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River Bank Stability Assessment Based on Engineering Properties of Soil Around the Majuli Island of Northeast India

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Abstract - *Severe bank erosion by river Brahmaputra along the south bank of Majuli island of northeast India, the largest inhabited river island in the world, is a burning issue that needs immediate attention from the scientific community. The present study aims to analyze the bank stability of Majuli along the south bank based on the engineering properties of the bank materials. Vulnerable and stable bank locations were identified based on temporal migration of river Brahmaputra along the bank of Majuli from 1975 to 2018, and soil samples were collected from the field, which was tested to be either silt with low compressibility or silt with medium compressibility types. Considering both saturated and unsaturated conditions of the soils, three distinguished zones, stable, unstable, and at-risk, have been created to analyze the bank stability of the island. The results demonstrated that samples collected from extreme erosion-prone locations fell either in unstable or at-risk zones, and samples collected from less eroded places fell in the stable zone that supports the practical utility of the study. The outcome of the study is expected to be helpful in acquiring elementary information required for riverbank management practices along the bank of Majuli island.*

Keywords - *Majuli island, Brahmaputra, Migration, Bank erosion, Bank stability, Critical height*

I. INTRODUCTION

Channel migration and associated riverbank erosion are among the most dynamic geomorphological processes and, therefore, of considerable scientific interest. Erosion along a riverbank mainly occurs due to the removal of grains from the bank by the flow of the river, and the severity of erosion depends upon the engineering properties of the bank materials [1], [2], [3], [4], [5]. Because of the strong, cohesive bond between the soil particles, the cohesive soils are more resistant to erosion compared to the non-cohesive soils [6]. Bank erosion is basically the combination of fluvial entrainment and subaqueous weakening of the grains [6]. Depending upon the engineering properties of the bank materials, the grains get

weakened under sub-aqueous conditions, and the eroded materials are supplied to the toe, which then is removed due to fluvial entrainment. The non-cohesive banks are detached, and entrained grain by grain, and the cohesive banks are eroded as aggregates of soil. Rinaldi and Casagil [7] proved that streambanks of alluvial channels are usually composed of loose materials, which are unsaturated in ambient conditions. Unsaturated soils are subjected to negative pore-water pressures, which cause an apparent cohesion. Although riverbank erosion is a common phenomenon, the prediction of the location and extent of erosion is difficult. The practical determination of the potential of riverbank erosion requires information on the streamflow conditions, soil composition of the banks, and the erosion rate of the soils exposed to the flow.

Majuli in the north-eastern state of Assam in India is bounded by river Subansiri, and its tributaries Ranganadi, Dubla, Dikrong, Tuni, etc., on the northwest, on the northeast by a spill channel of Brahmaputra named Kherkatia Suti, and on the south and southwest by the Brahmaputra River. Thus, the Majuli has become a riverine Island and, because of its large size and huge inhabitation, has also been declared as a district of Assam state. The island is situated within the geographic coordinates 26°45′N to 27°15′ latitude and 93°45′E to 94°30′ E longitude (Fig.1). Majuli has been the cultural capital and the cradle of Assamese civilization for the past five hundred years. However, the very existence of the island is in danger due to erosion caused by the bounding rivers, more specifically by the Brahmaputra river. The Brahmaputra is a highly braided and large alluvial river, and it carries huge sediment loads because of its flow through an active seismic region [8], [9], [10]. A braided river represents a high-energy fluvial environment often characterized by non-cohesive banks lacking vegetation and, consequently, high rates of bank erosion and bedload transport [11]. Among many other reaches, the Majuli island is the most notable example of Brahmaputra’s enormous erosion potential. The erosion around Majuli was known to be initiated to a large extent by the great Assam earthquake of 1950 of magnitude 8.7 Richter scale and became more severe after the 1954 flood. The severity is evidenced by the fact that an area of 1246 km^2 in 1950 of Majuli was reduced to 925 km^2 in 1971 [12]. Space Application Centre and Brahmaputra Board [13] assessed the bank erosion in Majuli and identified the areas subjected to erosion which is an indication of the dynamic behavior of the river. Brahmaputra board [12], in their report, mentioned the area of the island to be 925 km^2 in 1971. Mani and Patowary [14] determined the area of the Island as 486 km^2 in 1997 using LISSIII data of IRS1C. Using multi-temporal satellite data, Mani, Kumar, and Chatterjee [15] investigated the trend of erosion in Majuli from 1991 to 1998. They found that over a span of six years, from 1991 to 1997, 1900 ha of land got eroded from the island. Again 845 ha got eroded within just one year period from 1997 to 1998. Kotoky et al. [16] found from their study, the rate of erosion to be 1.9 km^2/yr in the Island during 1920-98. Kotoky et al. [17] studied a reach of Brahmaputra of 270km long that also covers Majuli island using Survey of India toposheets of 1914 and 1975 and IRS data of 1998. They indicated that the slumping intensity along the bank is mainly due to severe undercutting, which is because of inhomogeneous bank material and morphological changes of the river channel. Using Artificial Neural Network (ANN) and remote sensing technique, Sankhua et al. [18] assessed the erosion activity in the island. Dutta, Barman, and Aggarwal [19] analyzed the erosion and deposition processes along Majuli using remote sensing and GIS techniques from 1975 to 2008. They found an annual rate of erosion of 8.76 km^2/yr and deposition of 1.87 km^2/yr during this entire period. Lahiri and Sinha [20] carried out a morphometric analysis of Majuli and said that it is a very dynamic landform of Brahmaputra valley, which is mainly because of basement configuration and tectonic setting. Lahiri [21], from his statistical analysis, said that erosion along lower Majuli is much more severe than the other parts of the island. Sarma [22] suggested some remedial measures to protect the island after a thorough study of the erosion process. Thus, this region has become the playground of a flood, bank erosion, and channel shifting not only at the active floodplain zone but also very often destruct the normal flood-free area heavily, bringing great threat to the whole region.

It is clear from the literature that most of the studies in Majuli focussed mainly on the migration of the river Brahmaputra as well as erosion/deposition caused by it. The present study, however, aims to determine the stability of slope at different vulnerable locations along the southern bank of Majuli, i.e., the bank along which river Brahmaputra, by evaluating the bank geometry and geotechnical characteristics of the alluvial bank sediments.

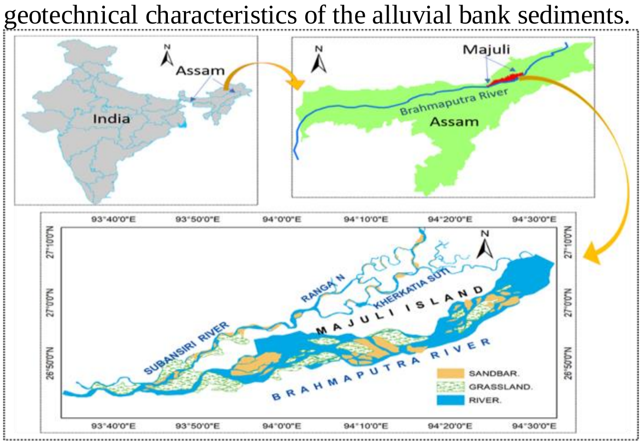

Fig.1: Location map of Majuli Island

II. MATERIALS AND METHODS

A. Identification of Locations of Erosion and Deposition and Collection of Soil Samples

To understand the erosion caused by any river, it is necessary to realize its sequential migration pattern in different time periods. In this study, the migration of the river Brahmaputra along the southern bank of Majuli has been studied from 1975 to 2018. This has been carried out by digitizing the bank using Survey of India toposheet of 1975, IRS 1B LISS II data of 1998, IRS P6 LISS III data of 2008, and Resources at 2 LISS III data of 2018. From the superimposed bank lines, the areas subjected to erosion and deposition by the Brahmaputra have been identified, out of which seven different locations have been selected for the present study. The migration of the river Brahmaputra in these particular locations has been analyzed for the periods 1975-1998, 1998-2008, 2008-2018, and 1975-2018 respectively. Using Garmin Global Positioning System, the exact geographic coordinates of the locations have been located in the field. Soil samples were then collected from those locations to study their engineering properties.

Different engineering properties viz., water content, field unit weight, liquid limit, plastic limit, and shear strength parameters of the soil samples have then been analyzed in the laboratory.

B. Bank Stability Analysis

The erosion of riverbanks is a natural process that contributes to the progression of river meandering across a lowland valley. The objective of this assessment is to evaluate the stability of the natural riverbank of Majuli island along Brahmaputra River and also to correlate the engineering properties of the bank soil with the erosion susceptibility. Few assumptions have been made in this study to attain acceptable and satisfactory results. First, as the soil samples collected from the field are composed mainly of alluvial sediments, they are considered to be isotropic and almost homogeneous in nature. Second, the riverbank is considered to have finite depth and infinite lateral extent that make the slope semi-infinite.

Soil during saturated conditions is considered to be most vulnerable to erosion as shear strength becomes zero. Hence, by taking friction to be zero, the saturated condition is considered as the most potential situation. Since the sediment is mainly of ML-MI type, it can safely be assumed that the water content at saturation is roughly equal to the liquid limit. This is based on the fact that from a slope failure point of view, the saturated condition exhibits maximum possible saturated unit weight, corresponding to maximum possible water content nearer or equal to the liquid limit.

$$W_{sat} = W_L \quad (1)$$

therefore,

$$\gamma_{sat} = \gamma_d (1 + W_L) \quad (2)$$

where W_L is the Liquid limit, W_{sat} is the water content at saturation, and γ_d is the dry unit weight of the alluvial samples.

Table1 and Table2 give soil parameters of the samples under saturated and unsaturated conditions.

Table 1:Soil parameters under saturated condition

Soil Parameters	Saturated condition
$c^{/}$(N/cm^2)*	0.91$^{(\#)}$
$\Phi^{/}$ *	0 $^{(\#\#)}$
γ(N/cm^3)	1.80x10$^{-2\ (\#\#\#\#)}$ $\gamma_{sat} = \gamma_d(1+w_L)$

Table 2: **Soil parameters under unsaturated condition**

Soil Parameters	Unsaturated Condition
c_m (N/cm^2) ** c_m=⅔c_u(N/cm²)	0.68$^{(\#\#\#)}$
Φ_m ** Φ_m=tan⁻¹(⅔tan Φu)	17.14$^{(\#\#\#)}$
γ(N/cm^3)	1.73x10$^{-2\ (\#\#\#\#)}$

(#) From the table of average soil properties as suggested by USBS, 1962 (Accepted by BIS) for ML type of soil. (Singh and Chowdhary, 1994).

(# #) Considering zero friction for saturated silt.
(# # #) The average mobilized values of shear parameters determined in the laboratory for the samples collected from the site
(# # # #) The average values of soil density determined in the laboratory on the samples collected from the site

***** Since the strength of soil in the saturated condition is mainly a combination of shear resistance and excess pore pressure, here the effective shear parameters, $c^{/}$and $\Phi^{/,}$ are considered instead of apparent values, $c_{U,}$ and Φ_U.
****** Since at the time of failure, most c – Φ soil exhibits local shear failure, the mobilized values $c_m$and Φ_m are considered instead of the apparent values c_U and $\Phi_{U.}$

C. Determination of Bank Angle, Stability Number, and Critical Height

Bank anglers in the field were determined by leveling staff.
If, X = Instrument height above the ground
Y = Height above ground + instrument height
Z = Horizontal distance between the two points
Then, the actual vertical distance between the higher and the lower point = Y – X.

So, Bank slope (β) is,
$\tan\beta = \frac{(Y-X)}{Z}$ (3)

$\beta = \tan^{-1}\left\{\frac{(Y-X)}{Z}\right\}$ (4)
The stability number (N_s) was determined for bank angles (β) from 25 to 90 degrees using the relationship:

$S_n = \frac{(4\sin\beta\cos\varphi)}{\{1-\cos(\beta-\varphi)\}}$ (5)

A critical bank height (H_c) was then calculated using the formula
$H_c = \frac{(4c\sin\beta\cos\varphi)}{\gamma\{1-\cos(\beta-\varphi)\}}$ (6)

Where c= Cohesion and γ = Bulk Unit Weight

D. Determination of Stability Condition

Considering both saturated and unsaturated conditions, the critical bank heights were estimated using equation (5) for the locations for which the bank sediments have been collected from the field. Since saturated cohesive soil is nearly frictionless, for saturated banks where river stage declines rapidly, Φsat = $\Phi^{/}$sat = 0, i.e., friction is almost zero. Accordingly, the stability under saturated conditions has been estimated using a zero friction angle. The results have been plotted with the bank angle as abscissa and the critical bank height as the ordinate. This chart of bank stability consists of two lines. Critical bank heights for the unsaturated conditions are represented by the upper line, and those for the saturated condition are represented by the lower line. Locations that fall above the upper line are considered to be unstable. Similarly, the locations for which the bank angles and critical bank heights fall below the lower line are considered to be in stable condition. The remaining bank geometry that falls in between these two lines is considered to be the at-risk condition.

III. RESULTS AND DISCUSSIONS

A. Bankline Migration Analysis for the Selected Locations

The superimposed temporal digitized bank lines for 1975, 1998, 2008, and 2018 of river Brahmaputra along the south bank of Majuli island have been analyzed to understand the migration of the river at the seven different selected locations showing the erosion and/or deposition that had taken place at a particular location during this more than four-decade period (Fig.2). The locations subjected to erosion/deposition selected for this study are given in Table 3.

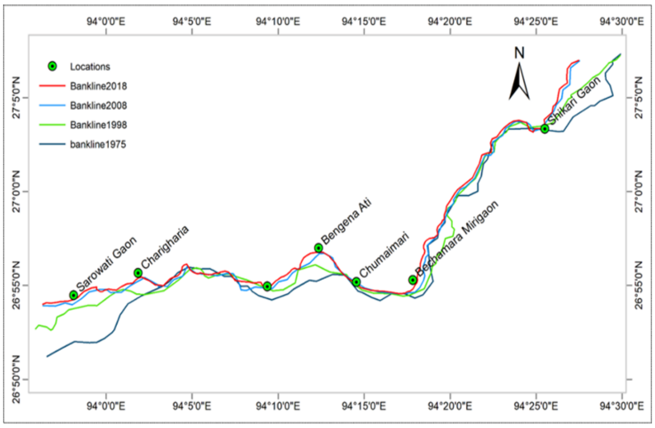

Fig.2: Superimposed southern bank ofMajulialong with the selected locations

Table 3: Selected locations for the study

Location	Pattern
Bengena Ati	Erosion
Charigharia	Erosion
Sarowati Gaon	Erosion
Kamalabari Ghat	Erosion
Bechamara Mirigaon	Erosion
Shikari Gaon	Deposition
Chumaimari	Deposition

The migration of the river at the locations during different time periods is shown in Fig.3.

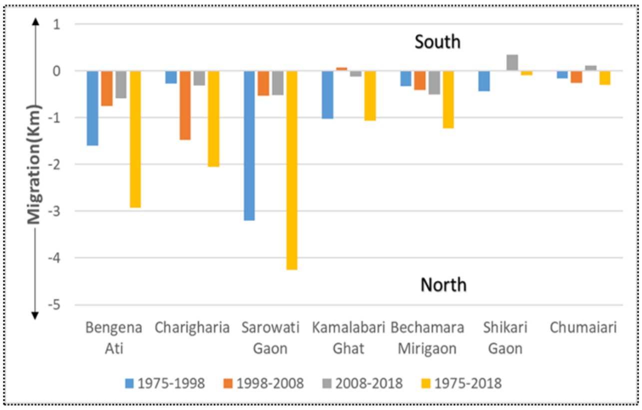

Fig.3: Bankline migration of river Brahmaputra along Majuli during different time periods

In the figure, migration of river towards north indicates erosion, and migration towards south indicates deposition as river Brahmaputra flows along the southern bank of the island. It is seen that during 1975-1998, for all the locations, the river migrated towards the north, causing erosion to the island. The maximum erosion was caused at the Sarowati Gaon with the river migrating by 3.2km followed by Bengena Ati (1.6km), Kamalabari Ghat(1.02km), Shikari Gaon (0.43km), Bechamara Mirigaon (0.32km), Charigharia (0.27km) and Chumaimari (0.16km). During 1998-2008, no migration could be seen at Shikari Gaon. Again, in Kamalabari Ghat, little deposition happened with the river migrating away from the island towards the south by 0.07km. For the remaining five locations, erosion happened with the maximum at Charigharia, where the river had migrated by 1.47km, followed by Bengena Ati (0.75km), Sarowati Gaon (0.53km), Bechamara Mirigaon (0.41km), and Chumaimari (0.26km). For the next time period from 2008 to 2018, the deposition could be seen at Shikari Gaon and Chumaimari, where the river had migrated away from the island towards the south by 0.34km and 0.12km, respectively. Maximum migration of the river towards the island causing erosion could be seen for Bengena Ati (0.58km) followed by Sarowati Gaon (0.52km), Bechamara Mirigaon (0.50km), Charigharia (0.32km), and Kamalabari Ghat (0.12km). Overall, from 1975 to 2018, the river migrated towards the island by 2.93km, 2.05km, 4.25km, 1.07km, 1.23km, 0.09km, and 0.3km for Bengena Ati, Charigharia, Sarowati Gaon, Kamalabari Ghat, Bechamara Mirigaon, Shikari Gaon and Chumaimari respectively. Hence, based on this analysis, Chumaimari and Shikarigaon have been chosen as deposition sites (deposition occurred during 2008-2018), and the remaining five locations have been chosen as erosion-prone sites.

B. Engineering Properties of the Soil Samples Collected from the Field

The samples under study can be grouped as ML (silt with low compressibility) and MI (silt with medium compressibility) types on the basis of relative engineering properties (Table 4). These ML and MI types of soils are characterized by their poor stability, susceptibility to liquefaction, and having poor drainage characteristics. They are low-density soil characterized by their low permeability and are prone to erosion during the rise of the water table. Soils having a higher percentage of silt content are easily detached, tend to crust, and produce a high rate of runoff and hence are most erodible of all soils.

Table 4: Types of soils determined for the selected locations

Location	LiquidLimit	Plastic Limit	Plasticity Index	Soil Type
Bengena Ati	31.11	26.31	4.8	ML
Charigharia	33.62	26.12	7.5	ML
Sarowati Gaon	36.87	24.8	12.07	MI
Kamalabari Ghat	46.9	31.9	15	MI
Bechamara Mirigaon	32.13	26.33	5.8	ML
Shikari Gaon	39.35	30.28	9.07	MI
Chumaimari	27.79	23.29	4.5	ML

The different engineering properties viz. water content, bulk unit weight, dry unit weight, shear strength (cohesion and angle of internal friction) of the soil samples collected from the field were determined in the laboratory to study the stability of the river bank with respect to the engineering properties of the bank material. The different engineering properties of the soils of sample locations, along with the bank angle of the slope, are shown in Table 5.

The water content of the soil samples varied between 24.07 to 40.98%. Again, field unit weight and dry unit weight ranged between 1.65 to 1.84 gm/cc and 1.22 to 1.38 gm/cc, respectively. The variation of liquid limit, plastic limit, and the plasticity index ranged from 27.79 to 46.9 %, 23.29 to 31.9%, and 4.5 to 12.07, respectively. It can well be attributed that the soil with similar geological history but differ in the limits may characterize with different permeability. Such types of soils under similar compressibility and load conditions may experience a higher degree of failure probability. The available parameters also characterize poorly stable soil types with poor drainage, susceptible to liquefaction, and prone to erosion. Another characteristic of such soils is low to medium cohesive strength. Liquefaction is the phenomenon where the soil drastically loses its strength to a very low value as a result of increased pore water pressure, usually under repeated or cyclic loading. Clay soils normally remain in open packing as the clay particles are surrounded by a water envelope, and hence, they get weakened on disturbances and tend to fail plastically.

Table 5: Engineering properties of the bank material of some sample locations

Location	Water Content	Bulk unit weight (N/cm^3)	Dry unit weight (N/cm^3)	Cohesion C_u	Cm $2/3C_u$ (N/cm^2)	The angle of internal friction (Φu) (°)	Φm $\tan^{-1}(\frac{2}{3}\tan\Phi u)$ (°)	Bank angle (°)
Bengena Ati	33.65	0.0180	1.38	0.8	0.53	30.62	21.53	82
Charigharia	40.98	0.0172	1.22	1.1	0.73	23.2	15.95	25.74
Sarowati	31.22	0.0171	1.3	1.4	0.93	20.17	13.76	53.34
Kamalabari Ghat	32.37	0.0184	1.37	0.75	0.5	24.18	16.66	56
Bechamara Mirigaon	24.88	0.0173	1.38	1.2	0.8	23.19	15.94	90
Shikari Gaon	37.1	0.0172	1.25	0.55	0.37	26.09	18.08	90
Chumaimari	24.07	0.0165	1.33	0.6	0.4	26.09	18.08	70

C. Bank Stability Analysis

The stability number (Sn) has been determined using equation (4), and accordingly, critical bank height (Hc) for saturated and unsaturated conditions has been determined using equation (5). The average mobilized values of shear parameters and the average values of bulk unit weight (density) determined in the laboratory on the samples collected from the field were taken for unsaturated conditions (Table 2). For saturated conditions, the values of cohesion and angle of internal friction were taken from the table of average soil properties as suggested by USBS, 1962 for ML type of soil (Table 1). The stability numbers and critical heights calculated for a range of bank angles from 25 to 90 degrees are shown in Table 6 and Table 7 for unsaturated and saturated conditions, respectively.

Table 6: Bank Stability Chart for Silty Soil (ML and MI) for unsaturated condition

Bank Angle (°)	Cm	Φ m	Bulk unit weight γ (N/cm3)	Stability Number (Sn)	Critical Height (Hc) (m)
25	0.68	17.14	0.0173	171.9452	67.5853
30	0.68	17.14	0.0173	76.1934	29.9488
35	0.68	17.14	0.0173	45.4939	17.8820
40	0.68	17.14	0.0173	31.2816	12.2956
45	0.68	17.14	0.0173	23.3185	9.1656
50	0.68	17.	0.017	18.3004	7.1932

		14	3		
55	0.68	17.14	0.0173	14.8754	5.8469
60	0.68	17.14	0.0173	12.3987	4.8735
65	0.68	17.14	0.0173	10.5277	4.1380
70	0.68	17.14	0.0173	9.0649	3.5630
75	0.68	17.14	0.0173	7.8889	3.1008
80	0.68	17.14	0.0173	6.9217	2.7206
85	0.68	17.14	0.0173	6.1107	2.4019
90	0.68	17.14	0.0173	5.4195	2.1302

Table 7: Bank Stability Chart for Silty Soil (ML and MI) for saturated condition

Bank Angle (°)	C′	Φ′	Bulk unit weight γsat (N/cm3)	Stability Number (Sn)	Critical Height (Hc) (m)
25	0.91	0	0.018	18.0428	9.1216
30	0.91	0	0.018	14.9282	7.5470
35	0.91	0	0.018	12.6863	6.4136
40	0.91	0	0.018	10.9899	5.5560
45	0.91	0	0.018	9.6568	4.8820
50	0.91	0	0.018	8.5780	4.3366
55	0.91	0	0.018	7.6839	3.8846
60	0.91	0	0.018	6.9282	3.5025
65	0.91	0	0.018	6.2787	3.1742
70	0.91	0	0.018	5.7125	2.8880
75	0.91	0	0.018	5.2129	2.6354
80	0.91	0	0.018	4.7670	2.4099
85	0.91	0	0.018	4.3652	2.2068
90	0.91	0	0.018	4.0000	2.0222

From the bank stability chart, a graph has been plotted considering the bank angles as abscissa and the critical bank height as ordinate (Fig.4). The upper line and lower lines represent critical bank heights for unsaturated and saturated conditions, respectively. Thus, any point that falls above the line of the unsaturated condition is considered to be always unstable as its bank height is more than the critical height even under the unsaturated condition. Again, a point that falls below the lower line represents bank height under saturated conditions and hence is considered to be always stable. Bank angle and height between these two lines represent at-risk conditions, i.e., though it will be stable under unsaturated conditions, it will be at risk under saturated conditions.

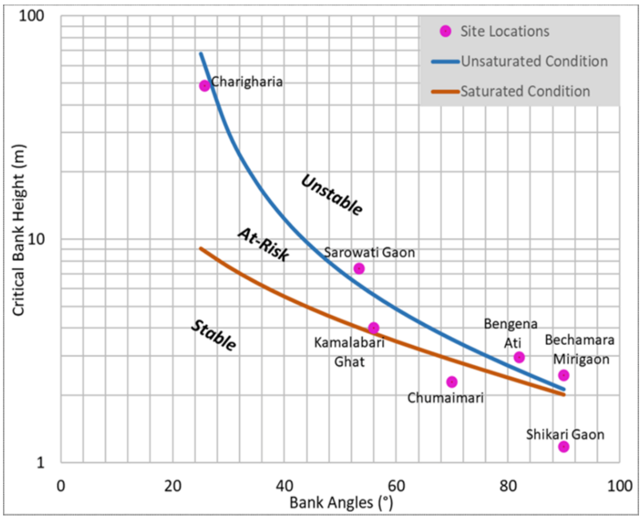

Fig.4: Bank stability chart to determine erosion potential of different locations

Various soil parameters and critical height with their respective stability zone for samples at different locations along the bank of Majuli island are presented in Table 8.

The practical utility of the study has been comprehended by considering soil samples from predominant areas of erosion and deposition along the bank of Majuli. Bengena Ati, Charigharia, Sarowati Gaon, Bechamara Mirigaon, and Kamalbari Ghat are the locations with high erosion potential. On the other hand, for the locations Shikari Gaon and Chumaimari, deposition has been found to be predominant. The resultant bank angles and heights as determined in Table 8 have been plotted graphically, as shown in Fig.3.It is observed that the sample locations with heavy erosion potential fall either in the unstable zone or in the at-risk zone. However, the dominant deposition locations are free from the risk of erosion and fall in the stable zone.

Table 8: Bank stability of different locations

Location	γ (gm/cc)	Bank Angle (β) (°)	Cu (gm/cm^2)	Φu (°)	$c_m = \frac{2}{3} c_u$ (gm/cm^2)	$Ø_m = \tan^{-1}(\frac{2}{3}\tan Ø_u)$ (°)	Hc (m)	Zone
Bengena Ati	1.80	82	1.1	30.62	0.73	21.53	2.96	Unstable
Charigharia	1.72	25.74	1.1	23.2	0.73	15.95	48.68	At Risk
Sarowati Gaon	1.71	53.34	1.4	20.17	0.93	13.76	7.39	Unstable
Kamalabari Ghat	1.84	56	0.75	24.18	0.5	16.66	4.01	At risk
Bechamara	1.72	90	1.2	23.19	0.8	15.94	2.47	Unstable

Mirigaon								
Shikari Gaon	1.73	90	0.55	26.09	0.37	18.08	1.18	Stable
Chumaimari	1.65	70	0.6	26.09	0.4	18.08	2.3	Stable

The stability analysis of the bank along the Majuli island has been carried out, taking into consideration the bank angle and critical bank height for the saturated and unsaturated conditions. The three different zones created from the bank angles and critical bank height are the basis of identifying the erosion potential of various locations.

When a location falls above the upper line, it indicates instability of that location even under unsaturated conditions. Any location that falls between these two lines indicates that the location is at-risk in the saturated condition only. Furthermore, an indication of stability or less erosion of a location is depicted when it falls below the lower line, i.e., the line plotted for saturated condition. Such kind of study is practically utilizable where erosion susceptibility of a location can be determined on the basis of identification and extrapolation of bank angle and critical bank height, and no detailed litho-geological investigation is required in the analysis.

IV. CONCLUSIONS

The present study represents slope stability analysis along the southern bank of the Majuli island of northeast India, where severe erosion takes place due to the erratic nature of the river Brahmaputra. From the superimposed digitized bank lines of 1975, 1998, 2008, and 2018, seven different locations have been identified subjected to both erosion and deposition, and the migration pattern of the river at these locations in different time periods has been analyzed. Soil samples from these locations have been collected to analyze their stability against erosion on the basis of various engineering properties. On the basis of liquid limit, plastic limit, and plasticity index, the types of soils were identified as ML and MI types which are characterized by their potential to erosion susceptibility. The water content of 24.07-40.98%, field unit weight of 1.65-1.84 gm/cc, dry unit weight of 1.22-1.38gm/cc, the liquid limit of 27.79-46.9%, plastic limit of 23.29-31.9%, and plasticity index of 4.5-12.07 has been found for the soil samples. These soils are low-density loose soils and thus prone to erosion with the water level rise in the channel.

Three different zones viz., unstable, at-risk, and stable have been created during stability analysis on the basis of bank angles and critical bank height. The stability analysis demonstrated that the soils collected from areas subjected to erosion, i.e., Bengena Ati, Charigharia, Sarowati, Kamalabari ghat, and Bechamara Mirigaon, either fall in the unstable zone or in the at-risk zone. Again, samples collected from less eroded areas, i.e., Shikari Gaon and Chumaimari, fall in the stable zone. It is expected that such studies may help in the identification of erosion potential of any location along the river bank and to adopt appropriate mitigation measures to prevent further erosion. This study was limited to the southern bank of Majuli. Further analysis can be done on the northern bank of Majuli to predict erosion potential by the Subansiri river and the stability of the bank materials. It is expected that the analysis presented in this paper can be advantageously used for better bank management practices by providing the necessary basic information that will be helpful for the sustainability of this largest inhabited river island.

Conflict of Interest

The authors declare no conflict of interest.

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