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Determination of River Bank Erosion Probability: Vulnerability and Risk in Southern Shoreline of Bangladesh

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Abstract

Riverbank erosion is one of the most critical type of disasters that takes into account the quantity of rainfall, soil structure, River morphology, topography of river, adjacent areas. Every year thousands of people have to be migrated due to this devastating disaster and thus it makes them bankrupt. Kirtonkhola River situated at Barisal is such a river who frequently makes its dwellers floating by dint of its natural character and flows. Samples were collected during field investigation and had been tested at Geotechnical laboratory of University of Dhaka. Specific gravity tests of soil sample show values describing the lowest value at 4th sample 2.23 which refers the high probability of eroding factor. Atterberg limit testing which explain about moisture content of soil present lower values. From the plasticity index it had been found 8.19, 10.3 and other proximate values which mean there are high probability of failure of riverbank slope. As the soil content low plasticity index values so those have low capacity of soil compaction and gradually will lose their stability and safety factor. Grain size analysis carried out with a view to finding out percentage of sand, silt and clay in soil. Among these soils most of them are found loose sandy soil which describes failure probability is getting higher in future. The grain size analysis it had been found that sand was 98.5% at 1st sample which means it will face eroding very soon. Sandy soil at river bank which content high amount of moisture most of the time are loose and it have high probability of failure. Hydrometer analysis also carried out and it had also same trend of values. The study suggested some steps based on people's property, homestead and agricultural field loss which should be taken by respective authorities to protect the study area.

Keywords

Riverbank Erosion, Soil, Vulnerability, Risk, Bangladesh

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1. Introduction

Riverbank erosion, associated sedimentation and land loss dangers are a resource management problem of global significance. It is one of the most unpredictable and dangerous type of disasters that takes into account the quantity of rainfall, soil structure, river morphology, topography of river and adjacent areas, and floods. [1-3]. Such calamity took tolls less in lives but more in livelihood as agricultural land and homesteads along with other livelihood options that are evacuated [4-7]. The study was conducted at one of the vulnerable regions of Bangladesh

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(i.e. Charcowa Union of Barisal Sadar Upazila under Barisal District) due to riverbank erosion. The study tried to find out the Geological causes and catalyzed soil characteristics of river bank portion influencing riverbank erosion and associated impact on livelihood and its supplementary displacement of river side dwellers. The study employed both primary and secondary data sources to find out the causes and effects. Primary data were collected through laboratory testing of collected sample from eroded portion of river of Kirtonkhola using purposive random sampling techniques to understand the adverse effects of soil low stability characteristics on bank erosion. On the other hand, tracking through Global Positioning System (GPS) gives the current bank line and image analysis from Google Earth (Arc GIS Map) gives the amount of area eroded in this year.

Kirtonkhola River is one of those districts which are causing severe riverbank erosion to many locations of several Upazila of district in Bangladesh. Within the last 15 years, the river came about half kilometer inside the catchment area damaging resources of about taka 30 crore including many educational institutions, agricultural field and vast tracts of croplands [8-10]. There are numerous ways of riverbank failure including Slumping, undercutting of bank base with formation of tension cracks, toppling and vertical bank erosion etc. But, usually riverbank failure governs by the erosion of the bank toe with the increased height of the adjacent channel bed and the angle of the bank at which the gravitational forces exceed the shear strength of the bank material [11-12]. The geotechnical properties of bank material are important in controlling the stability of riverbank and past studies have found that these properties are often variable spatially [13]. Therefore, for the good management of the stability problems, this study aims to find out the failure causes and probability of Kirtonkhola riverbank on the basis of its geotechnical properties as well as to suggest a new convenient approach for the stability analysis of the riverbank [12].

The study focuses on determining the soil characteristics from riverbank of the study area applying soil geotechnical properties investigation [14-16]. Determining basic geological causes which influence river to be eroded was the main motivation of the study. The data or sample was collected from the place where riverbank erosion is a common phenomenon and this natural disaster play with the people's life, shelter, properties and often people have to bind acting with crackpot of nature. In the 21st century nature is going more crucial to its child through different ways and riverbank erosion is assumed as one of the crucial way which bit people of lowering district [17-19]. Since past studies show a wide range of variation in flood discharge which is considered in our country the main causes of riverbank erosion, that flood flow will be increased by 15% by 2050 and 20% by 2100 for all the major rivers. However, this estimation can be revised for any percentage of flood flow increment. Average peak flood used in this study has been calculated using the BWDB discharge data for the period 1950-2009 for Bahadurabad (in the Jamuna), Hardinge Bridge (in the Ganges) and Baruria Transit (in the Padma) stations [20]. Riverbank erosion make hundreds of people in the study area displaced last 20 years. Socioeconomic impacts of riverbank erosion are getting higher day to day in the area. The main problem is people displacement with bag and baggage and have to take shelter in larger cities and leading challenging life. Riverbank erosion is one of the major natural calamities of Bangladesh that took place in almost every year. The effect of this disaster is widespread. The main aim of the study is to find out the geological factors which influencing the intensity of riverbank erosion. Furthermore, some objectives have been identified to fulfil the study goal, which are

a. To find out the root causes of bank erosion in the study area.
b. To find out the upcoming probability of riverbank failure due to geotechnical properties losses.
c. To find out some recommendations protecting the riverbank erosion.

2. Study Location

The Charcowa Union (Figure 1) is located within the Thana of Barisal Sadar, Upazila in Barisal Sadar and Barisal district. The domestic lunch Ghat at Barisal Sadar is located at about 2km north of Charcowa, which is connected by Barisal district. In Barisal district Erotted Area (HA) 8950, Acretted Area 100470 (HA) till 2015 [21]. The study area beside Kirtonkhola River situated at Old Meghna Estuarine Floodplain which belongs to smooth, almost level, floodplain ridges and shallow basins characterize this floodplain. Relief is made irregular locally by man-made cultivation platforms in east of Chandina and in parts of Munshigonj, Sonagaon and Sariatpur. Soils are relatively uniform within this region, both between adjoining ridges and basins, and between sub regions. Silty soils predominate, but there are significant proportions of silty clay of clay basin soils in Dhaka, Madaripur-Gopalpur and Barisal [22-23].

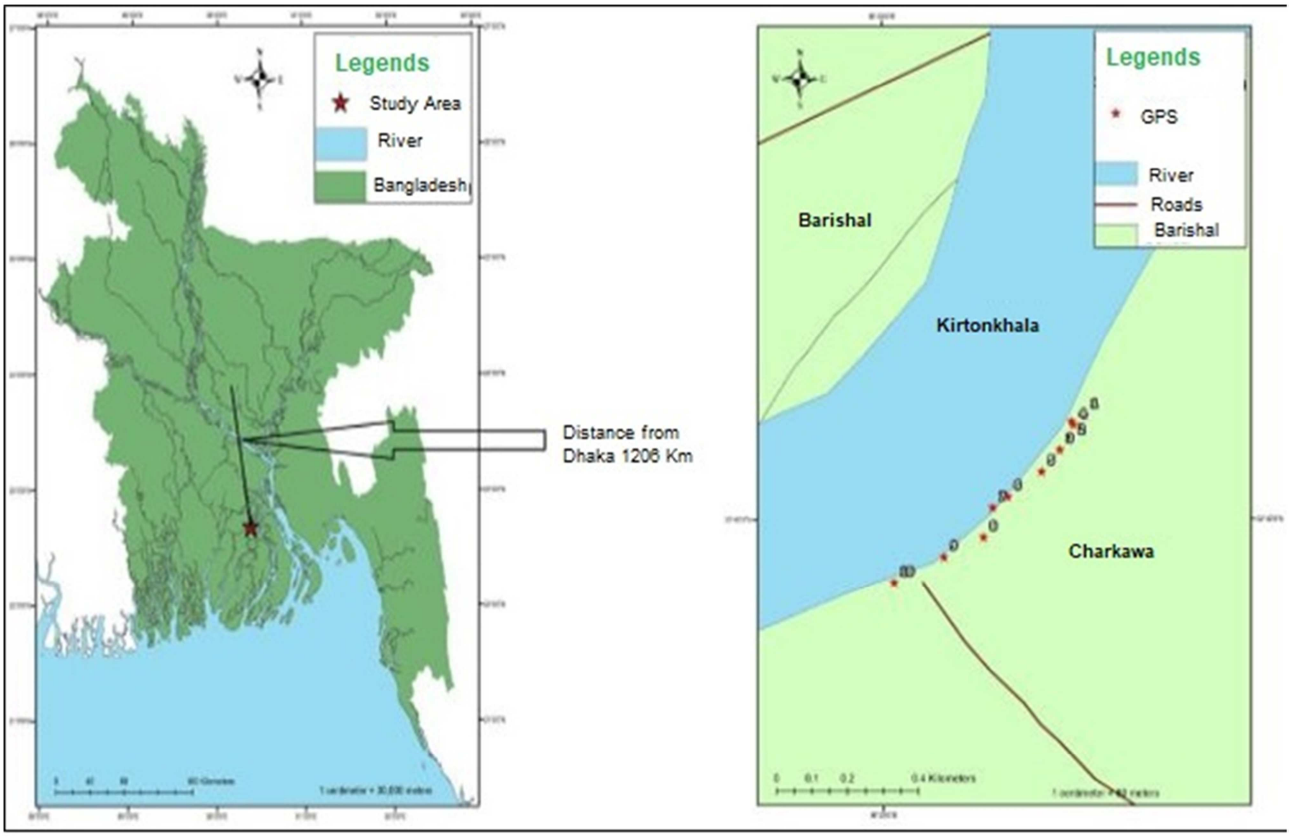

Figure 1. Study Area encrypting GPS value in perspective of Bangladesh.

3. Methods and Materials

To conduct this study both primary and secondary data were collected from various sources and forms. Primary data was collected through Laboratory test of the samples. Primary data was collected in August when river flow become quit and not extreme at that time. For conducting the study 10 sample were collected from the study area where soil had been eroded. During collecting the sample GPS map and information had been collected. The secondary data was collected through various institutes working with the issue and from different report, research articles, newspaper articles, journal papers and many more. The tasting values from different sample had been organized in one place and checked whether it may be completed. The irrelevant and inappropriate data do not take into account for further counting and irrelevant data had been screened out. The excel sheet and data collection form were prepared based on need and mathematical formation. Using software (Microsoft word 2013 and Excel), data had been analyzed to find out percentage of moisture content, specific gravity hydrometer and grain size analysis. Soil sample were collect from the field survey and testing result were taken and find out the geological properties of the soil. All soil sample testing was carried out at Geotechnical Laboratory and "Engineering Geology and Geophysics Lab" at Geology Department, University of Dhaka. There are 10 soil samples which have been collected from different location in the Charcowa union. Height, length was measured during sample collection. Furthermore, the different properties of soils such as grain size, unit weight of soil were measured by sieve analysis, specific gravity determination, hydrometer analysis, compaction test and atterberg limits measurement. Calculation of specific gravity of the soil solids using the following formula: Specific Gravity,

$$Gs=Wo/(Wo+(Wa-Wb))$$

Where: Wo = weight of sample of oven-dry soil, g = WPS - WP

Wa = weight of pycnometer filled with water

Wb = weight of pycnometer filled with water and soil

4. Result and Discussion

4.1. Scenario of Riverbank Erosion in Bangladesh

It has been found that rate of riverbank erosion varies in decade-scale along the major three rivers (Figure 2, 3 and 4). Sometimes variation may be naturally induced and/or sometimes it is induced by anthropogenic activities [24]

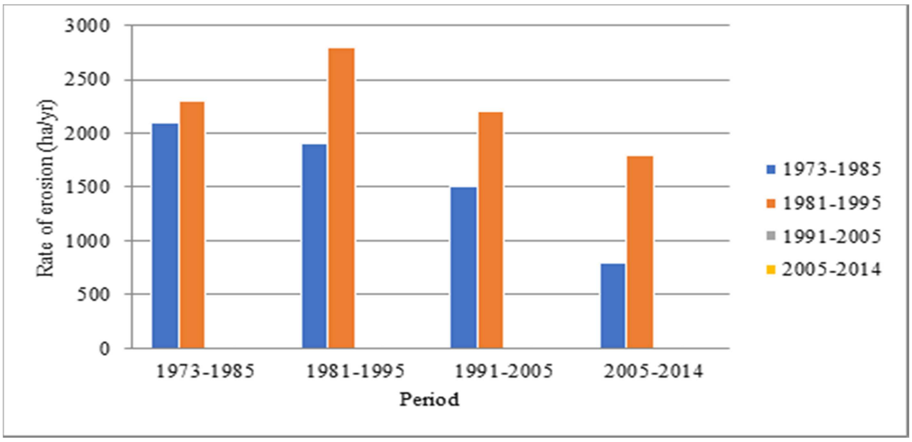

Figure 1. Decadal Erosion Pattern along the banks of the Jamuna River

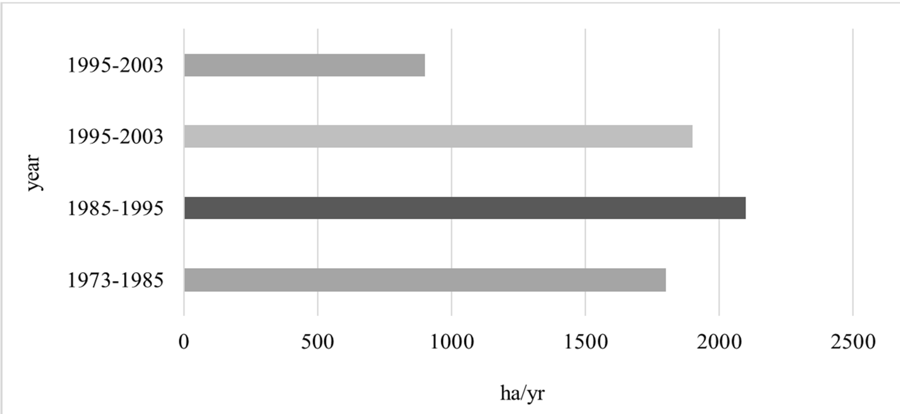

Figure 3. Decadal Erosion Pattern along the Ganges River.

Changing in morphological process has been observed in the Jamuna, the Ganges and the Padma over the period which makes fluctuation in bank erosion. The phases of meandering bend development and subsequent chute cut-off also determines the annual rate of riverbank erosion, which has been observed in the Ganges and partly in the Padma. Therefore, we can conclude that naturally riverbank erosion has a trend of fluctuation. So, to find out actual erosion change trend, we must eliminate natural trend first. Then we should attempt to find out relationship between flood discharge and bank erosion. Exactly this process has been followed here. However, after elimination of trend it has been found that the magnitude of riverbank erosion is dependent on annual flood discharge [8]

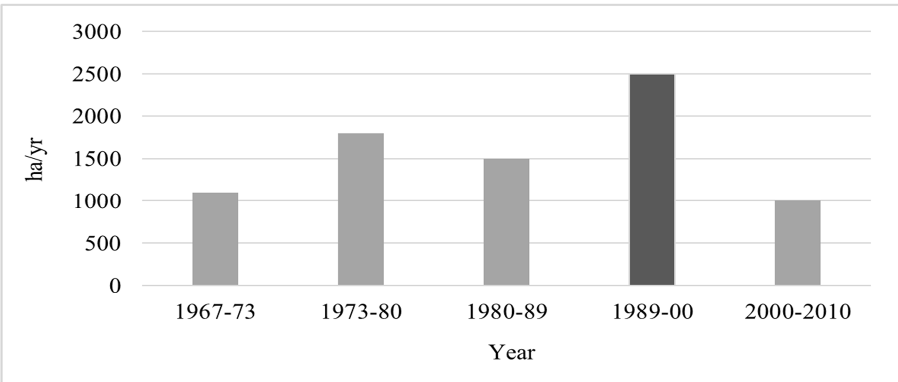

Figure 4. Decadal Erosion Pattern along the Padma River.

Annual average peak discharges have been calculated as 70,000 m^3/s, 50,000 m^3/s and 90,000 m^3/s for the Jamuna, the Ganges and the Padma rivers respectively for the period of 1950-2010. It has been found that an increase in flood discharge by 20% within the year 2100 will increase the annual rate of riverbank erosion substantially. The predicted riverbank erosion for 2050 and 2100 are presented in Figure 5 which shows that increase in the average annual erosion rate is higher for the Jamuna and the Padma by 2050 than that by 2100. On the other hand, the Ganges is in a balance position for 2010-2050 and 2050-2100 durations.

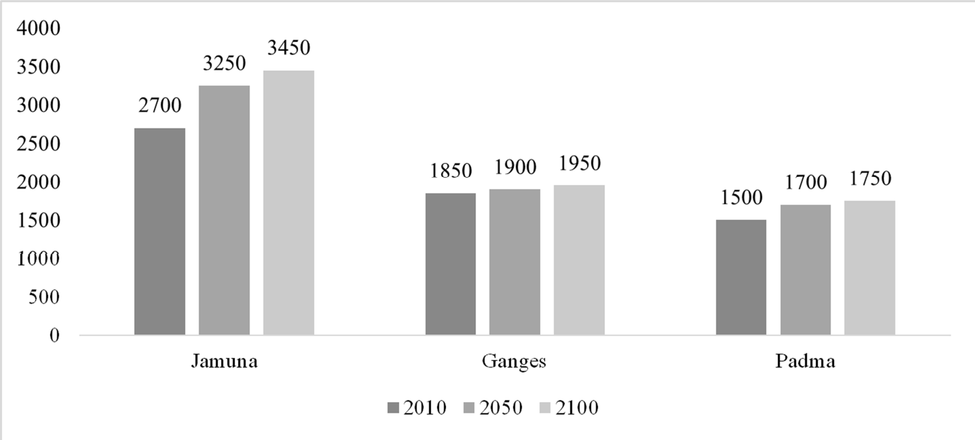

Figure 5. Predicted River Bank Erosion along the Jamuna, Ganges and Padma Rivers [25].

The soil texture, plasticity index, compressive strength and are most important geotechnical parameters of a River bank, for its stability, and to potential River bank breaching, which may aid to protect the flood and erosion [26-28]. Due to finding out the core geological factor influencing River bank erosion the study focuses on four types of soil tests, Specific Gravity, Atterberg test, Hydrometer test and Sieve analysis test. For all tests sample was collected from ten points. All of the points were situated in the vulnerable and affected area for River Embankment failure. All of the tests had been done at self-controlled condition.

4.2. Condition of Riverbank Erosion

4.2.1. Specific Gravity

Specific gravity of soil samples is found from 2.41 to 2.61 KN/m^2. Specific gravity of the soil sample is varying from 2.23 to 2.61 KN/m^2. The soil samples were collected from different depth such as surface level, 1.5-meter depth. By the laboratory test the specific gravity were calculated. The specific gravity of the soil samples was varying from place to place such as at the point of 1 (sample no #1) found 2.38, for point two value of specific gravity was 2.61 (Table 1) and then other point sequence 2.47, 2.23, 2.54, 2.52, 2.48, 2.53, 2.41, 2.55. Among the all values at the second point there found greatest value of soil specific gravity 2.61 and at point of one there found 2.23 which is lowest. The soil specific gravity determine which soil are cohesion less, loose, that is the causes of river bank failure. If the soil specific gravity value show below 2.50 it predicts in general that the area soil is more likely to be eroded though many other factors influence the soil erodibility.

Table 1. Specific Gravity Determination.

Sample No	Point	Latitude	Longitude	Depth (m)	Specific Gravity	Probability of Failure
1	1	22°42'9.004"N	90°23'19.840"E	1	2.38	High
2	2	22°42'8.467"N	90°23'18.557"E	1.5	2.61	Low
3	3	22°42'9.173"N	90°23'18.712"E	1.8	2.47	Moderate
4	4	22°42'6.012"N	90°23'17.409"E	2	2.23	Very High
5	5	22°42'4.132"N	90°23'15.538"E	1	2.54	Moderate
6	6	22°42'1.986"N	90°23'12.268"E	1	2.52	Moderate
7	7	22°42'1.017"N	90°23'10.755"E	2.5	2.48	Moderate
8	8	22°42'58.460"N	90°23'9.460"E	0.5	2.53	Moderate
9	9	22.69910°	90.38499°	0	2.41	High
10	10	22.69849°	90.38362°	1	2.55	Moderate

4.2.2. Atterberg Limit Testing

The moisture content between the plastic and liquid states is known as the liquid limit (LL). The difference between the plastic and liquid limits is called the plasticity index (PI) and indicates the size of the range over which the material acts as a plastic – capable of being deformed under stress but maintaining its form when unstressed. Highest plasticity index (PI) of the River bank at point 4 (sample #4) were found 36.33. At the first point the value of plasticity index 8.65 then respectively 13.48, -56.10, 36.33, 13.97, 10.30, 12.24, 14.10, 10.96, 12.61 (Figure 6) and so on. At the point number three plasticity index showed negative value which strongly describe as a non-plastic soil. The highly plastic materials are more likely to have high levels of saturation after compaction and subsequent low shear strengths by comparison with lower plasticity clays [29-30]. Field moisture control for high plasticity clays is a very effective means of controlling River bank breaching [31]. The Atterberg limit provides the soil moisture of the study area. The moisture content of the study area is higher; as a result, the soil is loose. That is the causes of earthen River bank failure. Used the % of water content for Y axis and Number of blows were used X axis to calculate the moisture content.

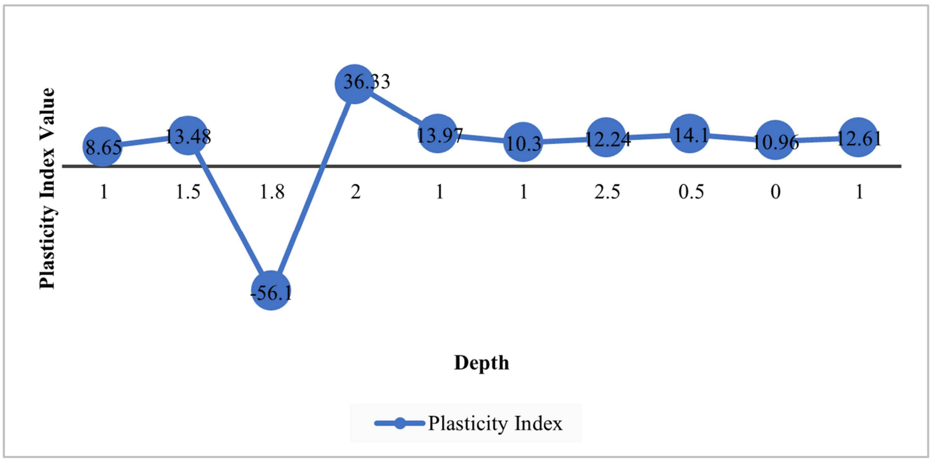

Figure 6. Plasticity Index.

4.2.3. Grain Seize Analysis

The detailed analytical results of collecting soil samples are described. The sieve analysis result shows that the soil samples are medium to very fine sand (Figure 7) consisting of large to fine grain with small amount of silt and clay. Sample, 1 to 10 consists mostly of fine grain loose sand (98.5%, 97.42%, 42.2%, 98.04%, 75.5%, 97.62%, 97.02%, 96.8%, 98.08%, and 66.2%, respectively). In the soil test it is showed that the River bank soil of the study area is mainly sandy. The silty soil contains high cohesion, stability and breakdown not very easily. Figure 7 shows that the study areas of Noyontara (point 3, 5 & 10) soil are silty and clay type and minimum sand, on the other hand Cowarchar village point area soil is sandy type. It is the causes of River bank failure, because sandy and silty clay bearing low shear strength.

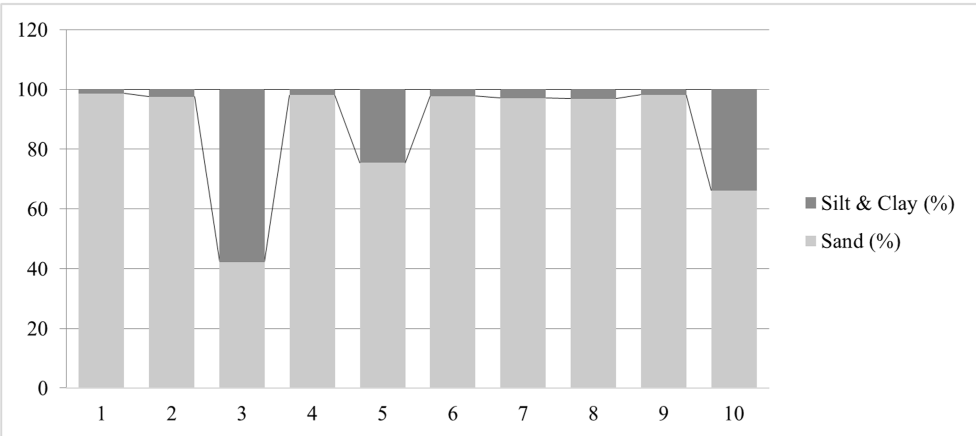

Figure 7. Sieve Analysis.

4.2.4. Hydrometer Analysis

From hydrometer analysis, the fine grain (<75µm) content in riverbank soil is found 92.36% (silt=90.506%, clay=1.854%) and the coarse grain (Sand) is 7.64%. The River bank soil was classified as silty soil with lower liquid limit (ML) which contents silt and clay more than 80% on average and other sand respectively. At the point 5 the soil contents highest amount (90.506%) of silt in contrast to at the point 8 lowest amount (79.82). Besides sample soil content highest amount of sand at the point number 4 which is 12.78 in percentage (Figure 8) compared to lowest amount at first point (3.02) available. All the values from hydrometer testing show high probability of failure as all are more likely sandy soil [32], [33].

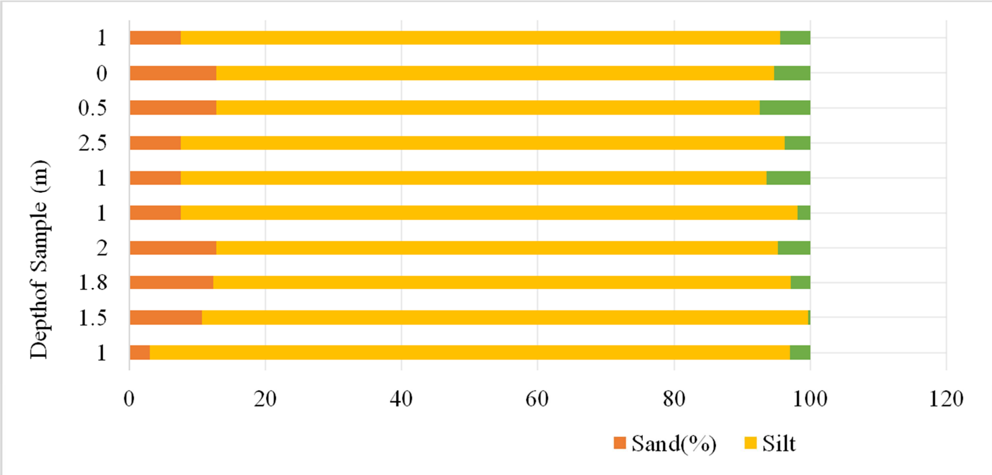

Figure 8. Hydrometer Analysis of Soil (<75µm).

5. Conclusion and Recommendation

Bangladeshis including the study area have been undergoing stress due to natural disasters of which riverbank erosion is a significant one which are displacing thousands of people. Bank erosion is a natural process in stable rivers; however, it can become accelerated and exacerbated by direct and indirect human impacts. In this study, different factors are analyzed in the study area and found as a push factor for migration due to erosion. People were found displaced due to this natural phenomenon. The most important findings of the study is, the specific gravity shows values from 2.23 to 2.61KN/m^2 which describe soil compaction rate and probability of influencing soil deformation. The Atterberg limit testing show values as plasticity index between -56.1 to 36.33 which describe soil moisture content and thus refers soil characteristics either influential to be eroded or stable slop. The sieve analysis result shows that the soil samples are medium to very fine sand (98.5%) consisting of large to fine grain with small amount of silt and clay. But at the point 3, 5 and 10 there are silty-clay soil. The hydrometer analysis testing describes soil character as silty soil where lowest amount is 82.36% and highest amount of sand is 12.78%. All values refer soil as more likely of being eroded. The earthen River bank failure depends on several factors, such as water content, plasticity index, untrained shear strength, mean grain size, percent passing #200, soil clay minerals, soil dispersion ratio, water salinity, soil pH and water pH, among other factors which all are described as geotechnical factors. One of the significant root cause of soil erosion at riverbank side is soil properties not being stable due to presence of course sand. The study area located at Kirtonkhola River beside Barisal city would be eroded if any protective steps cannot be taken. Interpretation of the factual information were carried out to estimate the properties of the soil profiles to be used for stability and deformation assessments. Preliminary recommendations for possible remedial works, together with advantages and disadvantages were presented. The geotechnical properties of riverbank material need to be improved by using additives or reinforcing materials like soil-cement, natural or geosynthetic fiber etc. It is also necessary to protect the slope by facing materials using geo-bags, cement composites with reinforcement. However, further research should be focused on comparing both geotechnical properties analysis of riverbank soil and wave velocity of river including friction angle of river flow, erosion rate and vulnerability of different locations as well as determining effective measures to decrease erosion severity. Thus findings would be more feasible for better implementation.

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