rainy season as shown in the flow chart given below. The studies contain the collection of soil sample and measured flow velocity from four different locations from Kolong and Kapili and test all the samples in the Geotechnical Engineering laboratory of Assam Engineering College, Guwahati.

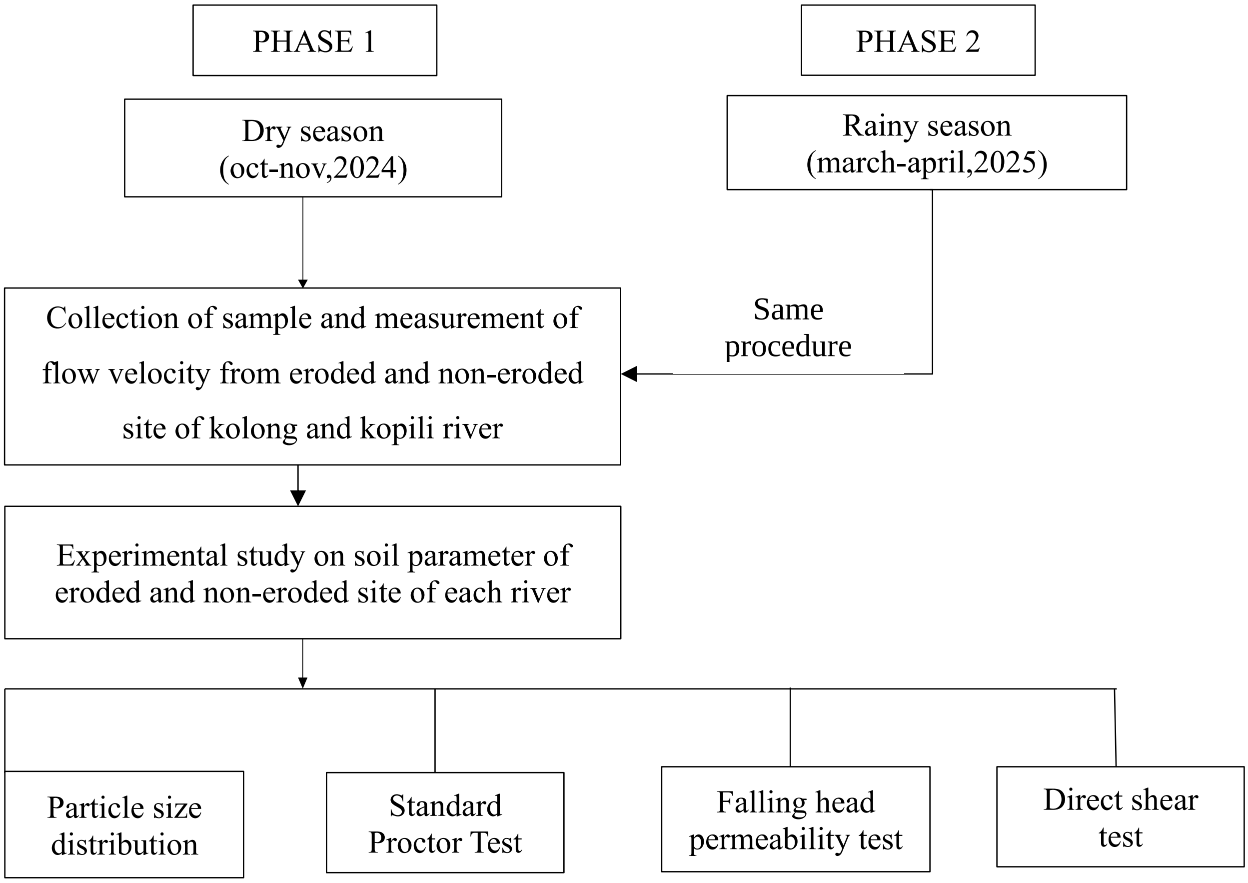


Fig4.1 Flowchart showing methodology

4.1 FIELD WORK

4.1.1 Sample Collection

On the basis of erosion/deposition activities and meandering of the two river as observed from the satellite image (google earthpro),the sites for sampling(both eroded and non eroded) are selected and bank soil samples are collected from both the sites along with the flow velocity was measured.The samples are then subjected to various laboratory test.

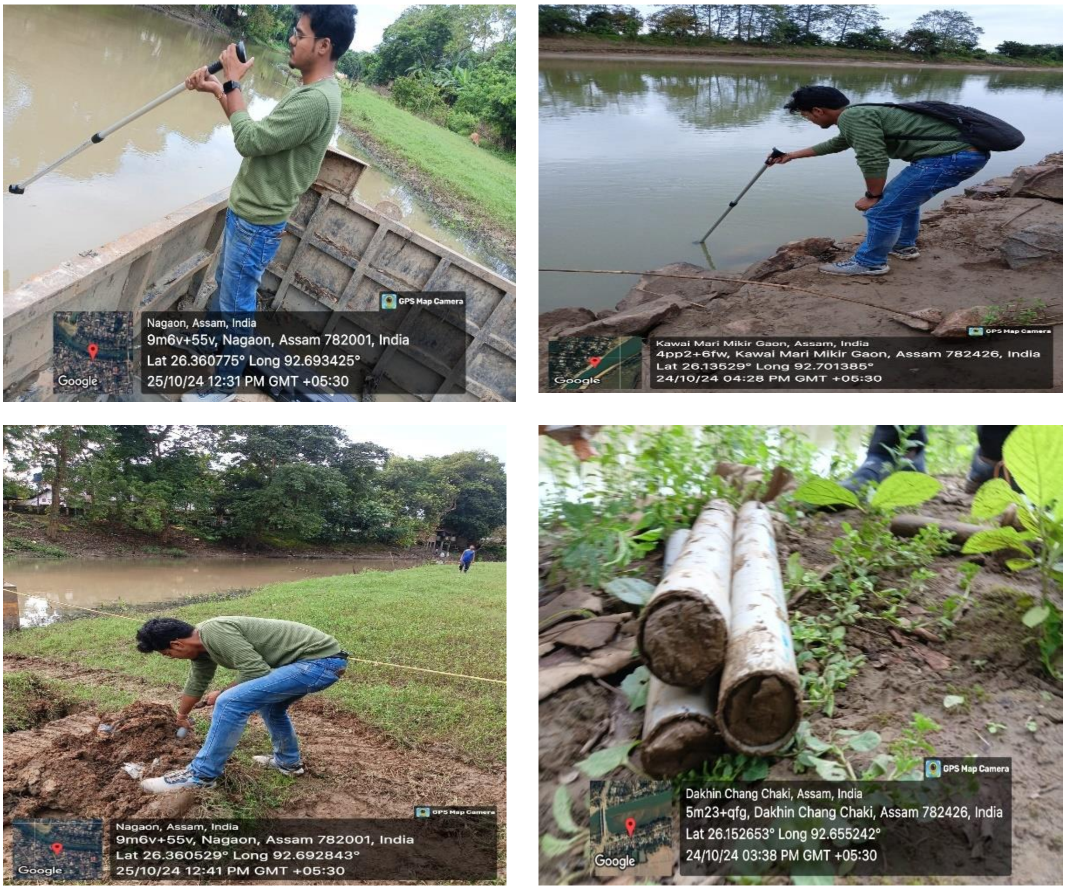


Figure 4.2: photo shows (a)and (b)flow velocity measued in eroded site of kolong and kapili(c)and (d)sample collection from non eroded site of kalang and kapili

4.2 LABORATORY WORK

After the collection of soil samples, are then subjected to the following laboratory test-

a) **Permeability Test**: The permeability test of soil samples are detertmined by Falling head permeability test.

Procedure:

The falling head test is used for relatively less permeable soils where the discharge is small. A stand pipe of known cross-sectional area "a" is fitted over the permeameter and water is allowed to run down. The water level in the stand pipe constantly falls as water flows. Observations are started after steady state of flow has reached. The head at any time instant "t" is equal to the difference in the water level in the stand pipe and the bottom tank.Let h_1 and h_2 be heads at time intervals t_1 and t_2 ($t_1>t_2$) respectively. The co- efficient of permeability is determined as

$K=2.303(aL/At) \log_{10}(h_1/h_2)$……………………………………………………………….(i)

Where,L=Length of the sample

A=Total crossectional area of the sample.

Fig 4.3: Falling head permeability test

(b)Grain Size Distribution

As the soil specimens were fine grained in nature, samples were passed through the arrangement of sieve sizes 4.75mm,2.36mm,1.18mm, 0.6mm, 0.3mm, 0.15mm,0.075mm and test was conducted as per IS. 2720 (part4)-1985.

Procedure:

The portion of the soil passing 4.75-mm IS Sieve obtained was oven-dried. This oven- dried material shall then be riffled so that a fraction of convenient mass is obtained. This shall be about 200 gm. if a substantial proportion of the material only, just passes the 4.75-mm IS Sieve or less if the largest size is smaller. The soil specimen should be passed thoroughly over the nest of sieves nested in order of their fineness with the finest sieve (75-micron IS Sieve) at the bottom. Passing shall be continued until the water passing each sieve is substantially clean. Care shall be taken to see that the sieves are not overloaded in the process. The fraction retained on each sieve should be emptied carefully without any loss of material in separate trays. Oven dried at 105 to 110°C and each fraction weighed separately and the masses recorded. The fraction retained on the sieve should be tipped without loss.

(C) Direct Shear Test

This test was carried out as per the provisions in IS 2720 (Part13):1986 on the disturbed soil specimens.

Procedure:

The test is carried out on either undisturbed samples or remolded samples.

To facilitate the remolding purpose, a soil sample may be compacted at optimum moisture content in a compaction mould. Then specimen for the direct shear test could be obtained using the correct cutter provided. Alternatively, sand sample can be placed in a dry state at a required density, in the assembled shear box. A normal load is applied to the specimen and the specimen is sheared across the pre-determined horizontal plane between the two halves of the shear box. Measurements of shear load, shear displacement and normal displacement are recorded from the dial gauge and the proving ring connected to the shear box. A graph of shear stress against displacement is plotted in a normal graph paper. From this graph, the highest values of shear stress for loads 0.5 kg, 1 kg and 1.5 kg are determined. Then another graph is plotted for these maximum shear stresses against normal stresses. From this graph, the value of cohesion and angle of internal friction of the soil sample is determined. The test is repeated for two or more identical specimens under different normal loads. From the results, the shear strength parameters can be determined.

Fig4.4: Direct Shear Test

(d) Standard Proctor Test

The Standard Proctor Test is a laboratory compaction test conducted to determine the optimal moisture content (OMC) and maximum dry density (MDD) of a soil.

Procedure

A standard Proctor test involves collecting a soil sample, preparing it with varying moisture contents, compacting the soil in a mold in three equal layers with a specified number of blows per layer using a compaction hammer, and then calculating the dry density of each sample to determine the optimum moisture content at which the soil reaches its maximum dry density; this is achieved by plotting the dry density against moisture content on a graph, with the peak point representing the optimum moisture content.

CHAPTER 5

RESULTS & DISCUSSION

5.1 Particle size distribution of soil sample for eroded and non-eroded site

After the analysis of particle size distribution of soil sample from both eroded and non eroded sites,it was found that Cu and Cc of eroded sample were 3.75 and 1.67 respectively and 6.72 and 2.84 respectively for non-eroded samples.These findings are summarized below in table 5.1

Table 5.1 Particle size characteristics table

Particle size characteristics	Soil sample(%)	
	Eroded site	Non eroded site
Coarse sand (4.75-2.00mm)	7.16	2.54
Medium sand(2-0.425mm)	8.61	20.16
Fine sand (0.425-0.075mm)	81.07	72.56
Silt and clay	0.125	4.74
Cu	3.75	6.72
Cc	1.67	2.84
Type of soil	Poorly graded sand with silt	Well graded sand with clay

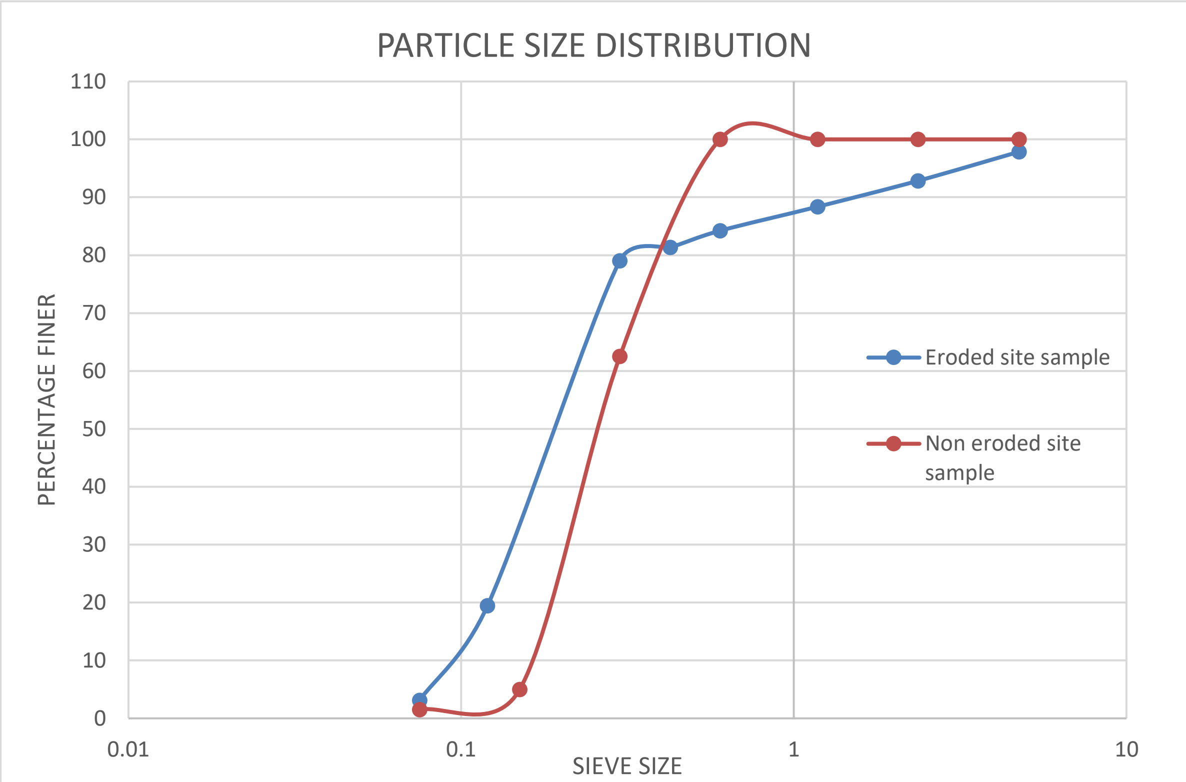


Fig 5.1: Particle size distribution of eroded and non-eroded sample

5.2 Results for Standard Proctor Test

After the testing of standard proctor test,it was observed that optimum moiture content(OMC) and maximum dry density(MDD) found to be 18.1% and 1.830g/cc^3 respectively for eroded site and 15.7% and 1.88g/cc^{3}for non eroded site respectively.

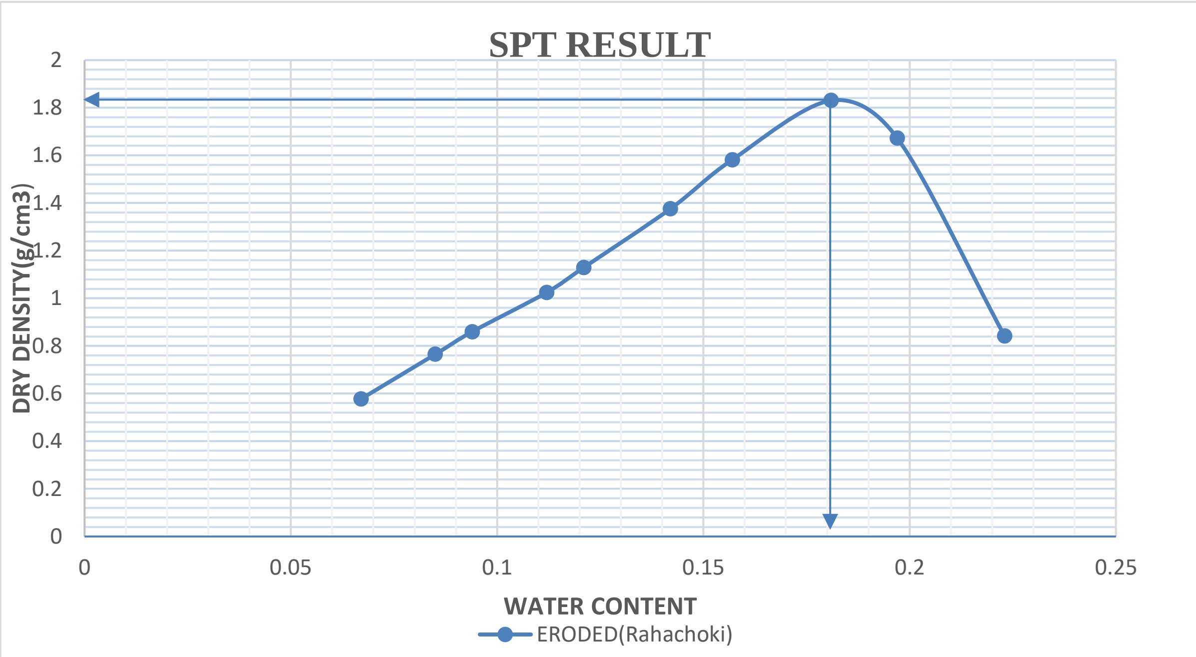


Fig 5.2: Standard ptoctor test for eroded sample

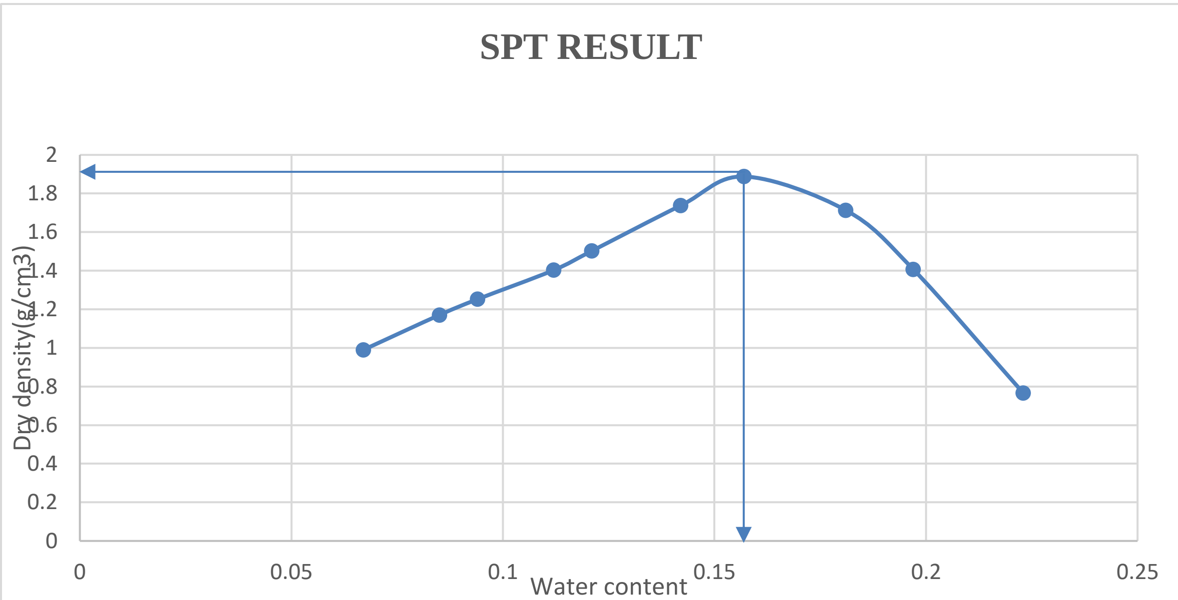


Fig 5.3: Standard ptoctor test for non-eroded sample

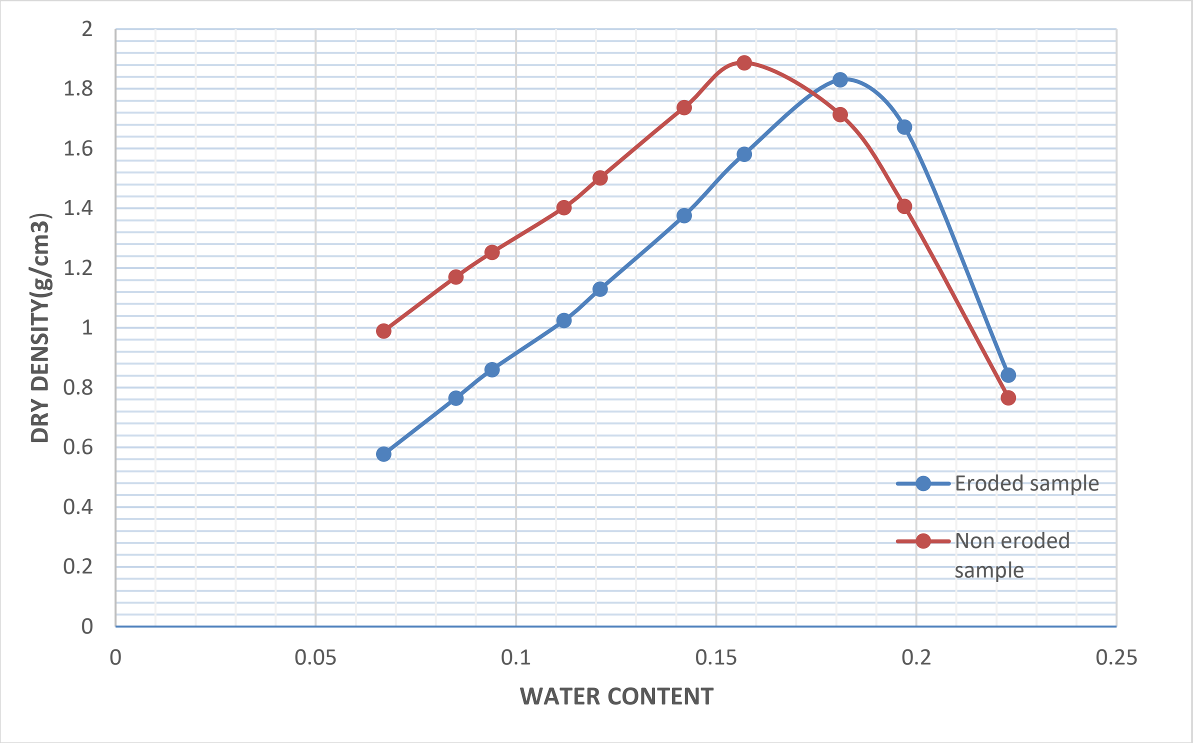


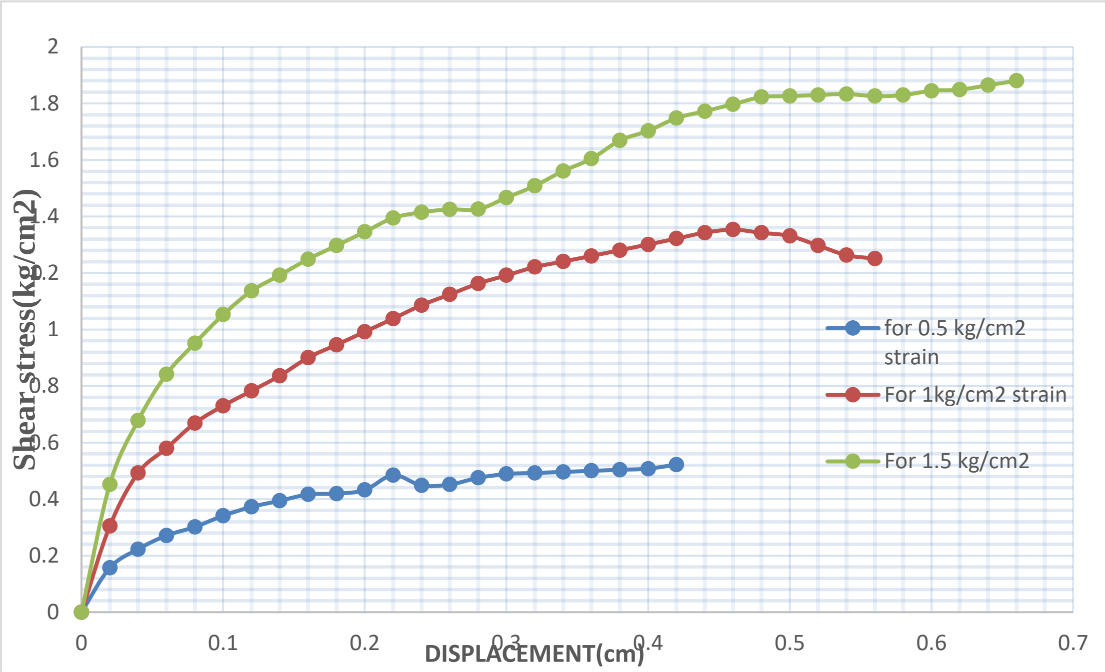
Fig5.4: Comparison of SPT of eroded and non eroded sample

Table 5.2: OMC and MDD of eroded and non eroded sample of Kolong river

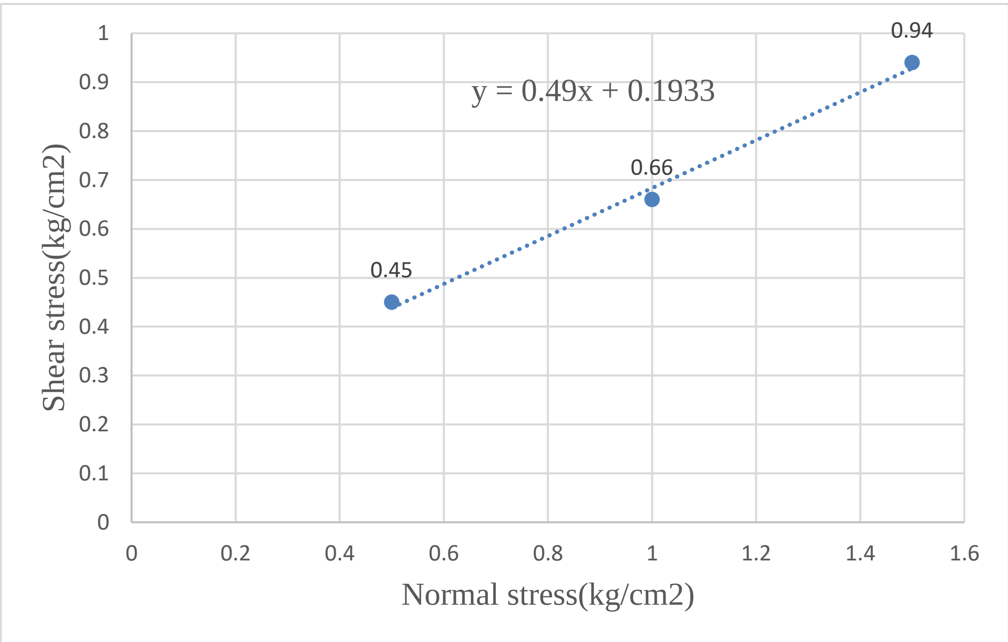
Type of sample	Eroded	Non eroded
OMC(%)	18.1	15.7
MDD(g/cm^3)	1.83	1.88

5.3 RESULT FOR DIRECT SHEAR TEST

From the direct shear test cohesive property and angle of internal friction were found for both eroded and non-eroded sample of kolong and kapili river which are shown in tabulated form Table 5.3

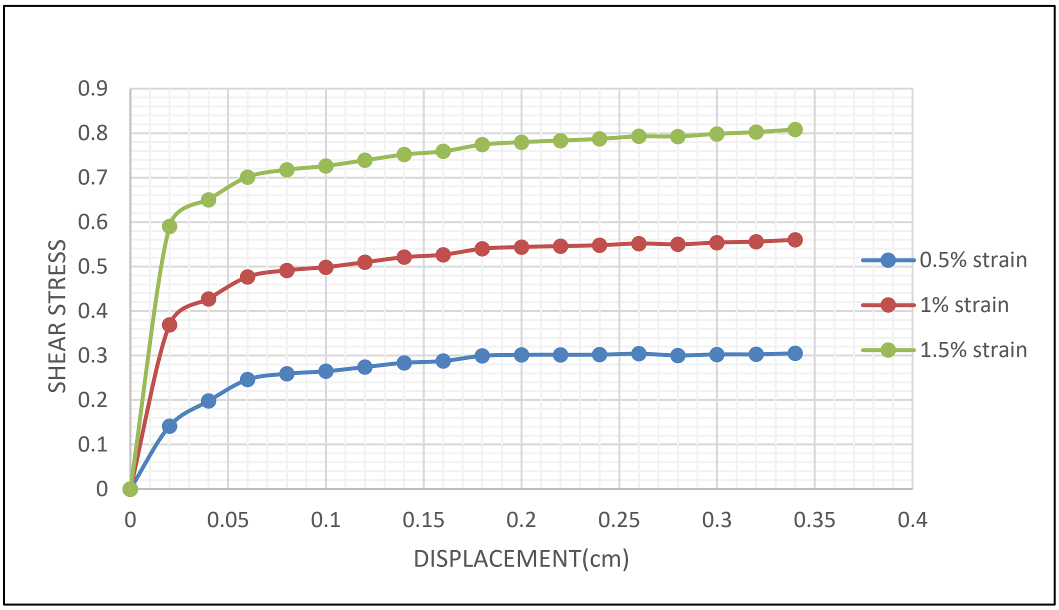


(a)

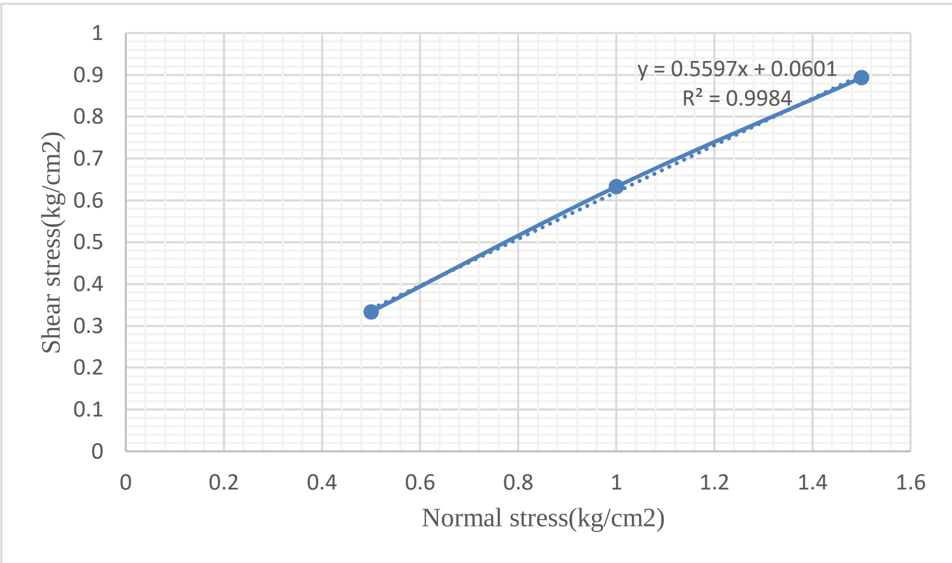


(b)

Fig 5.5: (a)Shear stress vs Displacement curve (b)Shear stress vs Normal stress curve for eroded sample



(a)



(b)

Fig5.6: (a)Shear stress vs Displacement curve (b)Shear stress vs Normal stress curve for non-eroded sample

From these result ,C and Ø value for eroded and non eroded sample are given below

Sample	**Eroded**	**Non eroded**
C(kg/cm)	0.19	0.06
Ø	26.10 °	29.2°

5.4 RESULT FOR PREMEABILITY TEST

The result of falling head permeability test performed on eroded (Rahachoki)and non eroded (kolongpar) samples are listed below

Table 5.3 : Permeability coefficient for both eroded and non eroded sample

K_{avg}(eroded)	7.44 x 10^{-6}
K_{avg} (non eroded)	4.14 x 10^{-4}

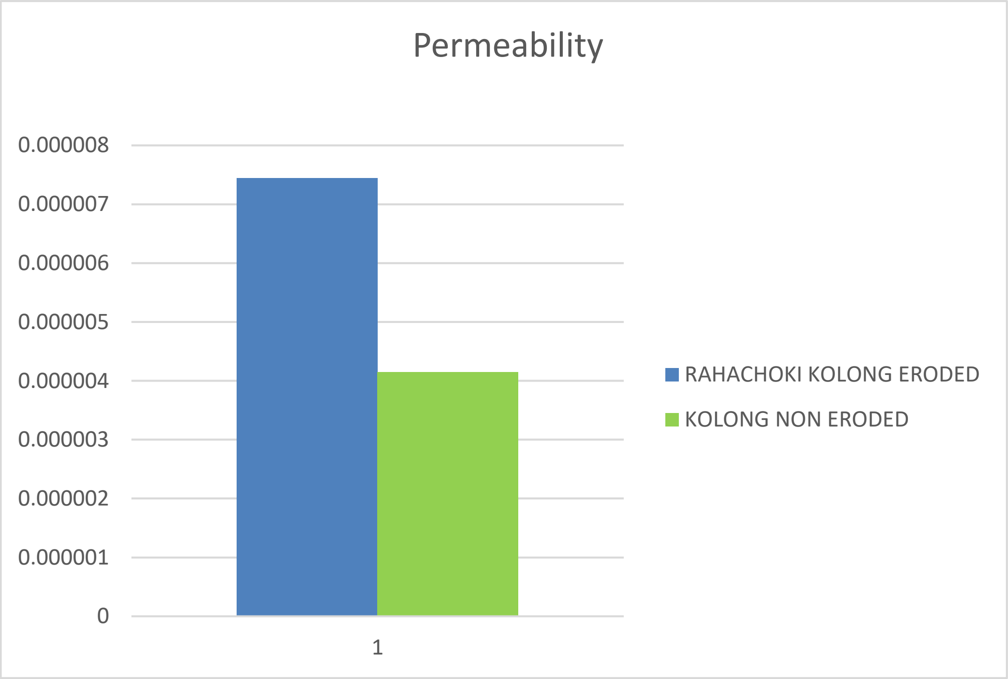


Fig 5.7: Coefficient of permeability of soil sample

5.5 FLOW VELOCITY MEASURES AT EROSIVE SITE OF KOLONG AND KAPILI

KOLONG			KAPILI	
SITE1	0.2m/sec	0.5m/sec	0.5m/sec	1m/sec
SITE2	0.4m/sec	0.7m/sec	0.7m/sec	0.8m/sec

CHAPTER 6

CONCLUSION

- After analysing the result till now, it was found that the eroded site i.e Rahachoki of kolong river was consist of poorly graded sand with silt. Thus this riverbank is more erodible due to low clay content.
- From Falling head permeability test for eroded and non-eroded site, it can be concluded that more the permeability more is the erosion. In case of dry season, permeability may increase due to cracking or reduced water content of silty sand. It will be compared and analyzed in the next season i.e wet season.
- The shear strength parameters C and Ø are not the inherent properties of soil. They depend upon the drainage condition. In case of dry season soils generally exhibit higher shear strength, especially if they are well-compacted or have developed matric suction.

CHAPTER 7

FUTURE WORK

- Comparative analysis of all the soil parameters for wet and dry season.
- DST analysis for remaining heavily eroded and non eroded site of kolong and Kopili river

CHAPTER 8

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