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A Simple Model for Factor of Safety in River Bank Stability Analysis: A Case Study in Lower Assam Region of River Brahmaputra.

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Abstract:*River bank erosion or the stream failure mechanism is a very complex fluvial process and it is the burning problem of Assam. In fluvial system, any bank failure occurs in one of the three main ways (Fischenich 1989). They are hydraulic failures, geotechnical failures and combined failures. In hydraulic failures, the flowing water imparts tractive force on soil particles or bank materials and if this tractive force exceeds the critical shear stress for that particular stream bank, then the soil particles are removed from the bank thus erosion occurs. The most common and prominent mode of bank failure is the failure due to combination of hydraulic failures and geotechnical failures. Due to hydraulic force the bank materials are eroded away at the toe level resulting the soil mass overhanging or steepening in bank angle and ultimately the soil mass collapsed due overhanging and formation of tension cracks. A cantilever failure will occur if any of the overhanging blocks have a safety factor of less than one. In this work a very simple mathematical model is developed for factor of safety and results so obtained are found to be quite satisfactory in predicting the probability of erosion after applying in sixteen selected locations in lower Assam region of river Brahmaputra. The model has been developed by using the various bank erosion hazard parameters.*

Key words:*Brahmaputra, erosion, eroded, factor of safety, river bank, vulnerability,*

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I. Introduction

The river Brahmaputra which is the identity of Assam is one of the major rivers of Asia.The river is originated in the Angsi glacier, located on the northern side of the Himalaya Mountain in Burang of Tibet and after flowing through three different sovereign countries it ends its journey at Bay of Bengal.During its journey throughout the Assam so many tributaries are combined at various locations to make it mightier.The nature and activity of the mighty river Brahmaputra is tremendous from the point of view of channel migration, channel cutting, flood formation and bank erosion.The annual rate of erosion of river Brahmaputra is very high in both banks in many locations in lower Assam region along with frequent change of channel depth due erosion and deposition of sediments.The hydrology of the Brahmaputra River is characterized by its significant rates of sediment discharge, the large and variable flows, along with its rapid channel aggradations and accelerated rates of basin denudation. Climatic change plays a crucial role in affecting the basin hydrology. Throughout the year, there is a significant rise in hydrograph, with a broad peak between June and September. The Brahmaputra River experiences two high-water seasons, one in early summer caused by snow melt in the mountains, and one in late summer caused by runoff from monsoon rains.All human beings of this globe are facing various natural as well man-madehazardslikeflood, draught, cyclone, fire, infectious diseases, river bank erosion, earthquake, etc. Out of all these hazards the river erosion hazard is more dangerous, recurrent, extensive and devastating to the people of Assam from all sides. Due to river bank erosion of river Brahmaputra and its tributaries, every yeara good number of families of Assam become homeless, hundreds of acres of fertile land devastated, huge economic lost incurred, social disorder appeared, demography of the state is changed.

The river bank erosion is a natural and key process in fluvial dynamics which create tremendous ill effects in socio economic field of human life, affecting a wide range of physical,ecological, morphological in fluvial environment (Hooke,1980; Millar and Quick,1993; Darby and Throne,1996a; Millar,2000; Goodson et al 2002).Failure of river bank results in extensive sediment production inall alluvial channels causingsevere environmental andeconomic problems such as loss of fertilization in agriculturalareas and destruction of infrastructure (Taghavi et al., 2010). Though extensive research works are going all over the world, but till date no any full proof mechanism has been developed to predict the extent of erosion in alluvial channel. In this work, an attempt has been made to identify the probable locations vulnerable to erosion using some river morphological parameters and geotechnical properties of soil with the help of the proposed simple model developed for determining the factor of safety (FOS), so that in any river the vulnerable locations can be easily identified andanti erosional measures could be adopted on priority basis to prevent the erosion.

II. Study Area And Methodology:

The riverBrahmaputra is flowing longitudinally through Assam from Sadiya to Bangladesh boarder covering near about 700 Km in the state. From the entry to exit point in the state Assam, the river Brahmaputra is eroding its both banks at alarming rate at many locations. For study purpose of river bank erosion all together sixteen locations in the lower Assam region have been identified and selected. Out of these sixteen locations eight locations(location number 1 to 8) are selected with no erosion or having very low erosion and other eight locations(location number 9 to 16) are selected having very high rate of erosion.
The selected locations are tabulated below in table1

TABLE:1

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

All selected locations are visited at least once in two months during the non-rainy season particularly during September to April for consecutive three years to collect some bank characteristics like bank angle, root density, root depth, surface protection, channel migration, extent of erosion etc. In each location about one km reach is taken for the purpose of study. Parameters are observed in about five spots of that considered one km.All such observations are noted down and finally the average of all parameters are taken into consideration for assessing the vulnerability of erosion and factor of safety of bank slopes. To assess the amount of erosion some spot like trees or permanent nearby structures etc are marked and measured the distance from the existing bank and in next visit again measuring the distances between the bank and the spot the extent of erosion could be assessed. The intensity of erosion in river Brahmaputra in highly eroded locations are so high that erosion pin become useless and hence such indirect methods are adopted.In case of soil sample collection, samples are collected from five spots of that considered one km reach with soil samples just on the bank in case of locations having very less or no erosion and samples from bank level and nearby from the locations with very high erosion. The samples were carried to the laboratories and tested as per Indian Standard for different physical propertieslike clay content. sand content, silt content, liquid limit, relative density, angle of shearing resistance, cohesion, relative density, permeability, specific gravity etc. During every visit nearby inhabitants were met and interrogated to obtain some specific information about the nature and intensity of erosion in their localities.

III. Model For Factor Of Safety:

After analyzing the average results of all bank characteristics and physical properties of soil, a very clear trends are observed between the values of eroded locations and non-eroded locations. The parameters like bank angle, root depth, root density, surface protection, clay content, sand content, silt content, liquid limit, relative density, angle of shearing resistance, cohesion, relative density, permeability etc are found to be related with river bank erosion in lower Assam region of river Brahmaputra.Some of these parameters are found to be directly proportional to erosion which means that if the value of these parameters increases than the risk of erosion also increases and some other parameters are found to be inversely proportional to erosion which means that if the value increases the risk of erosion decreasesand accordingly all erosion hazard factors or parameters are mainly divided into two categories
(A) Parameters proportional to erosion
i. Bank angle ii. Sand content iii. Silt content iv. Permeability

(B) Parameters inversely proportional to erosion
i. Clay content ii. Liquid limit iii. Root density iv. Root depth v. Surface protection
vi. Relative density vii. Cohesion viii. Angle of shearing resistance

Out of all these parameters all dimension less parameters like Bank angle, Angle of shearing resistance, Clay content, Sand content, Silt content, Relative density, Surface protection, Root depth, Root density are taken into consideration for developing the model for factor of safety (FOS) calculation by dividing the related resisting parameters by the related accelerating parameters.

FOS MODEL-1

$$FOS = \frac{\text{Angle of SR}}{\text{Bank angle}} + \frac{\%\text{ of (Clay+LL+Rdensity+Rootdensity+Rdepth+S P}}{\%\text{ (Sand + Silt)}}$$

Where
SR = Shearing resistance
R density = Relative density of soil
SP = Surface protection
R depth = Root depth

Using this relation, the factor of safety of all locations under consideration are calculated and results so obtained are tabulated in the table 2 with specimen calculation in location 1
Specimen Calculation of FOS by Model-1 at location no 1
Observed values of different parameters

(a) Angle of shearing resistance = 28.61^0
(b) Bank angle = 60^0
(c) Clay Content = 14.6 %
(d) Liquid Limit = 38.60 %
(e) Relative Density = 69.56 %
(f) Root Density = 45 %
(g) Root depth = 60 %
(h) Surface Protection = 50 %
(i) Sand Content = 80.4 %
(j) Silt Content = 5.0 %

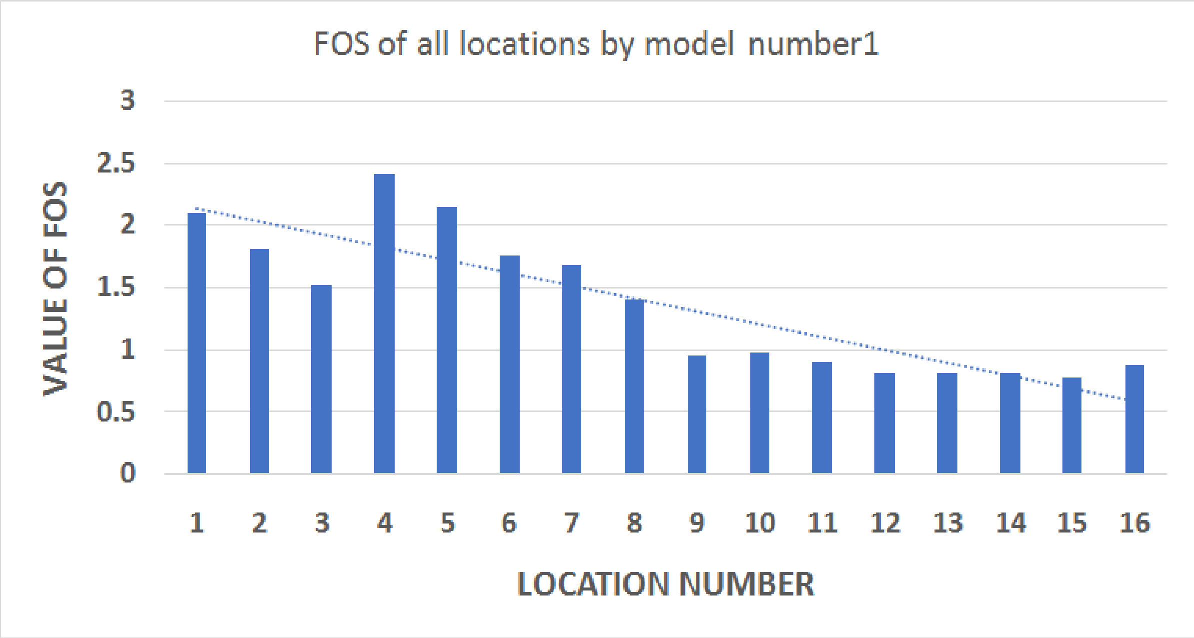
$$FOS = \frac{28.61}{60} + \frac{14.6 + 38.60 + 69.56 + 45 + 60 + 50}{80.4 + 5}$$

$= 3.73$

TABLE :2(Value of FOS of all locations as per model no 1)

Location number	Value of FOS	Average	Remarks
1	3.73	Average value of FOS for less or non-eroded area is found to be 3.13	Locations number 1 to 8 are of very less or non-erosion prone area
2	3.11		
3	2.52		
4	3.89		
5	3.63		
6	2.99		
7	2.74		
8	2.43		
9	1.55	Average value of FOS for highly eroded area is found to be 1.36	Locations number 8 to 16 are of very highly erosion prone area
10	1.62		
11	1.48		
12	1.26		
13	1.23		
14	1.21		
15	1.19		
16	1.35		

Fig: 1



FOS MODEL 2:The model 1 gives the satisfactory results by giving the average value of FOS of non-eroded or less eroded areas 130 % more than the average value of highly eroded areas ,but the FOS value of all locations are more than 1. So, another new model is proposed by giving the double weightage to the sand and silt content for calculating the FOS which is given below

$$FOS = \frac{\text{Angle of SR}}{\text{Bank angle}} + \frac{\text{\% of (Clay+LL+Rdensity+Rootdensity+Rdepth+SP}}{2x \text{ \% (Sand + Silt)}}$$

Where
SR = Shearing resistance
R density = Relative density of soil
SP = Surface protection
R depth = Root depth

Specimen Calculation of FOS by Model-2 at location no 1

Observed values of different parameters
(a) Angle of shearing resistance = 28.61^0
(b) Bank angle = 60^0
(c) Clay Content = 14.6 %
(d) Liquid Limit = 38.60 %
(e) Relative Density = 69.56 %
(f) Root Density = 45 %
(g) Root depth = 60 %
(h) Surface Protection = 50 %
(i) Sand Content = 80.4 %
(j) Silt Content = 5.0 %

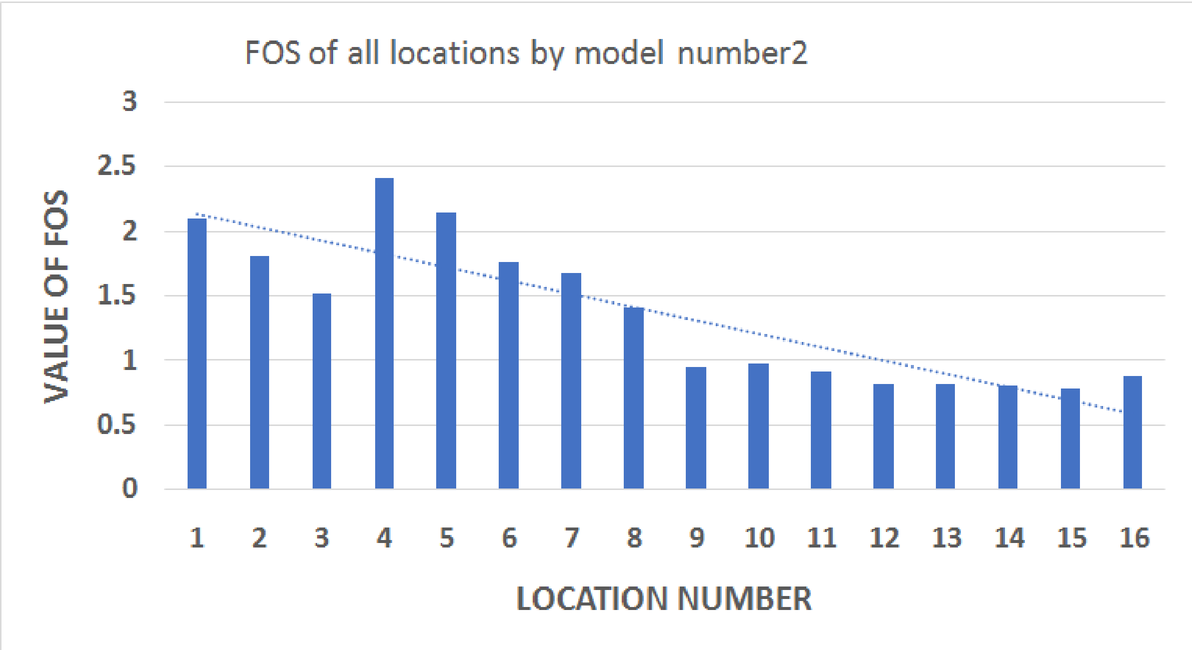
$$FOS = \frac{28.61}{60} + \frac{14.6 + 38.60 + 69.56 + 45 + 60 + 50}{2x\,(80.4+5)}$$
$$= 2.10$$

TABLE: 3(Values of FOS of all locations as per model no 2)

Location number	Value of FOS	Average	Remarks
1	2.10	Average value of FOS for less or non-	Locations number 1 to 8 are of very less or non-erosion prone
2	1.81		
3	1.52		
4	2.41		

5	2.15	eroded area is found to be 1.86 with any value more than 1.	area
6	1.76		
7	1.68		
8	1.41		
9	0.95	Average value of FOS for highly eroded area is found to be 0.87 with any value less than 1	Locations number 8 to 16 are of veryhighly erosion prone area
10	0.98		
11	0.91		
12	0.82		
13	0.82		
14	0.81		
15	0.78		
16	0.88		

Fig 2



The model 2 also gives the satisfactory results by giving the average value of FOS of non-eroded or less eroded areas 114 % more than the average value of highly eroded areas. Also, this model gives the values of FOS of all safe areas more than 1.0 with average of 1.86 and the average values of FOS of all highly eroded locations given by this model is less than 1.0 with average of 0.87.

IV. Conclusion:

The stability analysis of river bank in respect of erosion is a very complex and uncertain phenomena. But it is sure that some parameters like bank angle, root density, surface protection, root depth (Rosgen), velocity of flow, meandering etc are the factors which greatly affect the extent of erosion. Geotechnical properties of soil also play a vital and decisive role in river bank erosion. In case of a building if a column can carry a certain amount of maximum load and if the applied load is more than the allowable load, the column will fail. Before failing, the internal strength of the column will try to resist the applied load and it will be able to do so if the factor of safety i.e. the allowable load divided by applied load is more than one. In river bank stability analysis also, it is found that some factors are resisting factors of erosion and some are accelerating factors of erosion. If the ratio of resisting factors to the accelerating factors have a value more than one, then the bank will be stable like the building column. Otherwise it will collapse. This idea has been put forwarded to analysis the stability of river bank in lower Assam region of river Brahmaputra by developing a model for calculating the factor of safety on the basis of resisting and accelerating factors of erosion. It is found that the factor of safety so calculated were found to be less than one in all eight highly eroded locations and the same were found to be more than one in all other eight non-eroded locations. So, this very simple model could be used to assess the vulnerability of river bank erosion in any river. For this all required factors or parameters shall be collected from field and laboratory analysis and then by model number two, the factor of safety (FOS) will be determined. If such value comes less than one then the location may be assessed as erosion prone and if the value so determined comes more than 1, then that particular location may be assessed as erosion prone.

References

[1]. David L. Rosgen P.H. 2008, A practical method of computing stream bank erosion rate. Wildland hydrology
[2]. Darby, Stephen, E. & Throne, Colin R., (1997). Development and Testing of a River bank Stability Analysis. Journal of Hydraulic Engineering, 122, 433-454
[3]. Naser HafeziMoghaddas, Reza Jalilvand, Hamid Reza Soloki,2012. The role of soil engineering in producing bank erosion and morphological changes of Sistanriver.Archives of Applied Science Research,2012 4(4):1650-1658.
[4]. Chandan Nath, Pankaj Goswami2016. Effect of soil properties on river bank erosion in lower Assam region. International journal of research in engineering and management Vol 1 no 1 2016 P 7-15.
[5]. Darby, S.E., Throne, C.R. Hydraulic Engineering, 1997,123,1052-1053
[6]. E.R. Daly, G.A. Fox, A. K. Fox ,Correlating Site-Scale Erodibility Parameters from Jet Erosion Tests to Soil physical Properties. American Society of Agricultural and Biological Engineers, 2016, Vol 59(1) 115-128
[7]. Darby, S.E. and Throne, C.R. (1996). Stability Analysis for Steep, Eroding, Cohesive River Banks. Journal of Hydraulic Engineering. 122, 443-454
[8]. Duan, J.G. (2011b). Simulation of Streambank Erosion Process with a Two -Dimensional Numerical Model. Landscape Erosion and Evolution Modeling, Chap. 13, R.S. Harmon and W.W. Doe III, eds., Kluer Academic/Plenum, New York, 389-427.
[9]. Duan, J. G. (2005). "Analytical approach to calculate rate of bank erosion." J. Hydrologic. Engg., 131(11), 980-990.
[10]. IS1498-1970. Code for classification and identification of soils for general engineering purposes. Indian Standard Institution.
[11]. IS 2720 (Part 1), 1983, Methods for preparation of dry soil samples for various test. Indian Standard Institution
[12]. IS 2720 (Part 3, section 1),1980. Determination of specific gravity of fine grained soils. Indian Standard Institution
[13]. IS 2720 (Part 3, section 2),1980. Determination of specific gravity of fine, medium and coarse grained soils. Indian Standard Institution
[14]. IS 2720 (Part 4),1985. Methods of test for soils. Part 4, Grain size analysis. Indian Standard Institution
[15]. IS 2720 (Part 5),1985. Methods of test for soils. Part 5, Determination of liquid limit and plastic limit. Indian Standard Institution
[16]. IS 2720 (Part 13),1986. Methods of test for soils. Part 13, Direct shear stress. Indian Standard Institution
[17]. IS 2720 (Part 14),1985. Methods of test for soils. Part 14, Determination of density index (relative density) of cohesionless soils. Indian Standard Institution
[18]. IS 2720 (Part 17),1992. Methods of test for soils. Part 17, Laboratory determination of permeability. Indian Standard Institution
[19]. Dr. B.C. Punmia, Ashok Kr Jain, Dr. Arun Kr Jain, Soil Mehanics and Foundation Engineering (Laxmi Publication (P) Limited
[20]. Winkley, B.R. (1992), "River Channel Protection and Development", Int. Conf on Protection and Development of Nile River and other Major River.

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