Padma 川河川堤防の土質特性と破壊状況
(Geotechnical properties of Padma riverbank material and its failure mechanism)

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Introduction

Riverbank erosion and associated sedimentation and land loss hazards are a resource management problem of global significance. In Bangladesh, riverbank failure is a perennial problem occurs mainly in rainy season, causing loss of lands and livelihood along major rivers. Padma river is one of those which is causing severe bank erosion to many locations of Rajshahi, Nawabganj, Kushtia and Pabna districts in Bangladesh. Within the last couple of years, the river came about 12 to 14 kilometers inside the catchment area damaging resources of about Taka 3,000 crore including 15 educational institutions, many mango orchards and vast tracts of croplands (TNN, 2008). 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 (Osman and Thorne, 1988). 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 (Thorne, C.R. *et al.*, 2008). Therefore, for the good management of the stability problems, this study aims to find out the failure mechanism of Padma riverbank on the basis of its geotechnical properties as well as to suggest a new convenient approach for the stability analysis of the riverbank.

Figure 1 Location map of Padma River

Figure 2 Study area

Study area and material collection

Padma is a major trans-boundary river which entered Bangladesh from India near Chapai Nababganj district. Rajshahi is a major city in western Bangladesh which is situated on the north bank of the Padma River (Fig.1). Sample materials of this study were collected from Charghat area of Rajshahi where bank failure was occurring largely during the field visit in 2008 (Fig.2).

Table1: Physical properties of soil

Particle density	2.676g.cm^{-3}
Liquid limit	32%
Plastic limit	27%
Maximum size	850µm
Sand	6%
Silt	69%
Clay	25%
Soil type	ML

Geotechnical properties

For the characterization of bank material, a number of laboratory tests were conducted which include the Particle size analysis, Particle density, Liquid limit, Plastic limit, Compaction, Consolidation, Permeability, Direct shear test and unconfined compressive strength tests. All the tests were followed by the methods of Japanese Industrial Standard (JIS) and Japanese Geotechnical society (JGS). The Results of basic physical properties are summarized in Table 1. According to JGS engineering classification the soil can be classified as silty soil which contents a significant percentage of clay (25%). The characteristics of the bank material with the variation of moisture content are shown in Fig. 3. The maximum bulk dry density (ρ_d) was found 1.72gm/cm^3 at optimum moisture content of 16.5%. The value of permeability is found very low, 3.5×10^{-7}cm/s, at over 90% saturation. Unconfined compressive strength is seen maximum of about 280KN/m^2 (at w=13%). But, the strength decreases rapidly with the increase of the degree of saturation as observed from test results (Fig. 3).Direct shear test was conducted to determine the shear strength parameters (c and ø) of the bank material. The test results are plotted according to Mohr-Column failure criteria as shown in Fig. 4. From test results, it is found that the bank material has a good cohesive value (c) of about

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153KN/m^2 with the value of internal friction angle, ϕ=22°. The cohesion calculated from compressive strength ($c = \frac{q_u}{2}$) is about 115 KN/m^2 at optimum water content.

Riverbank failure mechanism

In the study area, the failure mechanism is mostly associated with the process of scouring at the base of riverbank causing the soil mass of the bank to slide downward and deposit on the toe. The deposited soil mass is then flushed away due to high velocity of water flow. As time passes, bank slope become steeper as a result of erosion at the lower part of the bank and again get ready for further failure in the same way. Small tension cracks at a distance from bank face are also seen that accelerate the mass failure of the riverbank (Fig.5). This type of failure can be described as Slab-type failure that includes both mechanisms of planar failure with tension crack, and toppling, involving failing blocks with the same geometry (slab-type blocks; Thorne, 1998).

Since the strength of bank soil decreases rapidly with the increase of water content, and permeability also becomes lower (<1×10^{-6}cm/s) at the same time (Fig. 3), bank material weight increases which results shear failure at the upper face of bank. Moreover, during rapid drawdown of river water at the end of flood season groundwater table in the bank reduce gradually due to low permeability of the bank. This causes an imbalance in water pressure on the riverbank slope which may cause sudden mass failure of the bank. In this circumstance, slope stability analysis of this riverbank is necessary and it could be done according to Darby and Thorne, 1996, by which the limiting value of the critical bank slope and height can be determined. This is a new approach for riverbank stability analysis which can be applicable for the steep, cohesive, non-layered riverbank that fails along planar failure surfaces. In this method, Pore-water and hydrostatic confining pressure are also included where the failure plane is not constrained to pass through the toe of the bank.

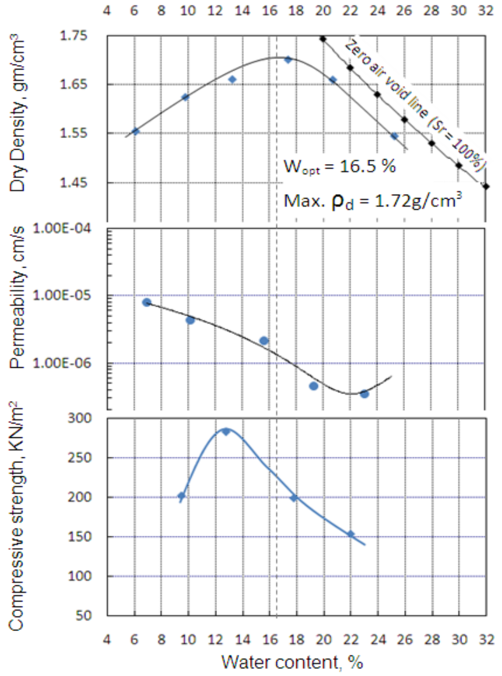

Figure 3 Variation of soil properties with water content

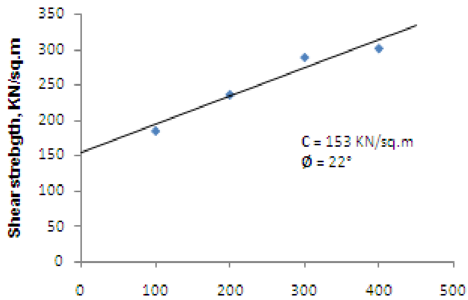

Figure 4 Failure envelop of bank soil

Conclusion

The soil of Padma riverbank in the study area is found silty with low permeability. Bank failures are usually associated with the development of tension cracks behind the bank and follow periods of heavy rainfall that maximize the bank material weight and minimize its strength which results erosion and finally failure of the bank occurs. Slope stability analyses can be used to assess the stability of riverbank and to predict limiting values for the bank height and slope angle.

Figure 5 Riverbank failure

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