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Effect of Soil Properties on River Bank Erosion in Lower Assam Region

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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 Gangadhar, Tipkai, 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 extremely flood prone areas.

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

Introduction

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.

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.

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.

Failures under 1, 3, 4 and 5 depend more on the properties of the bank material than direct erosive action of stream flow.

Effects of river bank erosion

River bank erosion is not only associated with the threat that it possess 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.

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^H , soil temperature, water temperature, water salinity, water $P^{H,}$ 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.

General features of the Brahmaputra basin

The Brahmaputra is one of the world's largest rivers, with a drainage area of 580,000 sq. km. (50.5% in China, 33.6% in India, 8.1% in Bangladesh and 7.8% in Bhutan). In India, its basin is shared by Arunachal Pradesh (41.9%), Assam (36.3%), Meghalaya (6.1%), Nagaland (5.6%), Sikkim (3.8%) and West Bengal (6.3%). Originating from the great glacier mass of Chema-Yung-Dung in the Kailas range of southern Tibet at an elevation of 5,300 m., it traverses 1,625 km. in China and 918 km. in India, before flowing 337 km. through Bangladesh and emptying into the Bay of Bengal through a joint channel with the Ganga**.**

In the course of its 2,880 km. journey, the Brahmaputra receives as many as 22 major tributaries in Tibet, 33 in India and three in Bangladesh. The northern and southern tributaries differ considerably in their hydro-geomorphological characteristics owing to different geological, physiographic and climatic conditions. The north bank tributaries generally flow in shallow braided channels, have steep slopes, carry a heavy silt charge and are flashy in character, whereas the south bank tributaries have a flatter gradient, deep meandering channels with beds and banks composed of fine alluvial soils, marked by a relatively low sediment load**.**

Erosion in the Brahmaputra River

The severity of erosion can be seen from the following Table (Source: National Disaster Management Authority of India, 2012). It is clear from this table that while the erosion prone length of the river is 10% higher along the South Bank of Brahmaputra compared to the same along North Bank.

Objective and Methodology

A river changes its cross section, longitudinal profile, flow period, and pattern for several times, by means of scouring, sediment transport and deposition processes. The process of bank erosion is closely related to the soil composition and hydraulic properties of the river bank materials. For stabilization of the river, it is essential to understand these processes. The objective of the study is to determine the soil parameters which cause river bank erosion and thereby causing severe yearly land loss.

The sites for sampling (both eroded and less eroded) are selected and the Bank sediment samples (disturbed) are collected for the study of geotechnical properties of the bank materials. The sediment samples are then subjected to various laboratory tests as per I.S code standards and a comparative study is made between geotechnical properties of the eroded and the less eroded samples. The various tests performed are permeability test, direct shear test, liquid limit, plastic limit, sieve analysis and determination of field unit weight by core cutter method.

Rivers considered in the study

Gangadhar: The Gangadhar river is situated near Golakganj, Dhubri. It joins the Brahmaputra river from the north. It is also known as Sankosh whose principle tributary is Raidak. It has a length of about 240km and contributes 2.81% of the total discharge of the Brahmaputra.

Table 1: Total erosion in north and south bank of the river Brahmaputra

Area wise division into 12 reaches in the river	North Bank			South Bank		
	Total Erosion Length (in km)	**1990 to 2007 – 08 (in sq. km)**	**1997 to 2007-08 (in sq. km)**	**Total Erosion Length (in km)**	**1990 to 2007 – 08 (in sq. km)**	**1997 to 2007-08 (in sq. km)**
Dhubri	40.19	124.461	94.129	7.05	194.983	10.791
Goalpara	39.5	79.046	40.902	4.85	17.816	5.052
Palasbari	54.87	48.668	42.914	14.02	23.006	15.859
Guwahati	21.02	7.92	1.654	24.38	5.385	12.079
Morigaon –Mangaldai	6	35.606	2.138	47.91	96.979	103.7
Morigaon – Dihing	24.86	29.057	7.275	47.8	10.795	56.72
Tezpur	8.58	38.758	4.733	52.95	16.628	44.774
Tezpur-Gohpur	8.85	31.187	5.794	44.16	26.098	71.227
Majuli-Bessamora	24.69	25.562	12.327	47.17	32.788	28.998
Majuli Sibsagar	16.93	60.657	16.878	54.95	44.018	42.118
Dibrugarh	37.86	37.506	43.529	43.89	46.595	6.066
U/s Dibrugarh	70.5	20.376	55.454	57.54	399.529	333.416
Total	**353.85**	**538.805**	**327.726**	**389.13**	**914.62**	**730.8**

Puthimari River: It is one of the of the main northern bank tributaries of Brahmaputra river. After originating in Bhutan Himalaya at an altitude of 3750 m the river flows north to south through the Nalbari and Kamrup districts of Assam to meet the Brahmaputra River at an acute angle. The river has a catchment area of 1,787 sq km and lies between 26^{o}10/N – 27^{o}18/N latitude to 91^{o}27/E – 91^{o}50/E longitudes. The area of the flood plain in the basin is 385sq km out of which an area of 374.38 sq km is more prone to flood. The Puthimari River flows from north to south.

Gaurang, Champamati, Tipkai: The Gaurang river originates in Bhutan and traverses in Kokrajhar district of Assam and confluences with river Brahmaputra. The Gaurang river is also known as Saralbhanga river. The major rivers and streams in Kokrajhar district are Champamati, Gaurang, Bhur, Dholpani, Laopani. The Saralbhanga and Bhur emerge from the Bhutan hills. Champamati, the Gaurang, the Tipkai and the Sonkosh are the rivers which flow down from north to south.

Palashbari: Palashbari is a town situated in the kamrup district of Assam. It is located at 26.13°N 91.5°E and has an average elevation of 46 metres (150 feet). 6794.58 ha of land have been eroded in palashbari till 1999 while in 2004 in the palashbari-gumi area it increased to 10,000 ha (water resource department, 2004). It is worth mentioning that some of the eroded villages such as keotpara, gabardia etc. of palashbari circle have been transformed into riverine char.

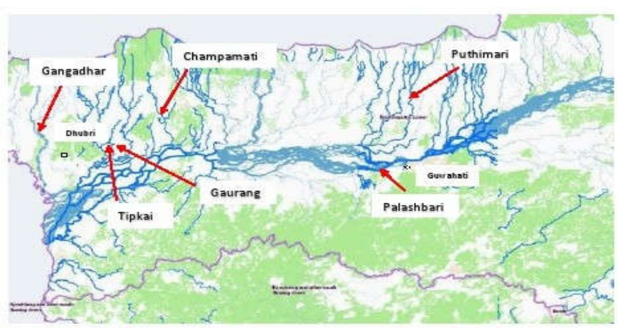

Fig 1: Location of the study area(from Dhubri to Guwahati.)

Laboratory and field measurements

Gangadhar River

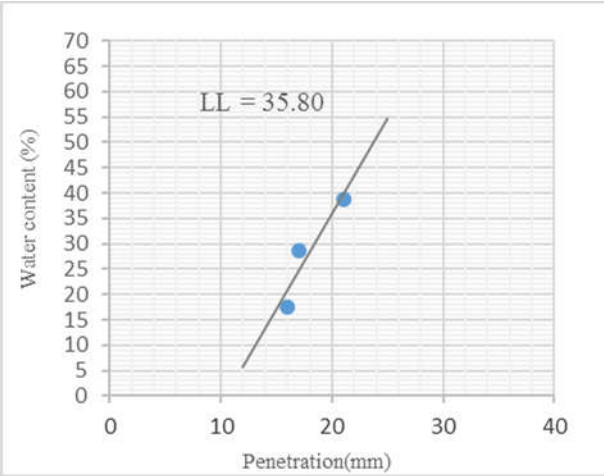

Fig 2 : Liquid limit curve for site 1(less eroded)

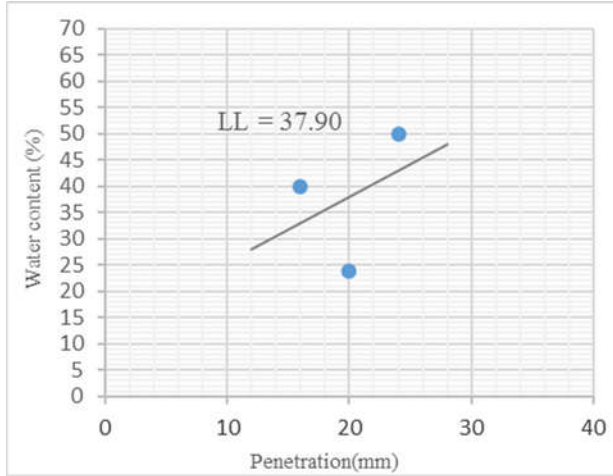

Fig 3: Liquid limit curve for site 2(less eroded)

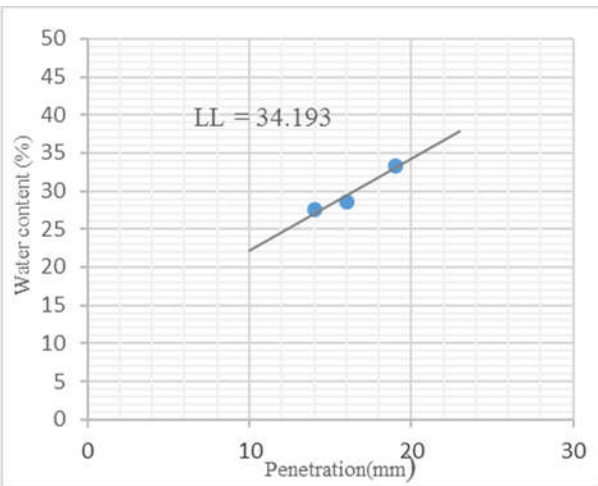

Fig 4 : Liquid limit curve for site 1(eroded)

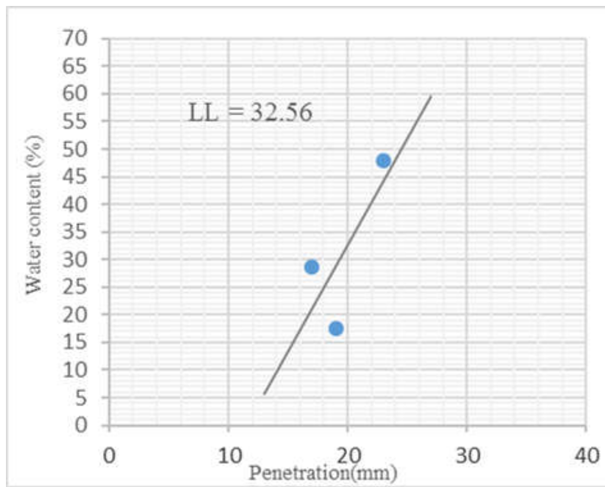

Fig 5 : Liquid limit curve for site 2(eroded)

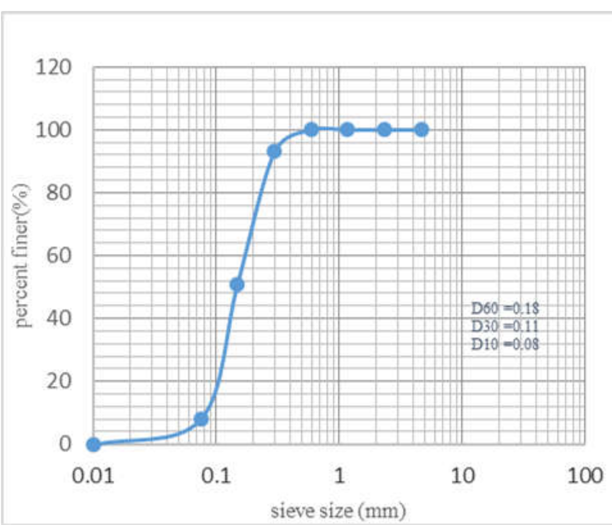

Fig 6: Grain size distribution curve for site 1(eroded)

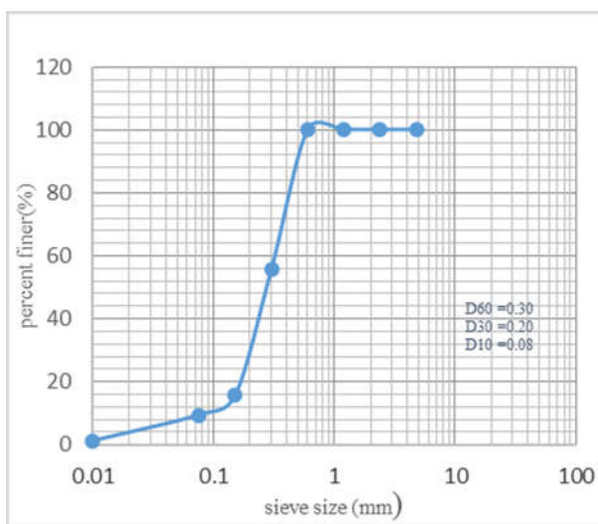

Fig 7: Grain size distribution curve for site 2(eroded)

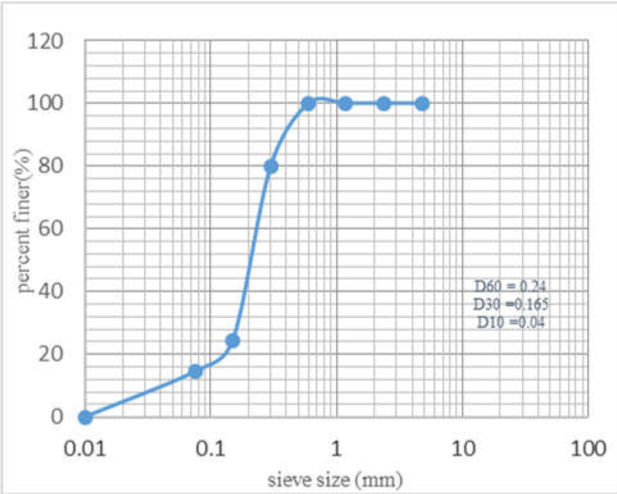

Fig 8: Grain size distribution curve for site 1(less eroded)

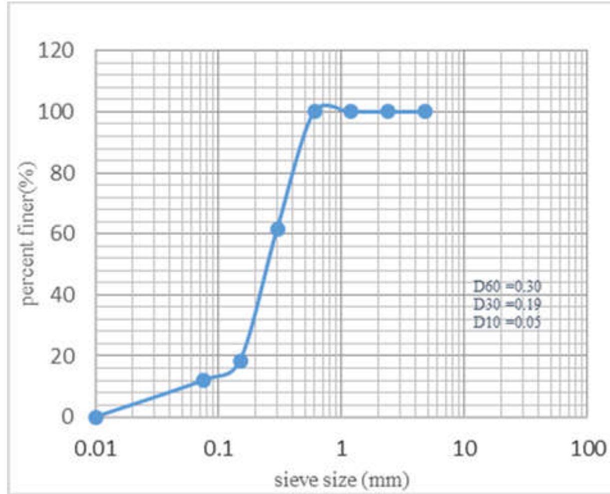

Fig 9: Grain size distribution curve for site 2(less eroded)

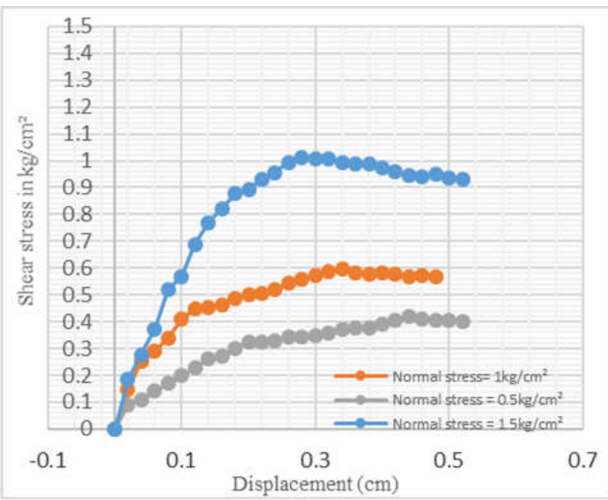

Fig 10: Shear stress vs shear displacement curve for site 1(eroded) at field density 1.65g/cm^3

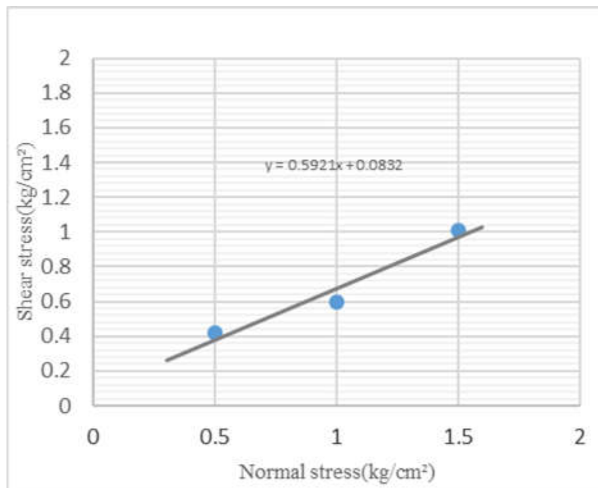

Fig 11: Shear Stress Vs Normal Stress Curve for site 1(eroded)

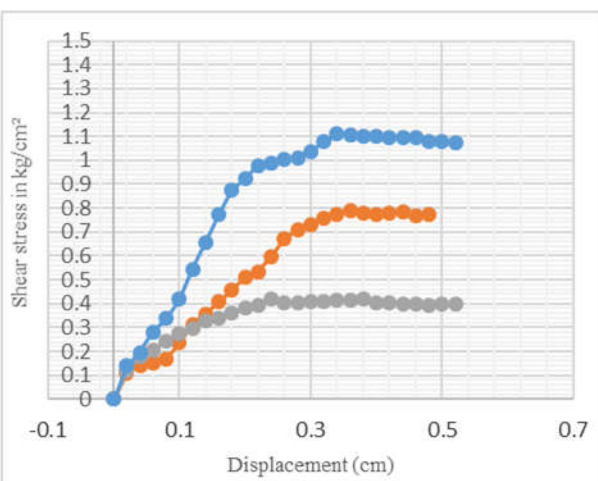

Fig 12: Shear stress vs shear displacement curve for site 2(eroded) at field density 1.65g/cm^3

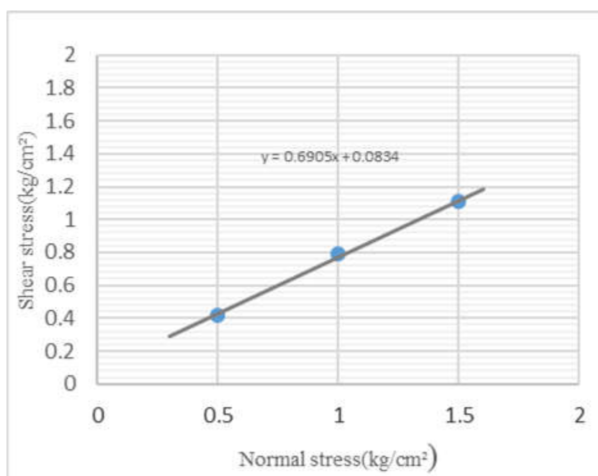

Fig 13: Shear Stress Vs Normal Stress Curve for site 2(eroded)

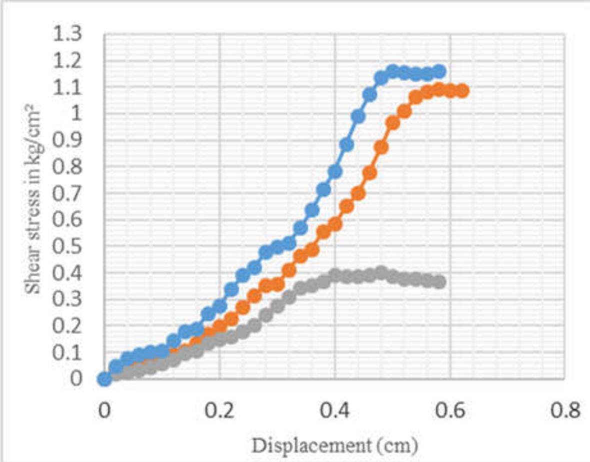

Fig 14: Shear stress vs shear displacement curve for site 2(less eroded) at field density 1.65g/cm^3

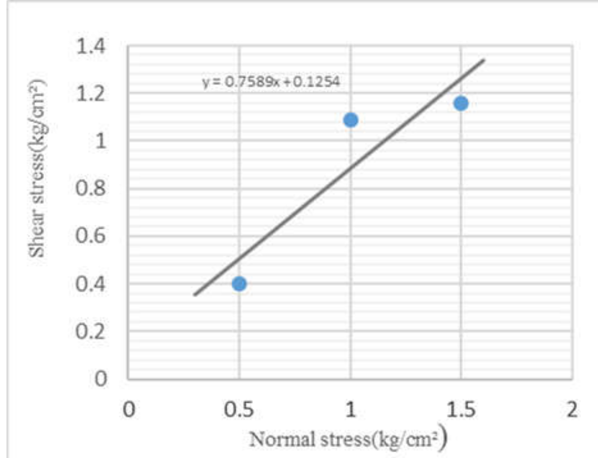

Fig 15: Shear Stress Vs Normal Stress Curve for site 2(less eroded)

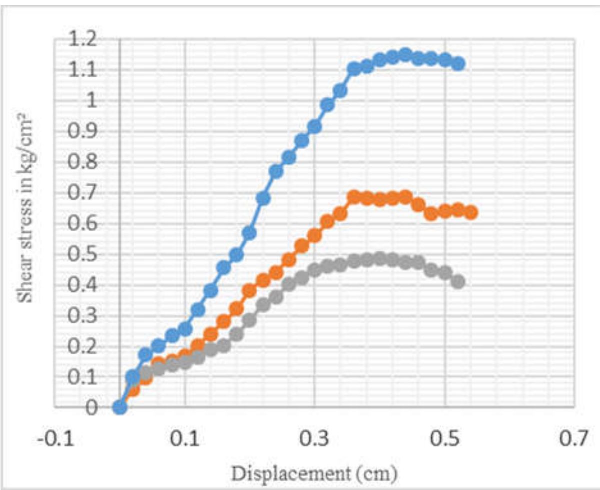

Fig 16: Shear stress vs shear displacement curve for site 1(less eroded) at field density 1.62g/cm^3

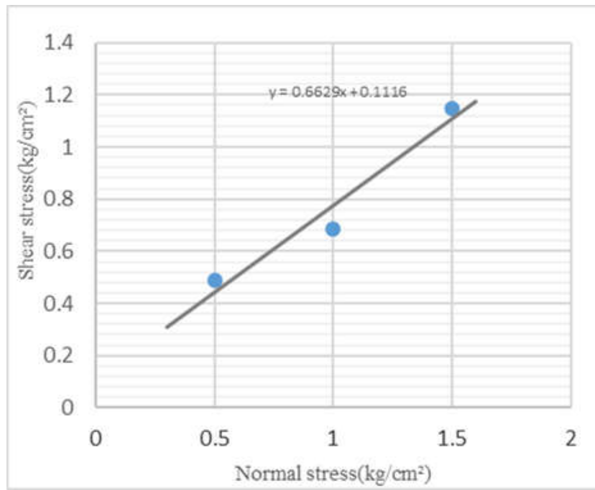

Fig 17: Shear Stress Vs Normal Stress Curve for site 1(less eroded)

Table 2. Laboratory tests performed for Gangadhar River

Sl no.	Laboratory tests performed for Gangadhar river	Eroded sample		Less eroded sample	
		Site 1(near Bhangaduli village)	Site 2(near Bhangaduli village)	Site 1(Moisa point II)	Site 2(Moisa point II)
1.	Liquid limit (%)	34.19	32.56	35.80	37.90
2.	Plastic limit (%)	-	-	11.73	14.40
3.	Permeability test K(cm/sec)	8.05 x 10^{-4}	4.56 x 10^{-4}	1.29 x10^{-5}	5.2 x10^{-6}
4.	Direct shear test i) cohesion (kg/cm²)	0.08	0.083	0.11	0.125
	ii) angle of internal friction (Ø)	30.63	34.63	33.54	37.195
5.	Sieve analysis i) sand %	97.79	98.78	78.38	72.70
	ii) silt and clay %	2.21	1.22	21.62	27.30
	iii) coefficient of uniformity	2.25	3.75	6.00	6.00
	iv) coefficient of curvature	0.840	1.67	2.84	2.41
	v) type of soil	Poorly graded sand with silt	Poorly graded sand with silt	Well graded sand with clay	Well graded sand with clay
	vi) Unified classification	SP-SM	SP-SM	SW-SC	SW-SC

Table 3. Laboratory tests performed for Gaurang River

Sl no.	Laboratory tests performed for Gaurang river	Eroded sample		Less eroded sample	
		Site 1 (near bamunpara, bilasipara town)	Site 2 (near bamunpara, bilasipara town)	Site 1 (near andurjhar point II)	Site 2 (near andurjhar point II)
1.	Liquid limit (%)	34.193	36.68	37.49	36.68
2.	Plastic limit (%)	15.56	18.85	23.56	27.01
3.	Permeability test K(cm/sec)	5.88×10^{-5}	4.99×10^{-4}	7.1×10^{-6}	0.67×10^{-5}
4.	Direct shear test i) cohesion (kg/cm²)	0.02	0	0.11	0.10
	ii) angle of internal friction (Ø)	31.14	30.04	36.07	35.15
5.	Sieve analysis i) sand %	85.74	86.31	83.00	80.32
	ii) silt and clay %	14.26	13.69	17.00	19.68
	iii) coefficient of uniformity	2.00	2.308	8.00	6.5
	iv) coefficient of curvature	1.23	1.24	2.42	1.16
	v) type of soil	Poorly graded sand with clay	Poorly graded sand with clay	Well graded sand with clay	Well graded sand with clay
	vi) Unified classification	SP-SC	SP-SC	SW-SC	SW-SC

Table 4. Laboratory tests performed for Tipkai River

Sl no.	Laboratory tests performed for Tipkai river	Eroded sample		Less eroded sample	
		Site 1(near mahamaya dham,bogribari)	Site 2(near mahamaya dham,bogribari)	Site 1 (near jhalopara)	Site 2 (near jhalopara)
1.	Liquid limit (%)	31.705	33.847	40.952	35.629
2.	Plastic limit (%)	-	-	20.67	21.06
3.	Permeability test K(cm/sec)	1.67×10^{-5}	0.45×10^{-4}	2.33×10^{-6}	9.78×10^{-5}
4.	Direct shear test i) cohesion (kg/cm²)	0.11	0.07	0.16	0.13
	ii) angle of internal friction (Ø)	34.93	35.03	35.34	37.15
5.	Sieve analysis i) sand %	92.25	93.20	76.95	72.289
	ii) silt and clay %	7.75	6.80	23.05	27.711
	iii) coefficient of uniformity	1.50	4.0	7.60	6.67
	iv) coefficient of curvature	1.10	2.56	2.10	3.75
	v) type of soil	Poorly graded sand with silt	Poorly graded sand with silt	Well graded sand with clay	Poorly graded sand with clay
	vi) Unified classification	SP-SM	SP-SM	SW-SC	SP-SC

Table 5. Laboratory tests performed for Puthimari River

Sl no.	Laboratory tests performed for Puthimari river	Eroded sample		Less eroded sample	
		Site 1(near kendukona)	Site 2(near kendukona)	Site 1(near rangia town)	Site 2(near rangia town)
1.	Liquid limit (%)	30.10	27.78	41.037	39.704
2.	Plastic limit (%)	-	-	-	19.45
3.	Permeability test K(cm/sec)	5.1×10^{-5}	0.16×10^{-4}	9.3×10^{-6}	2.24×10^{-6}
4.	Direct shear test i) cohesion (kg/cm²)	0	0.05	0.10	0.14
	ii) angle of internal friction (Ø)	35.83	35.03	36.75	36.054

5.	Sieve analysis i) sand %	82.00	82.00	86.50	95.00
	ii) silt and clay %	18.00	18.00	13.50	5.00
	iii) coefficient of uniformity	4.17	1.4	8.056	6.094
	iv) coefficient of curvature	1.50	1.14	1.619	1.939
	v) type of soil	Poorly graded sand with silt	Poorly graded sand with silt	Well graded sand with silt	Well graded sand with clay
	vi) Unified classification	SP-SM	SP-SM	SW-SM	SW-SC

Table 6. Laboratory tests performed for Palashbari River

Sl no.	Laboratory tests performed on Palashbari	Eroded sample		Less eroded sample	
		Site 1(near palashbari town)	Site 2(near palashbari town)	Site 1(near palashbari town)	Site 2(near palashbari town)
1.	Liquid limit (%)	34.439	28.20	43.537	36.355
2.	Plastic limit (%)	10.56	-	21.58	-
3.	Permeability test K(cm/sec)	1.2×10^{-4}	0.9×10^{-4}	5.2×10^{-6}	3.5×10^{-5}
4.	Direct shear test i) cohesion (kg/cm²)	0.08	0.07	0.13	0.11
	ii) angle of internal friction (Ø)	34.45	33.22	38.66	38.22
5.	Sieve analysis i) sand %	86.29	94.68	92.99	84.70
	ii) silt and clay %	13.71	5.32	7.01	15.30
	iii) coefficient of uniformity	3.43	1.47	7.60	9.26
	iv) coefficient of curvature	2.15	1.09	2.105	2.90
	v) type of soil	Poorly graded sand with clay	Poorly graded sand with silt	Well graded sand with clay	Well graded sand with silt
	vi) Unified classification	SP-SC	SP-SM	SW-SC	SW-SM

Table 7. Laboratory tests performed for Champamati River

Sl no.	Laboratory tests performed on Champamati river	Eroded sample		Less eroded sample	
		Site 1 (near village moinapara)	Site 2 (near village moinapara)	Site 1 (near village jalikura)	Site 2 (near village jalikura)
1.	Liquid limit (%)	28.912	33.754	36.083	38.193
2.	Plastic limit (%)	-	-	11.22	10.05
3.	Permeability test K(cm/sec)	5.5×10^{-4}	6.19×10^{-5}	2.72×10^{-5}	9.2×10^{-6}
4.	Direct shear test i) cohesion (kg/cm²)	0.08	0.02	0.12	0.14
	ii) angle of internal friction (Ø)	35.89	35.41	38.17	37.45
5.	Sieve analysis i) sand %	94.33	96.03	71.88	82.10
	ii) silt and clay %	5.67	3.97	28.12	17.90
	iii) coefficient of uniformity	3.714	1.57	7.25	6.11
	iv) coefficient of curvature	1.78	1.17	2.95	2.84
	v) type of soil	Poorly graded sand with silt	Poorly graded sand with silt	Well graded sand with clay	Well graded sand with clay
	vi) Unified classification	SP-SM	SP-SM	SW-SC	SW-SC

Result and discussion

After analyzing the experimental results, it was found that majority of the eroded sites of the river consist of poorly graded sand with silt and the less eroded sites consists of well graded sand with clay /silt. This implies that the soil consisting of well graded sand with clay or silt undergoes less erosion. Thus grading of the soil particles in the soil is an influencing factor in riverbank erosion

The eroded sites were found to be more permeable than the less eroded sites. Permeability is also an important parameter in case of riverbank erosion. More the permeability more is the erosion. Similarly the liquid limit is distinctly higher in less eroded soils as compared to eroded soil samples. The less eroded soils was found to have medium plasticity whereas the erodible soils have low or no plasticity This shows that there is more erosion in soils having less plasticity.

The shear strength parameters, cohesion and angle of internal friction was found to be low in erodible soils due to low clay content. The shear strength parameters cohesion and angle of internal friction has a major role in river bank erosion problem. The cohesive force of the river bank materials produces adequate resistance against bank erosion and soil instability. It deflects the water flow of the river producing nominal or no scour at river bed and in return banks remain stable without any significant bank erosion. Alluvial sandy soil has no cohesion in between the particles for which these particles are easily lifted by river water velocity producing high bed scour resulting heavy bank erosion. On the other hand, soil having adequate cohesive strength is more stable and behaves like rigid boundaries.

Conclusion

The following conclusions were drawn from the study i) the majority of erodible river banks was made of poorly graded sand with silt. ii) these river banks are very erodible due to low clay content and weak erosion resistant strength in the bank soil which is one important reason causing serious bank erosion iii) frequent occurrence of bank failure during flood seasons occur due to the fact that values of shear strength parameters such as cohesion and angle of internal friction decrease with the increase of water content in river bank soil.

The above results can be explained in a reverse way. In case of construction of embankments, spurs, guide banks etc. where land filling is required, the soil having well grading, lower permeability, high liquid limit, high cohesion should be selected to counteract erosion. The present investigation related to geotechnical properties of the bank sediments of the above rivers helps to understand many important aspects in relation to the associated erosion mechanisms. It is expected that correlating the findings of such interdisciplinary studies, with other geomorphic attributes attempt can be made to regulate the gap towards collection of necessary baseline information for practically viable erosion management practices.

References

Coleman, J.M. (1969). “Brahmaputra River: Channel processes and sedimentation.” Sedimentary Geology, Vol. 3, 129-239
Dutta, M. K., Barman S., et al (2010), A study of erosion-deposition processes around Majuli Island,
Goswami, D. C. (1998) Fluvial Regime and Flood Hydrology of Brahmaputra River, Assam. In: V. S.
IS-1498 (1970) “Classification and Identification of soils for general Engineering purposes”. Bureau of Indian Standard (BIS), New Delhi.
IS-2720 Part V. (1965) “Determination of liquid and plastic limits”, Indian Standard Institution, New Delhi.
Murthy VNS “a textbook of soil mechanics and foundation engineering”