CONSIDERATION OF SOIL PROPERTIES FOR STABILITY ANALYSES OFPADMA AND JAMUNA RIVERBANK

M.S. Islam[1*], L. Sarker[1], M.A. Islam[1], M.A. Islam[1]& R. Karim[2]

[1]*Department of Civil Engineering, Bangladesh University of Engineering and Technology, Dhaka, Bangladesh*
[2]*Department of Civil Engineering, Military Institute of Science and Technology, Dhaka, Bangladesh*
**Corresponding Author:msharifulbd@gmail.com*

ABSTRACT
This study deals with the characterization of Padma and Jamuna river bank soil and evaluation of river bank stability corresponding to those soil characteristics. It has been found that in some cases Padma and Jamuna river bank show distinct soil characteristics. A typical river bank section has been taken considering the geometric pattern of the rivers of Bangladesh. Stability analyses were conducted for three slopes, 33°, 45° and 56°, for different conditions using Geo-Studio 2012. For Padma and Jamuna river bank soils, specific gravity and liquid limits are quite similar whereas plastic limits are slightly higher for Jamuna soil. Again permeability of these soils is quite low leading to greater hydrostatic pressure. Cohesion and friction angle of Padma and Jamuna river bank soils are also comparable but their variation with change in water content and depth needs further study. In addition, from embankment section analysis, it is found that the factor of safety (FS) is overestimated about 25 to 30% if seepage is not considered in designing embankment. For river banks, it has been estimated that a slope of 1V:1.5H is safe against stability, providing a factor of safety greater than 1.2.

Keywords: Riverbank, embankment, slope stability, seepage.

INTRODUCTION

Rivers in Bangladesh are highly dynamic in terms of morphology and erosion processes are quite unpredictable here resulting in dramatic consequences in the lives of people living in the erosion prone areas (Rahman, 2010). Bangladesh is an agricultural based country with most of its agricultural lands near the riverbanks of Padma and Jamuna. Every year this erosion phenomenon has been taking away those lands from the farmers resulting in a great loss in national economy. Studies have shown that the most common factors that are responsible for riverbank erosion are the properties of soil, the geology and climatic condition of the surrounding area and most importantly the geometry of the river channel (Zomorodian, 2010). The main objectives of this study are (i) to characterize the soil of Jamuna and Padma riverbank, (ii) to determine the stability and failure pattern of those riverbank areas and (iii) to compare different methods of slope protection of riverbank and to provide suggestions for preventive measures.

REVIEW ON BWDB DESIGN

According to Bangladesh Water Development Board (BWDB), the slope mostly fails due to the drag forces generated by the velocity and this local velocity is mostly influenced by the boundary geometry in the immediate neighbourhood. Additionally, during thunderstorm wind velocity and direction have a major effect stimulating the water waves to cause slope instability. Due to high flow turbulence scour occurs frequently beneath the revetment to damage the protection measures. Standard code of practice recommends stable slope to be designed for a minimum safety factor of 1.5. Permeable as well as impermeable groyne, Guide Bundh, CC block revetments etc. are very common practices that have been taken by BWDB. n addition, biological treatment to slope protection is getting popularity recently because of its environment friendly nature (Islam et al., 2013). However, very few cases consider the soil properties in river bank design (BRTC, 2003).

COLLECTION AND TESTING OF SOILS

The soil samples were collected from the broken part of the Padma riverbank near Mawa ferrighat and also from the Jamuna riverbank near Sariakandi Upazila as shown in Figure 1. Soil was collected from approximately 0.5 m depth using Shelby tube as well as PVC pipe from each location shown in Figure 2. Thus, the collected soil samples were slightly disturbed. The testing procedures were in accordance with ASTM Standards and the soils have been classified according to USCS. The constant head method was followed to determine the coefficient of permeability. Unconfined compression test was carried out on samples having different water content.

Fig. 1: Soil sampling locations from Jamuna and Padma river banks.

(a) (b)

Fig. 2: (a) Pushing the PVC pipe into soil using a wooden plank, (b) soil sample collection by PVC pipe

RESULTS AND DISCUSSIONS

Soil Properties

Index Properties

From laboratory analyses, it has been found that liquid limit and specific gravity of those soils are quite similar but plastic limit is reasonably higher for Jamuna riverbank soil. Maximum dry density for Padma riverbank is found to be 1.54 gm/cc which is greater than the corresponding 1.28 gm/cc for Jamuna riverbank. From particle size distribution curve, it can be inferred that silts and clay governs the majority and this relation is shown in Fig. 3. Both the soils are low plastic clay (CL). Optimum water content has been determined for both soils which can be significantly useful in riverbank construction. Relationship between dry bulk density and water content has been shown in Fig. 4.

Shear strength

Cohesion and friction angle have been determined at 29% water content for Padma riverbank and found to be 31 kPa and 13°, respectively. For Jamuna riverbank, the corresponding values are found to be 28 kPa and 10° respectively at 26% water content. As water level fluctuation is very frequent in this region, shear strength parameter variation with change in water content and depth needs to be considered.

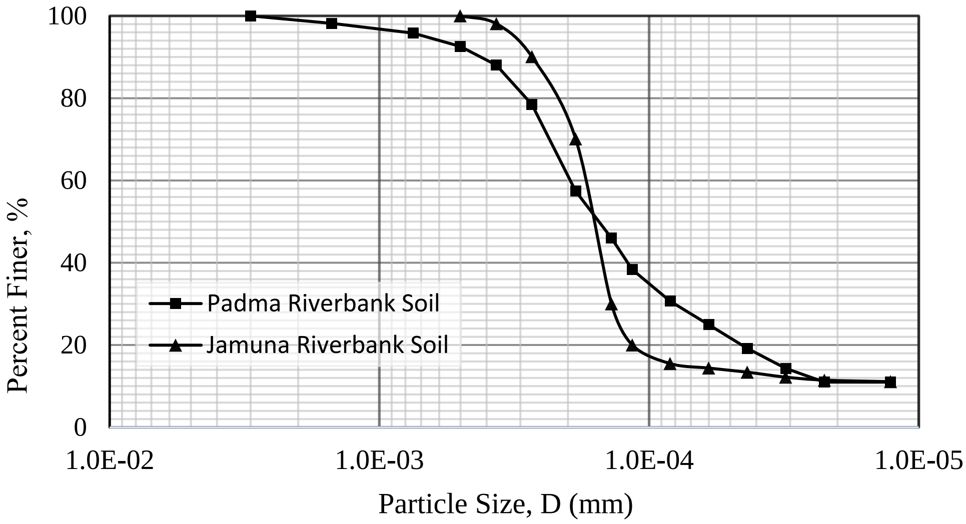

Fig. 1: Particle size distribution of the riverbank soils

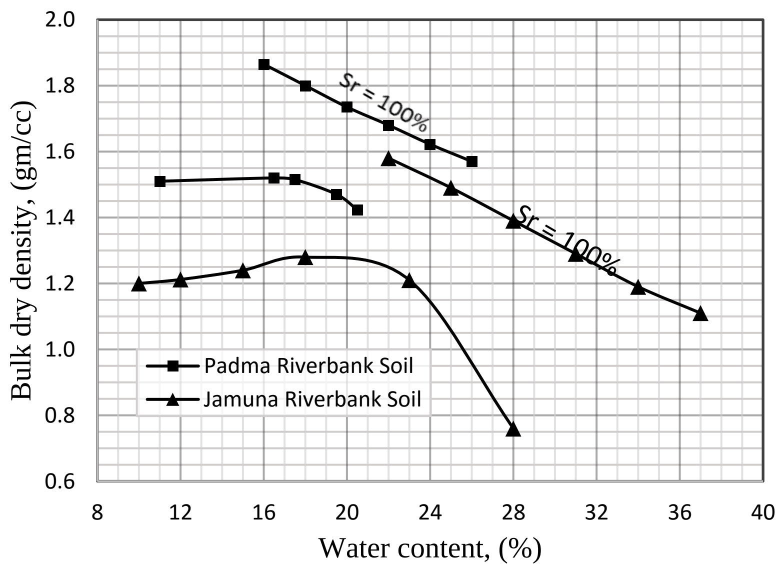

Fig. 2: Bulk dry density vs water content

Table 1: Properties of soils collected from Padma and Jamuna river bank

Soil Properties		Padma river bank		Jamuna river bank (24º53′32″N,89º34′43″E)
		Current study (23º28′17″N,90º15′16″E)	Hossain et al. (2010)	
Index Properties	Liquid limit (%)	33	32	32
	Plastic limit (%)	21	27	27
	Optimum water content (%)	17.2	21	21
	Maximum dry density (gm/cc)	1.54	1.56	1.28
	Specific gravity (Gs)	2.66	2.66	2.65
	Sand (%) (USCS)	4.2	6.0	5.6
	Silt and clay (%) (USCS)	95.8	94	94.4
	Soil type	CL	CL	CL
Shear Strength	Cohesion, cu (kPa)	31 (at 29% Wn)	--	28 (at 26% of W_n)
	Frictional angle (ϕ)	13	10	22
Permeability	Permeability (cm/s)	2.73×10^{-3}	2.43×10^{-3}	1.29×10^{-4}

Permeability

Constant head permeability method has been adopted in this case to determine the permeability. The permeability found in this research are considerably low causing a greater hydrostatic pressure in case of sudden drawdown of water, which results in frequent tension cracks in the upper layer and these cracks are the prime reason for riverbank failure. Henceforth, this parameter should be carefully used in seepage analysis to predict the failure precisely.

Stability Analyses

SLOPE/W is formulated in terms of moment and force equilibrium factor of safety equations. In this program, stability can be analyzed by several Limit Equilibrium Methods including Ordinary, Bishop, Spencer, Janbu, Morgenstern-Price methods etc. This program allows integration with other applications, for example, finite element computed stresses from SIGMA/W or QUAKE/W can be used to calculate a stability factor by computing total shear resistance and mobilized shear stress along the entire slip surface. Then, a local stability factor for each slice is obtained. Using a Monte Carlo approach, program computes the probability of failure in addition to the conventional factor of safety.

Soil Parameters Used

For riverbank section the soil that has been taken into consideration is a c-ϕ soil with cohesion taken as 30 kPa, friction angle 10°, water content 29% and dry density to be 18 kN/m^2. For embankment section, permeability is taken as 2.43×10-3 cm/s with dry density of 18 kN/m^2. Cohesion and friction angle remain the same as riverbank section.

Water Level and Slope Conditions

For the typical riverbank section shown in Fig. 5, a water level of 8m has been assumed and three different slopes of 33°, 45° and 56° at different conditions has been taken to predict the safest slope. Factor of safety in each method has been shown in Table 2. Fatema and Ansary (2014) recommends a factor of safety greater than 1.2 to ensure a riverbank to be safe. So from this analysis, a slope of 1V:1.5H can be safe.

Again a typical embankment section shown in Fig. 6, has been taken to know the effect of seepage in designing embankment. Three different water tables have been taken and their corresponding factor of safety has been shown in Fig. 7. The study has found out that the factor of safety (FS) is overestimated about 25 to 30% if seepage is not considered in designing embankment which is similar to the results of Hossain et al. (2010).

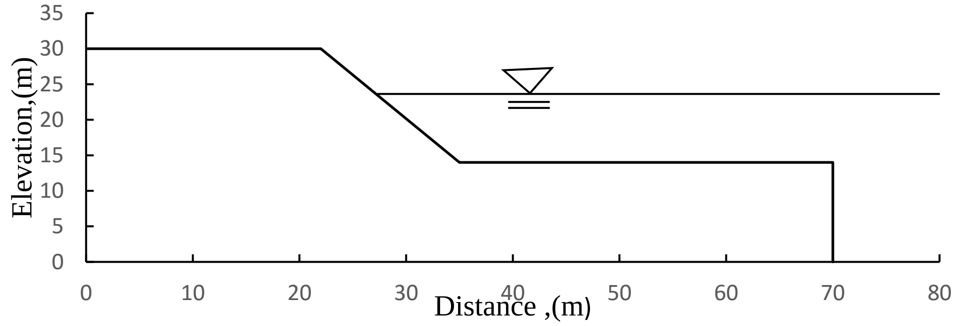

Fig. 3: Typical riverbank section

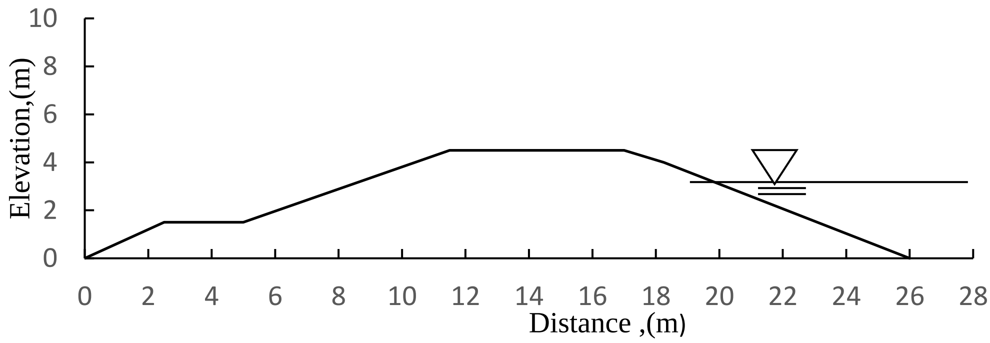

Fig. 4: Typical embankment section

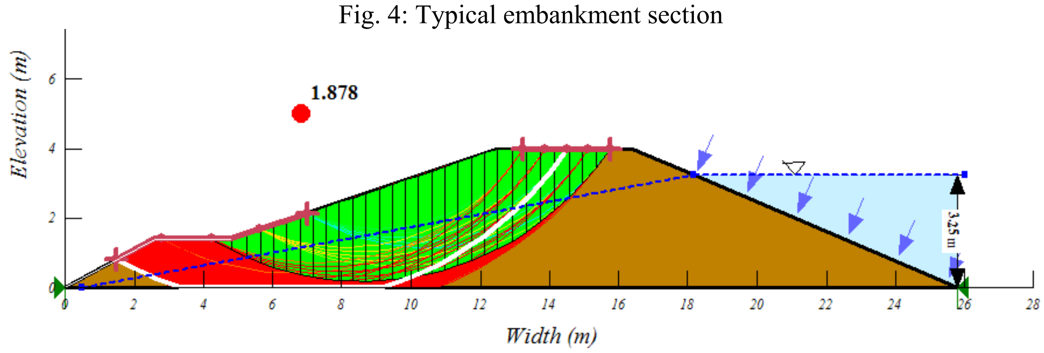

Fig. 7: FS against seepage failure for embankment with 3.25m water level from riverbed

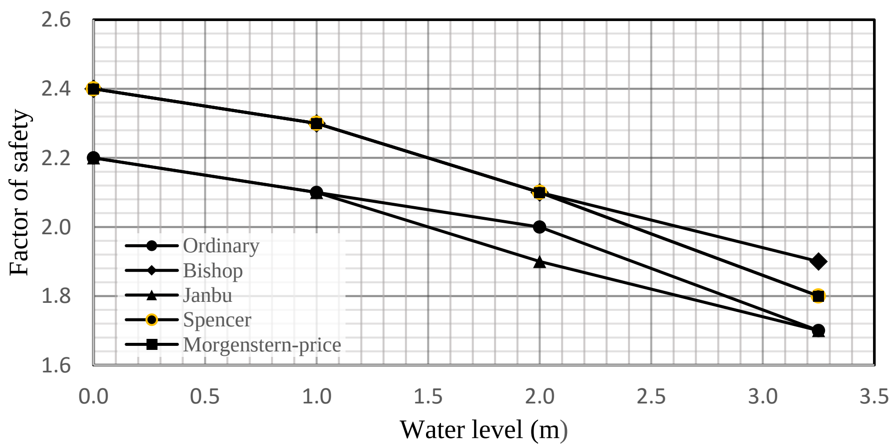

Fig. 8: Water level vs Factor of safety

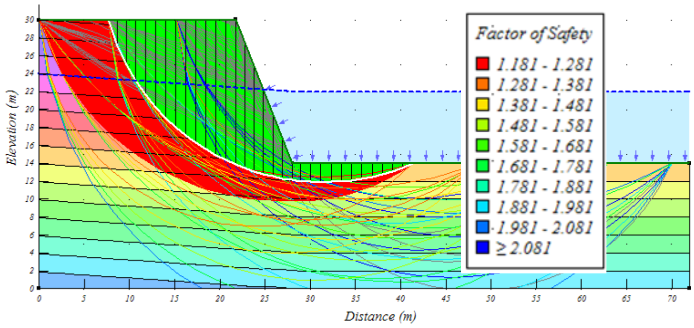

Fig. 9: FS for typical riverbank section by Bishop Method for slope of 1V:0.667H

Table 2: Factor of safety for typical riverbank section with water level of 8m

Slope)V:H(	Ordinary method (1927)	Bishop method (1955)	Janbu method (1973)	Spencer Method (1967)	Morgenstern- price (1963)
1:1.5 (33°)	1.24	1.38	1.24	1.34	1.34
1:1 (45°)	1.20	1.24	1.17	1.24	1.24
1:0.667 (56°)	1.11	1.18	0.96	1.11	1.12

CONCLUSIONS

Riverbank failure is a major devastating issue in Bangladesh. Preventive measures must be taken as early as possible to check this issue. Soil conditions must be considered in designing those measures. The following conclusion can be drawn from this study:

(1) Padma and Jamuna riverbank have distinct soil properties in terms of soil strength parameters.
(2) Seepage is a major issue for riverbank stability causing scour hole and different soils behave differently in case of rising water level and drawdown.
(3) A slope of 1V:1.5H satisfied all the criteria in different methods of slope stability analysis. Thus it is safe against stability failure. It agrees with the guidelines of BWDB.
(4) If seepage is not considered, the factor of safety is overestimated by about 25~30%.

Further study is being conducted to investigate and categorize the major riverbank soil so that proper and durable protection can be provided.

ACKNOWLEDGMENTS

The Directorate of Advisory, Extension & Research Services (DAERS), Bangladesh University of Engineering and Technology (BUET), Dhaka financially supported this work.

REFERENCES

BRTC. 2003. Technical Evaluation of some selected flood protection and river bank erosion control works already implemented by BWDB, Bangladesh University of Engineering and Technology (BUET), Dhaka-1000, Bangladesh.

Fatema, N and Ansary, MA. 2014. Slope stability analysis of Jamuna river. *Journal of Civil Engineering (IEB)*, 42(1): 119-136.

Hossain, MB; Sakai, T and Hossain, MZ. 2010. River embankment and bank failure in Bangladesh: a study on geotechnical characteristics and stability analysis. *International Conference on Environmental Aspects of Bangladesh (ICEAB10)*, Japan: 171-174.

Islam, MA. and Sarker, L. 2016. *Stability Analyses of Riverbank*. B.Sc Engg. Thesis, Department of Civil Engineering, Bangladesh University of Engineering and Technology, Dhaka-1000, Bangladesh.

Islam, MS, Hossain, MS and Nasrin, S. 2013. Effectiveness of vetiver root in embankment slope protection: Bangladesh perspective. *Int. Journal of Geotechnical Engineering*, 7(2): 136-148.

Rahman, MR. 2010. Impact of river bank erosion hazard in the Jamuna floodplain. *Journal of Science Foundation*, 8(1&2): 55-65.

Tatewar, SP and Pawade, LN. 2012. Stability analysis of earth dam by GEO-Studio software. *International Journal of Civil Engineering and Technology*, 3(2): 437-446.

Zomorodian, SA. 2010. Slope Stability Analysis under Rapid drawdown. *International Journal of Geology*, 4(4), 1-6.