バングラデシュにおけるマヌ川堤防の浸透及び安定解析に関する研究

Seepage and stability analyses of Manu river embankment of Bangladesh: A case study

○ベルラル　ホッセイン, 酒井　俊典,　座狩屋　保世院
○Md. Bellal Hossain, Toshinori Sakai, Md. Zakaria Hossain

Introduction

The earthen embankments in Bangladesh are facing problems like erosion, breaching or retirements in every year for various reasons where improper design and construction technique is one of those. It is to mention that seepage analysis is one of the important tasks for designing earthen embankment and its stability analysis. In Bangladesh, however, seepage analysis is often overlooked while designing embankment. In this study, a case study was conducted on the Manu river embankment which is located in Moulvibazar district of Bangladesh. The embankment is recently designed by Bangladesh Water Development Board (BWDB) under FCD sub-project. In the slope stability analysis, the free surface in embankment due to seepage was considered by assuming a saturation line where the slope is decided based on soil type. In this study, the free surface is reasonably determined by conducting seepage analysis using Finite Element Method (FEM). The slope stability analysis was performed by limit equilibrium methods and the results were compared with the existing values.

Fig. 1 Location of study area

Information on Manu river embankment

The Manu River is a flashy river which is located in Moulvibazar district of Bangladesh (Fig. 1). It has originated from the vast hilly area in Tripura of India. Every year flash flood occurs in the Manu basin in several times which causes damage of flood embankment, erosion of bank, scour and sliding of embankment in many locations of the flood embankment. During the last devastating floods severe scour and erosion took place at Gazipur along the left bank from 17.700km to 17.970km. Therefore, to protect the crop, assets, various infrastructures of this locality, it was necessary to reconstruct the embankment immediately. Bangladesh Water Development Board (BWDB) was authorized to design thisembankment under FCD sub-project and in January 2008, the design of embankment was finalized[1] (Fig. 2).

Data collection

All primary design data such as yearly highest and lowest flood water level, monthly rainfall data, soil type, riverbed slope etc. were collected from local office of BWDB. The highest water level (HWL) was considered 3.25m (10.66ft) above the base of embankment taking 20 years of return period. According to design manual, return period is taken 20 years for full flood control embankment where agricultural damage is predominant. The material used for the construction of embankment was classified as Sandy-clay type soil. The design procedure was mainly followed by BWDB standard design manual.

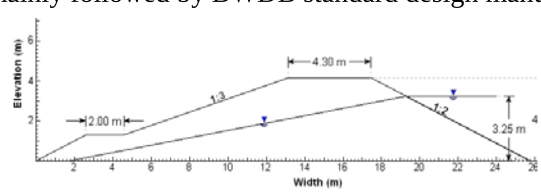

Fig. 2 Section of Manu river embankment

Seepage analysis

Hydraulic model used for seepage analysis

Of all available soil hydraulic models, the Van Genuchten–Mualem[2] model is the most widely used model in simulation of unsaturated flow processes and, therefore, it has been used in this study for representing the relationship between the hydraulic

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conductivity and the pressure head as shown in Eq. 1.

$$k_h = k_s\sqrt{S_e}\left\{1 - \left[1 - S_e{}^{(n/n-1)}\right]^{1-1/n}\right\}^2 \ldots (1)$$

Where,

k_h is the coefficient of permeability at any pressure head h, k_s is the saturated coefficient of permeability,

$$S_e = [\frac{1}{1+(\alpha h)^n}]^m$$

$$m = 1 - \frac{1}{n}$$

h is the soil water pressure head in meter

α (1/m) and n are curve shape parameters

These hydraulic parameters (k_s, α and n) was obtained by using a database program ROSETTA[3] that used soil texture data for predicting the parameter values.

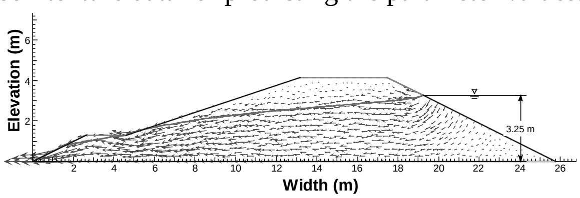

Fig. 3 Free surface location predicted by FEM

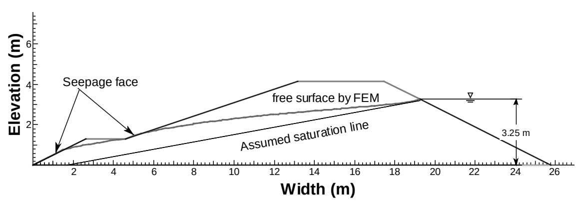

Fig. 4 Location of free surface and seepage face

Slope stability analysis

Stability of the Manu river embankment was checked in terms of factor of safety. Limit equilibrium slope stability analysis was conducted both for assumed saturation line (1:5.45) and free surface predicted by FEM seepage analysis. The saturated and unsaturated unit weight of soil was taken as 120 pcf (18.8KN/m^3) and 115 pcf (18.1KN/m^3), respectively. The Mohr-Coulomb strength criterion was used with the shear strength parameters of cohesion, c = 100psf (4.78 KN/m^2) and friction angle, φ = 18°. Random technique for generating circular surfaces has been used to find a critical failure surface from 100 trial surfaces. The lower and upper angle limit of each failure surface at toe was set as -5° and -45° (-ve for anticlockwise direction), respectively. Table 1 shows the summary of limit equilibrium analysis.

Table 1 Results of slope stability analysis

Methods	Minimum Factor of safety(FS)		Deviation (%)
	Assumed saturation line	Predicted free surface	
Bishop simplified	2.011	1.622	23.98
Janbu simplified	1.880	1.541	21.99
Spencer	2.012	1.622	24.04
Crop of eng#1	2.043	1.648	23.96
GLE/Morganstern-price	2.011	1.622	23.98

The results show that the factor of safety is over estimated about 22-24% in case of assumed saturation line. Moreover, the assumed saturation line does not satisfy the Laplace equation for two-dimensional flow through a homogeneous, isotropic medium. Hence, seepage analysis is necessary to solve the seepage problem as well as to get the reliable factor of safety value and safe design of embankment.

Conclusions

In slope stability analysis, the factor of safety is found overestimated about 22-24% if the location of free surface in embankment is assumed by a straight saturation line. So, it is recommended to locate the free surface in embankment by conducting seepage analysis prior to conduct slope stability analysis to obtain more reliable factor of safety value.

References

1. BWDB, 2008. Report on Design of Physical Structure of Manu River Embankment. Design Circle-1, Bangladesh Water Development Board, Dhaka.
2. Van Genuchten, M. Th. 1980. A closed-form equation for predicting the hydraulic conductivity of unsaturated soils. Soil Sci. Soc. Am. J. Vol. 44, 892-898pp.
3. Schaap, M.G., F.J. Leij, and M. Th. van Genuchten, 2001. ROSETTA: a computer program for estimating soil hydraulic parameters with hierarchical pedotransfer functions. Journal of Hydrology, Vol. 251, 163-176pp.

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