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Role of Physical Properties of Soil in River Bank Erosion Assessment: A Case Study in Lower Assam Region of River Brahmaputra of India.

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ABSTRACT*:River bank erosion is an acute natural hazard all over the world. The same hazard is also very much common, recurrent and frequent in Assam due to river Brahmaputra, Barak and their tributaries. Every year the river Brahmaputra is eroding both banks at alarming rate creating enormous difficulties, havoc and multi-dimensional loss to the affected people. Although the river is eroding its bank here and there, but the extent of erosion is not same in all locations. It is understood that the extent of erosion depends on many factors. The properties of river bank soil is also one major factor related to erosion. This particular study is carried out to ascertain the role of geotechnical properties of soil in river bank erosion in lower Assam region of river Brahmaputra of India so that these properties of soil could be used as erosion predictor or assessor to assess the vulnerability of locations in river reach and finally the whole river stream might be categorized locations wise as vulnerable or non-vulnerable to erosion for taking anti erosive measure preference wise.*
KEYWORDS*: Assam, Barak, Brahmaputra, Erosion, River Bank, Rosgen, Vulnerable,*

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I. INTRODUCTION

All major tributaries along with mighty river Brahmaputra and Barak are creating havoc to the people of riverside by regularly eroding their banks. In respect of other rivers, the extent of erosion by river Brahmaputra is tremendous and devastating. The extremely braided river Brahmaputra is eroding the banks in its entire course in Assam(India) by increasing its area and forming and destroying sand bars or chars causing huge amount of sediment.At present the river bank erosion is the main natural problem to the riverside people of Assam and it isalso the main concern to the Government of Assam. The ill effect of river bank erosion is multi-dimensional- political, economic, demographic and environmental. The direct effect of river bank erosion includes- Huge economic loss, Losses of fertile land ,Losses of crops and other resources, displacement of people from one place to other, affect in public health, poverty in the society, unemployment problem increased, increase in landless labor, decrease in agricultural productivity, affect productivity in eroded soil, forced occupation of government land, educational structure is negatively changed, effect on environment, effect in individual occupation, effect in transport system, social disorder etc. The Government of Assam is trying to take effective anti-erosional measures to reduce the intensity of erosion. It has been observed that the nature and degree of erosion varies from location to location in the entire reach of the river Brahmaputra. In some location it is very high, in some location it is moderate or low. The degree of erosion of river bank depend on various parameters. The physical properties of soils also play vital role in producing or preventing erosion in river bank. So, in this work it is attempted to ascertain the role of physical properties of bank soil in producing river bank erosion by comparing the soil physical properties of highly eroded locations and non-eroded locations and ultimately use these properties as predictors of erosion to zone the various locations as low, moderate, high etc so that anti erosive measure could be taken on priority basis.

II. SITE SELECTION AND METHODOLOGY

For the study purpose of role of physical properties in river bank erosion, the entire reach of river Brahmaputra in lower Assam region has been roughly observed and finally sixteen locations are chosen for study and collecting soil samples. These locations are tabulated in Table number 1. Out of these sixteen locations, first eight locations are of no or vey less erosion prone and next eight locations are of very high erosion prone.

Table :I (Description of selected locations)

Sl No	Position of locations	Name of locations	Remarks
1	$26^0 11' 13.92''$;$91^0 44' 33.12''$	Joypur(South bank)	No or less erosion
2	$26^0 12' 4.07''$;$91^0 44' 26.95''$	UzanBazar Ghat(South bank)	No or less erosion
3	$26^0 11' 9.55''$; $91^0 43' 16''$	Ferryghat(North Guwahati)	No or less erosion
4	$26^0 8' 22.6''$; $91^0 34' 9.16''$	Majirgaon(South bank)	No or less erosion
5	$26^0 11' 9.71''$;$90^0 36' 43.15''$	Goalpara (South bank)	No or less erosion
6	$26^0 11' 1.7''$;$90^0 32' 57.1''$	Pancharatna(Both bank)	No or less erosion
7	$26^0 12' 1.04''$;$90^0 33' 52.1''$	Jogighopa(Both bank)	No or less erosion
8	$26^0 0' 48.92''$;$89^0 58' 57.5''$	Dhuburi (North bank)	No or less erosion
9	$26^0 06' 58.1''$;$91^0 25' 52.7''$	Dakhala(South bank)	Highly eroded
10	$26^0 7' 34.18''$;$91^0 32' 20.6''$	Palasbari (South bank)	Highly eroded
11	$26^0 08' 44.52''$;$90^0 14' 11.12''$	Nayer Alga char (North bank)	Highly eroded
12	$26^0 08' 13''$;$90^0 11' 52.8''$	Mayer Char (North bank)	Highly eroded
13	$26^0 08' 16.8''$;$90^0 15' 16.1''$	Sonamukhi hills (North bank)	Highly eroded
14	$26^0 15' 26.41''$;$91^0 06' 30.93''$	Bahari(North bank)	Highly eroded
15	$26^0 06' 30.69''$;$91^0 15' 58''$	Garaimari(South bank)	Highly eroded
16	$26^0 05' 52.89''$;$91^0 17' 55.87''$	Saupata Pt-I(North bank)	Highly eroded

All these selected locations are visited and soil samples are collected from the just bank level from the locations having no or very less erosion and same were collected from bank and nearby havingvery high erosion taking at least five samples from each location covering a length of minimum one km. The laboratory tests were conducted in the Laboratory of Bongaigaon Polytechnic and Assam Engineering college of Assam(India) as per the IndianStandard. The physical test conducted mainly includeparticle size analysis (IS2720, Pt-IV, 1985), specific gravity (IS 2720, Part III, Sec 1, 1980), particle density (IS 2720 , Pt XXIX,1975), liquid limit and plastic limit (IS2720, Pt-V,1985), compaction characteristics (IS 2720, Pt VIII, 1985), permeability (IS 2720, Pt XVII,1985), direct shear test (IS 2720, Pt XIII,1985) and relative density (IS 2720, Part 14. 1983) .The average laboratory test results of basic physical properties of five samples collected from each 16 locations under consideration are tabulated in Table number 2 and 3.

On the basis of the test results, the soil was also classified by IS classification. During each visit all river side inhabitants are met and interrogated to have some specific information like the extent of erosion in their localities, loss of fertile land, nature of erosion etc. The intensity of erosion in a particular location were tried to assess in every visit by comparing the distances of some trees or nearby structure with the existing bank line and previous bank line as erosion pins are practically useless in highly eroded locations of river Brahmaputra. After conducting the physical tests of all soil samples, the average results are tabulated in table -2 and table- 3.

Table :2 (Results of particle size analysis)

Location	Cu	Cc	% of Sand	% of Clay	% of Silt	% of Clay and Silt
1	12.3	2.6	80.4	14.6	5.0	19.6
2	9.4	1.82	82.6	15.5	1.9	17.4
3	8.6	1.26	89.2	8.6	2.2	10.8
4	6.2	2.24	80.8	13.6	5.6	19.2
5	7.2	1.96	78.6	18.2	3.2	21.4
6	11.3	1.7	81.4	16.5	2.1	18.6
7	9.1	1.5	89.2	9.4	1.4	11.8
8	11.6	1.9	87.0	8.6	4.4	13.0
9	4.5	1.08	94.6	2.7	2.7	5.4
10	3.0	0.86	95.2	2.4	2.4	4.8
11	6.2	0.98	91.9	4.05	4.05	8.1
12	3.8	1.85	88.8	3.2	8.0	11.2
13	4.6	1.26	97.5	1.25	1.25	2.5
14	3.6	1.71	94.9	2.55	2.55	5.1
15	3.4	1.23	98.6	2.2	8.2	1.4
16	3.1	1.31	94.4	2.8	2.8	5.6

(In case of particle size analysis, the hydrometer analysis is not done if the percent of silt and clay is less than 10% and for calculation purpose the clay and silt content are assumed to be equal of the finer amount)

Table:3(Results of other physical properties)

Location	Sp gravity	Particle density (kg/m^3)	Liquid limit (%)	Permeability (cm/sec)	Bulk density(kg/cum)	Relative density (%)	Cohesion (Kg/sqcm)	Angle of shearing resistance (degree)
1	2.71	2710	38.60	$2.6x10^{-5}$	2130	69.56	0.18	28.61
2	2.69	2690	36.40	$8.3x10^{-5}$	1956	73.24	0.13	22.45
3	2.77	2770	40.52	$5.6x10^{-5}$	2036	59.10	0.15	26.10
4	2.67	2670	39.60	$2.1x10^{-5}$	1987	62.35	0.13	28.00
5	2.69	2690	37.82	$9.2x10^{-5}$	1991	66.32	0.11	26.54
6	2.70	2700	38.62	$2.6x10^{-5}$	2054	61.56	0.16	23.51
7	2.70	2700	38.00	$8.3x10^{-5}$	2006	58.30	0.21	30.26
8	2.71	2660	40.20	$1.26x10^{-5}$	1897	58.64	0.15	22.69
9	2.66	2610	31.85	$8.2x10^{-4}$	1789	41.65	0.06	32.45
10	**2.61**	**2610**	**30.61**	$3.1x10^{-4}$	1765	**31.25**	**0.05**	**38.62**
11	2.56	2560	34.45	$4.6x10^{-4}$	1896	36.54	0.08	33.58
12	2.62	2620	34.78	$7.9x10^{-4}$	1881	26.41	0.03	42.56
13	2.61	2610	30.12	$8.0x10^{-4}$	1821	28.96	0.04	41.50
15	2.62	2620	29.88	$8.2x10^{-4}$	1794	36.41	0.07	39.68
15	2.60	2600	30.26	$3.5x10^{-4}$	2136	41.57	0.06	36.25
16	2.56	252 0	31.89	$4.1x10^{-4}$	1842	30.89	0.06	37.56

III. RESULT ANALYSIS

Results of particle size analysis clearly indicates that the clay content plays vital role in resisting erosion in lower Assam region of river Brahmaputra. In all less erosion prone area the percentage of clay is quite high in comparison to highly eroded location.The average particle density of soil particles in erosion free areas are found to be 2698.75 Kg/m^3 and the average of same for highly eroded locations are 2593.75 Kg/m^3 which signifies that the lighter soil particles are more susceptible to erosion. In case of liquid limit also, it is observed that the liquid limit value of safe areas is higher than the unsafe or risky areas. The average value of liquid limit of all eight less eroded areas are found to be 38.72 % whereas the same for highly eroded locations are found to be 31.73 % . The values of permeabilities of all non or less eroded locations are less and in the range of 10^{-5} cm/sec whereas the values of permeabilities of all eroded locations are high and all are in the range of 10^{-4} cm/sec. The values of relative densities of all non-eroded locations are comparatively very high than the values of highly eroded locations with average of 63.63 % and 31.74 % respectively. From gradation point of view, it is found that the soil of non- eroded locations is more or less well graded in comparison to the soils of other locations. Considering all these, finally six physical properties are taken as erosion predictors to assess the erosion vulnerability of river bank. They are be permeability, liquid limit, clay content, particle density, relative density and gradation of soil.

IV. DEVELOPMENT OF MODEL

From the analysis of results of properties of soil in lower Assam region of river Brahmaputra, it has come to light that the values of some physical properties of soil of eroded and non-eroded locations are widely varied which means that these properties have either negative or positive contribution in erosion. So, these particular properties can be taken as erosion hazard predictors to assess the extent of erosion in a particular location. For this a model is proposed in the line of Rosgen's modified method of bank erosion hazard index (BEHI). In Rosgen's modified method, the stream bank erosion predictors are related to field observation and they include -root depth, root density, surface protection and bank angle.These four matrices or stream bank predictors are used in modified method (Rosgen,2001) to develop bank erosion hazard index (BEHI) as given in table 4.

Like Rosgen, in this model also the considered stream bank erosion predictors or parameters permeability, liquid limit, clay content, particle density, relative density and gradation of soil are used to calculate the hazard scores in a certain location which are all physical properties of soil and related to laboratory observation. The index for various category of risk rating in new model is kept same as in Rosgen's modified method and value for different risk category are assigned logically after comparing the minimum and maximum observed value of all parameters under consideration and a table for bank erosion hazard index (BEHI) is prepared which is shown in table 5.

Table:4(Bank erosion hazard index as per Rosgen's modified method)

Risk rating category		Root depth/Bank ht	Root density in %	Bank angle (degrees)	Surface protection in %	Total
Very low	Value	1.0-0.9	100-80	0-20	100-80	
	Index	1.0-1.9	1.0-1.9	1.0-1.9	1.0-1.9	4-7.6
Low	Value	0.89-0.5	79-55	21-60	79-55	
	Index	2.0-3.9	2.0-3.9	2.0-3.9	2.0-3.9	8-15.6
Moderate	Value	0.49-0.3	54-30	61-80	54-30	
	Index	4.0-5.9	4.0-5.9	4.0-5.9	4.0-5.9	16-23.6
High	Value	0.29-0.15	29-15	81-90	29-15	
	Index	6.0-7.9	6.0-7.9	6.0-7.9	6.0-7.9	24-31.6
Very high	Value	0.14-0.05	14-5.0	91-119	14-10	
	Index	8.0-9.0	8.0-9.0	8.0-9.0	8.0-9.0	32-36
Extreme	Value	<0.05	<5	>119	<10	
	Index	10	10	10	10	37-40

Table:5(Assignment of bank erosion hazard index in new model)

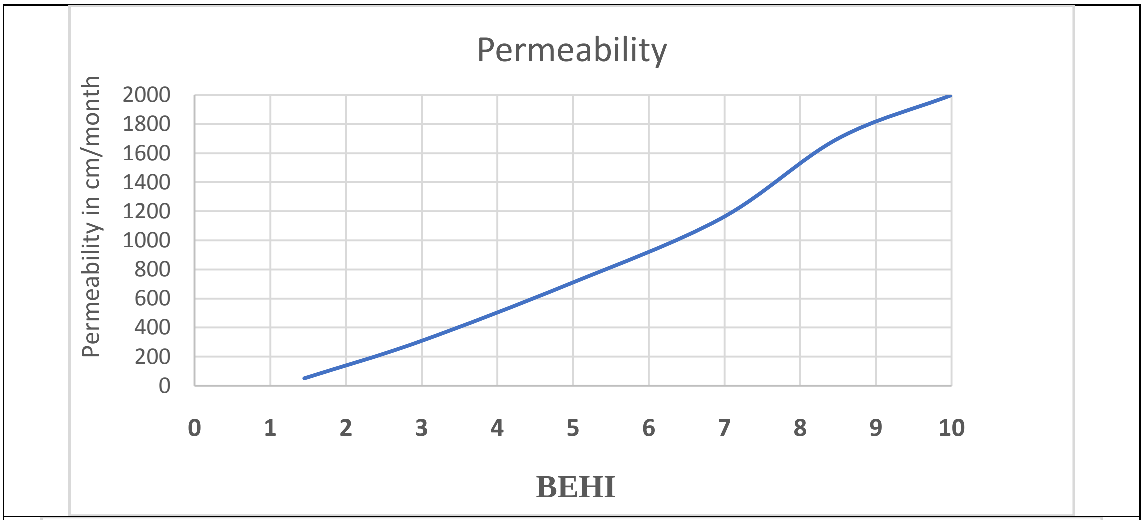
Adjective Hazard or risk rating category		Permeability(cm/month)	Liquid limit(%)	Clay content(%)	Particle density (kg/m^{3}))	Relative density (%)	Gradation of soil	Total
Very low	Value	1-100	>44	90-100	>2800	>80	*(1)	
	Index	1.0-1.9	1.0-1.9	1.0-1.9	1.0-1.9	1.0-1.9	1.0-1.9(1.45)	6-11.4
Low	Value	101-500	44-40	60-89	2800-2700	80-65	**(2)	
	Index	2.0-3.9	2.0-3.9	2.0-3.9	2.0-3.9	2.0-3.9	2.0-3.9(2.95)	12-23.6
Moderate	Value	501-900	39-35	20-59	2699-2650	64-50	***(3)	
	Index	4.0-5.9	4.0-5.9	4.0-5.9	4.0-5.9	4.0-5.9	4.0-5.9(4.95)	24-35.4
High	Value	901-1400	34-30	10-19	2649-2600	49-35	****(4)	
	Index	6.0-7.9	6.0-7.9	6.0-7.9	6.0-7.9	6.0-7.9	6.0-7.9(6.95)	36-47.4
Very High	Value	1401-2000	29-25	5-9	2599-2500	34-25	*****(5)	
	Index	8.0-9.0	8.0-9.0	8.0-9.0	8.0-9.0	8.0-9.0	8.0-9.0(8.5)	48-54
Extreme	Value	>2000	<25	<5	<2500	<25	******(6)	
	Index	10	10	10	10	10	10	55-60

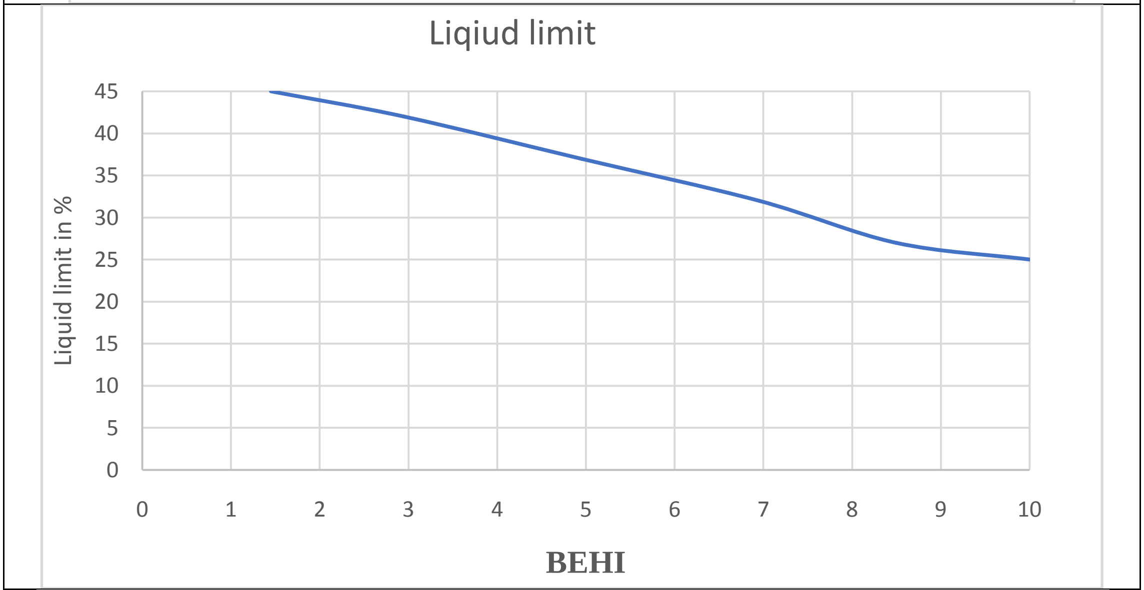
V. DEVELOPMENT OF HAZARD GRAPH

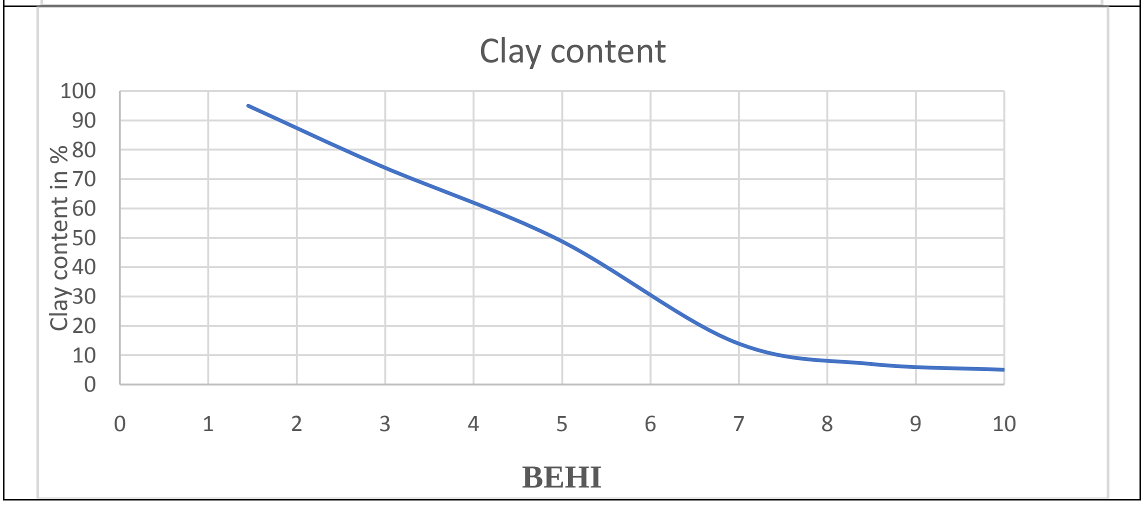
Using the values and indices of Table 5, the graph for determining the hazard index for any observed value of hazard parameters are developed by using excel and shown in Fig1, putting bank erosion hazard index (BEHI) in abscissa and hazard parameters in ordinate. For gradation of soil the graph is prepared by slightly different way as per the following Table number 6. In this case the clay is considered strongest against erosion and hence given least minimum score 1.45 and uniformly graded soil is considered as weakest against erosion and given highest score 10.

Table:6 (Guidelines for preparing graph for gradation)

Gradation of soil	Symbol used	Value assigned (Y- axis)	Score assigned (X-axis)
Only clay	*	1	1.45
Well graded sandy clay	**	2	2.95
Medium graded Clayey sand	***	3	4.95
Medium graded sand	****	4	6.95
Poorly graded sand	*****	5	8.50
Uniformly graded sand	******	6	10


Permeability
Permeability in cm/month
2000
1800
1600
1400
1200
1000
800
600
400
200
0
0 1 2 3 4 5 6 7 8 9 10
BEHI


Liqiud limit
Liquid limit in %
45
40
35
30
25
20
15
10
5
0
0 1 2 3 4 5 6 7 8 9 10
BEHI


Clay content
Clay content in %
100
90
80
70
60
50
40
30
20
10
0
0 1 2 3 4 5 6 7 8 9 10
BEHI

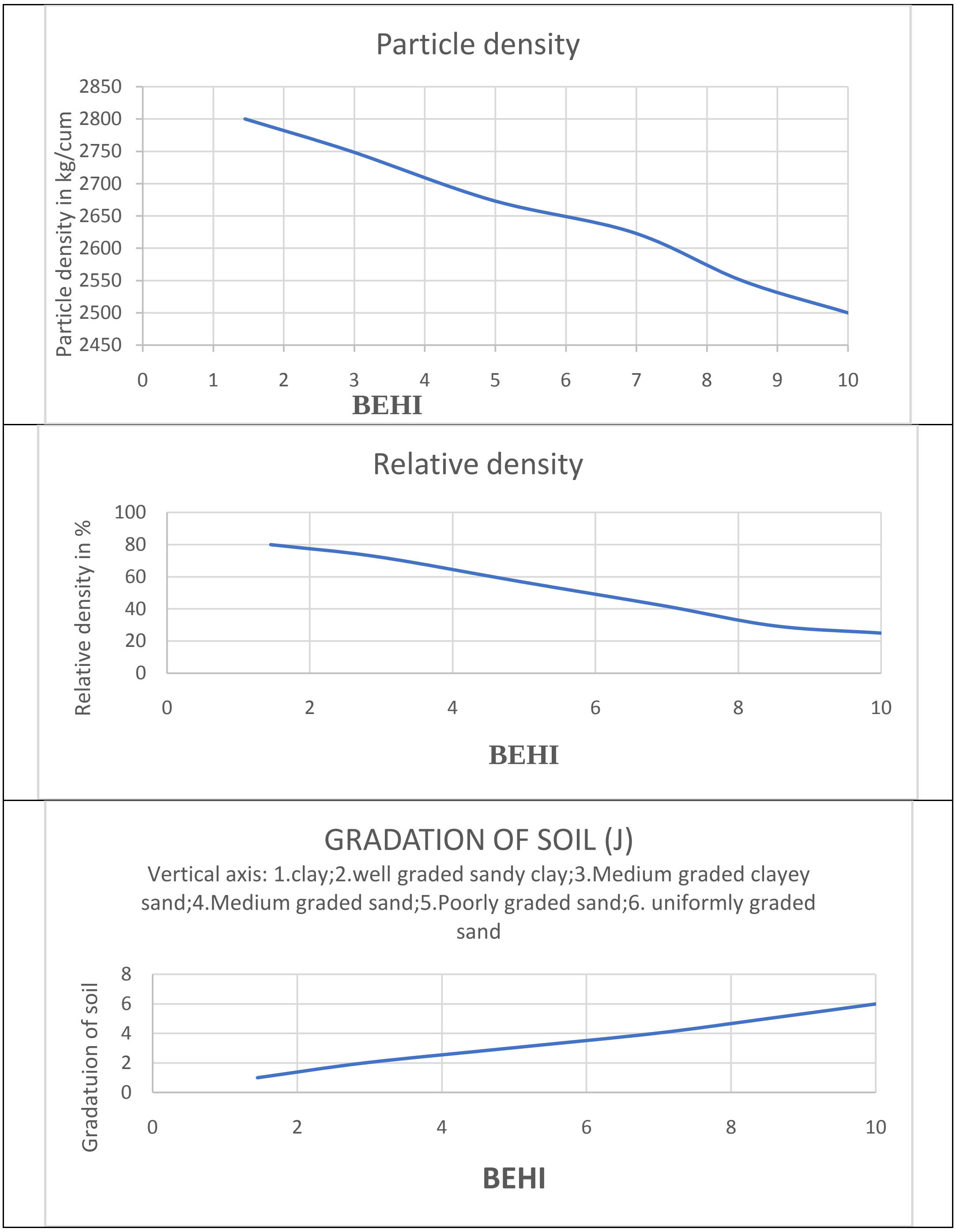


Fig: 1 (Developed graphs of hazard parameters)

VI. APPLICATION OF THE MODEL

The developed hazard model is applied to calculate the total score obtained on the basis of considered six parameters to assign the adjective hazard or risk rating category as very low, low, medium, high, very high or extreme as per table 5 in all selected sixteen locations with specimen calculation in location number 2 and location number 10.

Table : 7 (Specimen calculation of hazard scores)

1.Locationdetails :- Uzan Bazar Ghat Location No:- 2
2.Latitude:-$26^0 12^/ 4.07^{//}$
3. Longitude: - $91^0 44^/ 26.95^{//}$
4. Present Status: Very less erosion

BEHI Category	Symbol used	Observed value/ details	Score obtained	Total Score	Remarks
Permeability (cm/month)	E	215.13	2.5	26.75	Rate of erosion is expected to be moderate as per table 5
Liquid limit (%)	F	36.40	5.5		
Clay content (%)	G	15.5	6.7		
Particle density (Kg/cum)	H	2690	4.3		
Relative density (%)	I	73.24	2.8		
Gradation of soil	J	Medium graded Clayey sand(***)	4.95		

Table: 8 (Specimen calculation of hazard scores)

1. Location details :- Palashbari Location No:- 10 2.
2. Latitude: - $26^0 7^/ 34.18^{//}$;
3. Longitude: -$91^0 32^/ 20.6^{//}$
4. Present Status: Very highly eroded

BEHI Category	Symbol used	Observed value/ details	Score obtained	Total Score	Remarks
Permeability (cm/month)	E	803.52	5.6	47.6	Rate of erosion is expected to be very high as per table 5
Liquid limit (%)	F	30.61	7.6		
Clay content (%)	G	2.4	10		
Particle density (Kg/cum)	H	2610	7.5		
Relative density (%)	I	31.25	8.4		
Gradation of soil	J	Poorly graded sand (*****)	8.50		

Table:9(Calculation of total scores using developed graphs)

Location	Score(E)	Score(F)	Score(G)	Score(H)	Score(I)	Score(J)	Total score	Expected erosion hazard
1	1.45	4.5	6.8	4.0	3.2	4.95	24.90	moderate
2	2.5	5.5	6.7	4.3	2.8	4.95	26.75	moderate
3	1.9	3.6	8.5	2.8	4.5	4.95	26.25	moderate
4	1.45	4.1	7.1	4.9	4.2	4.95	26.70	moderate
5	2.6	5.0	6.4	4.3	3.8	4.95	28.05	moderate
6	1.45	4.5	6.6	4.2	4.2	4.95	26.60	moderate
7	2.5	4.4	7.5	4.2	4.9	4.95	28.45	moderate
8	1.45	3.7	8.5	5.6	4.9	4.95	29.10	moderate
9	10	7.2	10	7.5	7.0	8.50	50.20	very high
10	5.6	7.6	10	7.5	8.4	8.50	47.60	very high
11	7.1	5.8	10	8.3	7.6	4.95	43.75	high
12	10	5.8	10	7.4	9.4	8.50	51.10	very high
13	10	7.5	10	7.5	8.8	8.50	52.30	very high
14	10	7.6	10	7.4	7.6	8.50	51.10	very high
15	6.0	7.4	10	7.5	10	8.50	49.40	very high
16	6.6	7.2	10	9.5	8.5	8.50	50.30	very high

Table- 10 (Average assignment of bank erosion hazard index in new model)

Adjective Hazard or risk rating category		Permeability (cm/month)	Liquid limit(%)	Clay content(%)	Particle density (kg/m^3)	Relative density (%)	Gradation of soil	Total
Very low	Value	1-100	>44	90-100	>2800	>80	*(1)	
	Av Index	1.45	1.45	1.45	1.45	1.45	1.45	6-11.4
Low	Value	101-500	44-40	60-89	2800-2700	80-65	**(2)	

	Av Index	2.95	2.95	2.95	2.95	2.95	2.95	12-23.6
Moderate	Value	501-900	39-35	20-59	2699-2650	64-50	***(3)	
	Av Index	4.95	4.95	4.95	4.95	4.95	4.95	24-35.4
High	Value	901-1400	34-30	10-19	2649-2600	49-35	****(4)	
	Av Index	6.95	6.95	6.95	6.95	6.95	6.95	36-47.4
Very High	Value	1401-2000	29-25	5-9	2599-2500	34-25	*****(5)	
	Av Index	8.50	8.50	8.50	8.50	8.50	8.50	48-54
Extreme	Value	>2000	<25	<5	<2500	<25	******(6)	
	Av Index	10	10	10	10	10	10	55-60

The total hazard score can also be calculated taking the average indices as shown in table 10 without reading the value from the graphs. The total scores so calculated are show in table 11

Table:11(Calculation of total scores using average indices as per Table 10)

Location	Score(E)	Score(F)	Score(G)	Score(H)	Score(I)	Score(J)	Total score	Expected erosion hazard
1	1.45	4.95	6.95	2.95	2.95	4.95	24.20	Moderate
2	2.95	4.95	6.95	4.95	2.95	4.95	27.70	Moderate
3	2.95	2.95	8.50	2.95	4.95	4.95	27.25	Moderate
4	1.45	4.95	6.95	4.95	4.95	4.95	26.20	Moderate
5	2.95	4.95	6.95	4.95	2.95	4.95	27.70	Moderate
6	1.45	4.95	6.95	2.95	4.95	4.95	26.20	Moderate
7	2.95	4.95	6.95	2.95	4.95	4.95	27.70	Moderate
8	1.45	4.95	8.50	4.95	4.95	4.95	29.75	Moderate
9	10	2.95	10.00	6.95	6.95	8.50	45.35	High
10	4.95	6.95	10.00	6.95	8.50	8.50	45.85	High
11	6.95	6.95	10.00	8.50	6.95	4.95	44.30	High
12	10	6.95	10.00	6.95	8.50	8.50	50.90	Very high
13	10	6.95	10.00	6.95	8.50	8.50	50.90	Very high
14	10	6.95	10.00	6.95	6.95	8.50	50.90	Very high
15	6.95	6.95	10.00	6.95	10.00	8.50	49.35	Very high
16	6.95	6.95	10.00	8.50	8.50	8.50	49.40	Very high

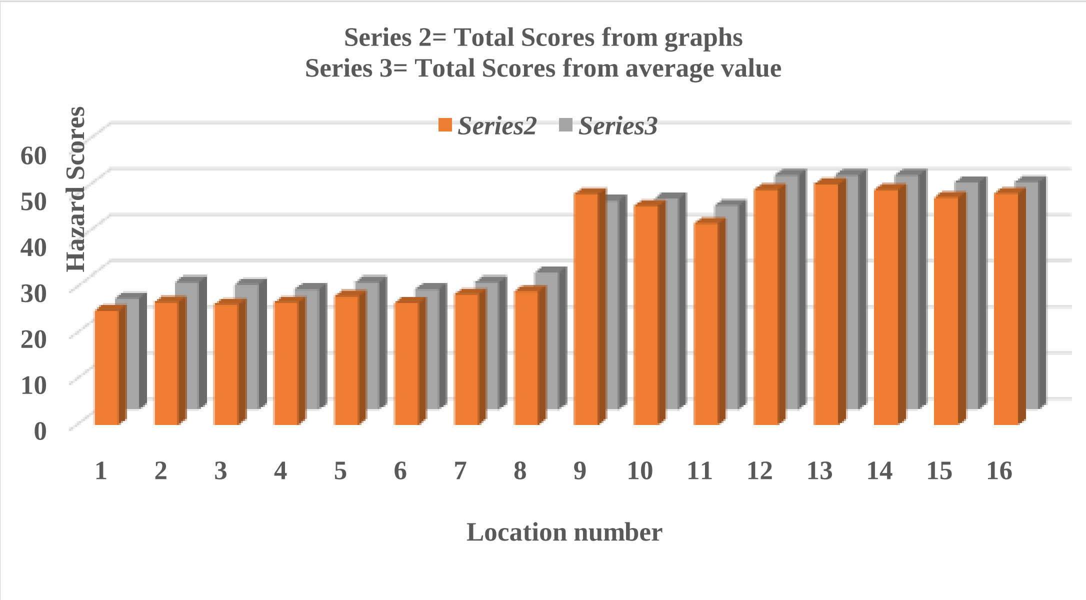


Fig :2 (Total hazard scores of all locations)

VII. CONCLUSION

The problem of river bank erosion is universal and it is very much common and hazardous in Assam (India) due to various rivers particularly due to river Brahmaputra. Every year the poor state suffers many folded losses due to river bank erosion. This particular hazard is recognized as burning problem all over the world and intensive researches are going on for the solution of the problem. But till date no concrete and full proof solutions are obtained. Experts opine that this particular natural hazard is not possible to eradicate but it can be controlled to great extent by using appropriate anti erosive techniques or by appropriate river training works. To implement these anti erosive measures, in any river course, it is necessary to identify the locations vulnerable to erosion so that anti erosive measures could be taken in advance on priority basis. Keeping all these in mind an attempt has been made to evolve a mechanism or simple method to identify a location, whether it is erosion prone or erosion free by observing the physical properties of river bank soil so that using this mechanism or model, the whole reach of a river can be kept marking as ready reference to implement the anti-erosive measures and accordingly from the selected sixteen locations samples are collected and tested. From the comparative study of the obtained results, it is clear that the that the average values of the considered soil parameters widely differ for erosion free and erosion prone locations. So, these six soil physical properties- permeability, liquid limit, clay content, particle density, relative density and gradation of soil could be used as indicator of erosion vulnerability in river bank by developing a model and hence the proposed model is developed in the line of Rosgen's modified method of bank erosion hazard index (BEHI). After analyzing the results obtained from this model, it can be concluded that this model gives very satisfactory results in identifying the vulnerable locations as last eight really very high erosion prone locations are predicted as high or very highly expected erosion prone by the model. But actually, all very less erosive locations are predicted as moderate by the model giving slightly exaggerated results. The average final scores of all non-eroded locations are found to be 27.10 and the average scores of all highly eroded locations are found to be 49.50 showing a very huge difference in average scores. So, finally it may be concluded that this model can effectively be used to predict the vulnerable locations, if the calculated scores indicate the hazard expectation as high, very high or extreme. If the calculated scores indicate the hazard expectation as moderate or below then the observed location may be marked as erosion free from geotechnical properties point of view.

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