APPLICATION OF PLAXIS FOR CALCULATING THE CONSTRUCTION STABILITY AND SOFT EMBANKMENT IN PROTECTING HA THANH RIVER, BINH DINH PROVINCE

[a] Thanh Nhan Duc Tran, [b] Zeeshan Ahmed, [c] Quang Binh Nguyen

a, c: Water Resources Department, University of Science and Technology - The University of Danang
duc.dut.wr@gmail.com
b: Water Resources and Glaciology Department, Global Change Impact Studies Centre (GCISC)
zeeshanahmed44@outlook.com

Abstract- The study aims to assess the anti-erosion efficiency of Ha Thanh embankment system to the downstream river sections nearby Dieu Tri bridge, which has been affected significantly by heavy floods, especially during flood season. With a great curvature, the loss of land (riverbank erosion) and the gain of land (riverbank accretion) are happening frequently and significantly. Besides, this study would clarify the model of stress, work ability and deformation calculation of embankment application in reality. With the significant development of natural and uncontaminated measures as Geotextile fabric Soft Rock and Vetiver grass in riverbank and coastal protection, this study would assess the stability through scenarios for both hard and soft embankments and comparison of these measures with current methods applied against erosion.

Keywords- Stability, flood, model of stress, deformation, embankment, geotextile fabric Soft Rock.

1 INTRODUCTION

The calculation of construction stability is often based on the theory using the method named “limit equilibrium” with the stable coefficient K [1]. Recently, due to the common use of computer software, Plaxis - a stable construction calculation is used commonly in dealing with geotechnical problems, due to its accuracy and ability to solve problems. For the slope stability problem, Plaxis is designed on a theoretical basis, which is a method of attenuating shear strength to determine the foundation stability coefficient. Besides, the use of soft embankments to replace the concrete embankments has shown many economic advantages [2].

The Ha Thanh river (Figure 1a) is one of the largest rivers of Binh Dinh Province. With a total amount of water around 675 million m^3, the Ha Thanh river supplies 7.3% of the total surface water out of 9,260 million m^3 annually. The distribution of flows resulted in large floods, the frequency of which is growing up rapidly and producing destructive floods in that area. Moreover, it causes serious erosion along the riverbank, and it also causes floods in the downstream areas. Due to low terrain and river branches unifying with the Kon river nearby Dieu Tri bridge, the flood drainage capacity has been affected greatly, especially during flood season. As a result, it causes heavy floods in the downstream, destroying inhabitant areas, important transportation systems as well as vital infrastructures of Quy Nhon city and Tuy Phuoc district, Vietnam [3].

This study has used 2 typical softwares, Geoslope and Plaxis for calculating the stability in two kinds of embankments i.e. soft and hard-concrete embankments in order to indicate and analyze the difference between two distinguished structural designs. Also, this study aims to evaluate the efficiency of these kind of designs and help engineers to choose the best method for their projects when comparing the stability analysis along with economic efficiency.

a. b.

Figure 1: a) Map of Quy Nhon city, and b) Ha Thanh embankment system

The Ha Thanh embankment was built to decrease the erosion at southern areas of Ha Thanh river and the downstream area of Dieu Tri bridge. This embankment system is the only riverbank protection construction for the study area. Previously, due to lack of government actions and care, the area did not get attention from researchers. This paper has initiated steps to gain deeper insight of this study area. Many earlier studies used only one method to clarify purpose and results. In this research, authors combined Plaxis with Geoslope to enhance the quality of paper output.

2 MATERIAL AND METHODS

2.1 *Software*

Based on the topographical map, geological and working characteristics of coastal constructions affected by waves, the software - Plaxis V8.2 was used to evaluate the stability of the study area.

2.2 *Methodology*

The calculation phases were established based on initial stresses, the advantage is that the stresses are balanced in all cases, the calculation phases are shown as following:

2.2.1 *Phase 1 (Plastic calculation)*

This phase includes setup steps with necessary factors added for calculation in Phase 2. Flexibility calculations were based on deformation theory, small displacement assumptions could be applied appropriately. The calculation results of this step are the basis for the next calculation steps.

2.2.2 *Phase 2 Stability calculation (Phi - C reduction)*

This is an independent calculation step in PLAXIS that can be applied to many stages of construction or load bearing works. The calculation method is to gradually reduce the load capacity of the soil (internal friction angle and cohesion force) until the destruction of the soil mass occurs (surface slip - collapse). The ratio between the actual load capacity of the soil and the load at the time of failure is the safety factor that was needed.

2.3 *Mohr - Coulomb (MC): Linear elastic-perfectly plastic*

The Mohr-Coulomb model is a simple and well-known model which is used commonly nowadays. In Plaxis, Mohr-Coulomb could be considered as a first estimation of soil behaviour. The linear elastic part of the Mohr-Coulomb model is based on Hooke's law. The perfectly plastic part is based on failure criterion, formulated in a non-associated plasticity framework. The Mohr-Coulomb model consists of 5 basic parameters: elastic module E, Poison coefficient ν, cohesion force of soil C, internal friction angle φ and expansion angle of soil (dilatancy) ψ [4].

2.4 *Input Data*

2.4.1 *Topographical data*

The topographic data was collected mainly from geographical surveys.

2.4.2 Geological documents for soil and surface covering

Table 1 shows the basic mechanical properties of the ground layers. It is based on the actual geological report of the embankment in the south of Ha Thanh river.

Table 1-Mechanical properties of soil layers

Layers	Depth of Layers (m)	μ_{sat} (kN/m^3)	μ_{unsat} (kN/m^3)	μ $(radian)$	C (kN/m^2)	E (kN/m^2)
Surface	0 – 1.8	21.4	18.1	22.3	22.3	48.8×10^3
1	1.8 – 3.0	18.83	15.6	22	9.8	19.613×10^3
2	0.6 – 4.0	20	16.77	20	19.6	18.623×10^3
3	2.3 – 3.0	19.35	15.68	27.52	3.5	2.045×10^3

2.4.3 River water level

Based on the details in the stage of construction investment in the project, the design river water height was +6.82 m and dry river water height with 20 years frequency was about +2.5 m.

2.5 Vetiver grass

Vetiver grass (Figure 2a) is a special grass which is common in tropical and temperate regions of the world. This material plays an important role as a natural method for watershed protection. Indeed, it slows down the speed of river water and alleviate the siltation of drainage systems. Besides, it could decrease the bad effects of chemical productions, alleviate contamination, and makes soil clean. On the other hand, vetiver grass could endure significantly high level of metals especially with heavy metals. To control the soil erosion, vetiver grass has been applied as the most effective method for many areas [5].

a. b.

Figure 2: a) Vetiver grass against river erosion, and b) Geotextile Soft Rock R601 along the river

2.6 Geotextile Soft Rock R601

Soft Rock geotextile (Figure 2b) is one of the effective methods to decrease erosion along riverbank and coastal line. It is formed from local material and arranged suitably in front of protected areas. Geotextile Soft Rock R601 is used to control the erosion in waterfront construction, enhance the renourishment of beach, or to construct artificial reef. It can also be applied for many other purposes that requires high strength and the flexibility with long-term performance [6].

2.6.1 Material design

Geotextile width: 1.25 m, Geotextile length: 2 m, and Geotextile height: 0.4 m.

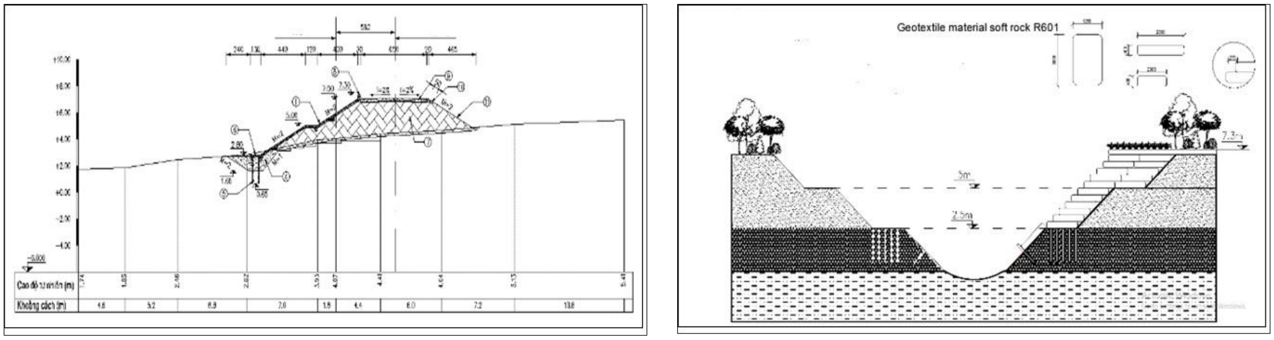
2.6.2 Material parameters

Tensile strength: 120 kN, weight of sand: 18.66 kN/m^3, weight of water: 10000 kN/m^3, surface slope - Taluy: 450, and deformation module E = 0.14 kN/m^2.

3 CALCULATION MODEL

3.1 Calculation of model with hard concrete embankment

In this scenario, it was decided to calculate the hard-concrete embankment with height H = 7.3 m, width B = 6.5 m, roof coefficient m = 2, concrete with gradients MAC250 and backfill K = 0.98 (Figure 3a).



a. b.

Figure 3: a) Hard-concrete embankment section, and b) Soft-concrete embankment section

3.2 Calculation of model with soft concrete embankment

The calculation of the soft-concrete embankment with height H = 7.3 m, width B = 6.5 m, roof coefficient m = 1, concrete with gradients MAC250 and backfill K = 0.98 is shown in Figure 3b. The anti-erosion construction has been built with concrete (hard- concrete embankment), so the results of the calculation are stable with high ratio and it satisfy the required values according to the Vietnamese standard. The evaluation results are relatively good when compared with the allowable slip stability factor [K] (Table 2) [7]. Simulated results are compared with similar scenario from Geoslope in order to get the most objective assessments. When calculating stress and deformation of the embankment, the following scenarios were used:

3.2.1 Hard-concrete embankment

- Scenario 1: Height H = 7.3 m, width B = 6.5 m, roof coefficient m = 2, concrete with gradients MAC250, backfill K = 0.98 with the design river water height = +6.82 m.
- Scenario 2: Height H = 7.3 m, width B = 6.5 m, roof coefficient m = 2, concrete with gradients MAC250, backfill K = 0.98 with the dry river water height = +2.5 m.

3.2.2 Soft-concrete embankment

- Scenario 1: Surface maintained by Geotextile Soft Rock R601 combined with Vetiver grass. Its height H = 7.3 m, as section with design river water height h = +6.82 m.
- Scenario 2: Surface maintained by Geotextile Soft Rock R601 combined with Vetiver grass. Its height H = 7.3 m, as section with the dry river water height h = +2.5 m.

3.3 Scenarios simulation

The Ha Thanh embankment has serious erosion every year and it is necessary to propose scenarios (structural difference) to assess stability of the construction, then it could be recommended reasonable solutions such as typical aspects: the loading capacity and different structures based on the conditions of the construction site. Through the typical cross-section and based on the analysis of simulation models on Plaxis, the author proposes to use Mohr-Coulomb model and soft soil model to apply to 4 main soil layers. The calculation model based on the scenarios simulated on Plaxis 2D version 8.6 as follows:

Table 2-The anti-slip coefficient of concrete or rock embankment [K]

Loading capacity	**Construction level**					
	Rock foundation					
	Special	**I**	**II**	**III**	**IV**	**V**
Basic	1.20	1.15	1.10	1.10	1.05	1.05
Special	1.15	1.10	1.05	1.05	1.00	1.0
Loading capacity	**Other material foundations**					
	Special	**I**	**II**	**III**	**IV**	**V**
Basic	1.40	1.35	1.30	1.25	1.20	1.15
Special	1.25	1.20	1.15	1.10	1.05	1.05

3.3.1 Concrete revetment

The natural stones and concrete blocks could enhance the energy absorption of waves in coastal protection, due to minimizing reflection and wave run-up. Revetment is a passive solution which act against the wave effects , erosion caused by water surge, extreme weather conditions i.e. hurricane, flood, and currents. In this study, the mesh of the building with fineness also affects the simulation results. After finishing the steps of applying input data, the simulated water level for two phases of concrete revetment, h = +6.82m and h = +2.50m is as: Phase 1: Plastic analyst and Phase 2: Stability calculation (Phi - C reduction). The result of the stability coefficient - M_{sf} for the hard-concrete embankment shows that the coefficient k is 2.95 compared to the permitted stability coefficient (Table 3). The sliding surface brings hazards on upstream of embankment, with maximum dangerous sliding surface depth is + 6.75m (Figure 4). The result when simulated using Geoslope was similar to the sliding surface of concrete embankment, when using Plaxis on the upstream side.

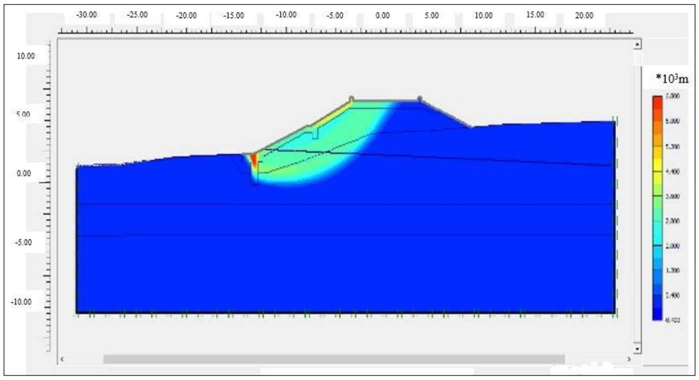


Figure 4: The location of dangerous sliding surface in (Concrete revetment), when having load (Plaxis)

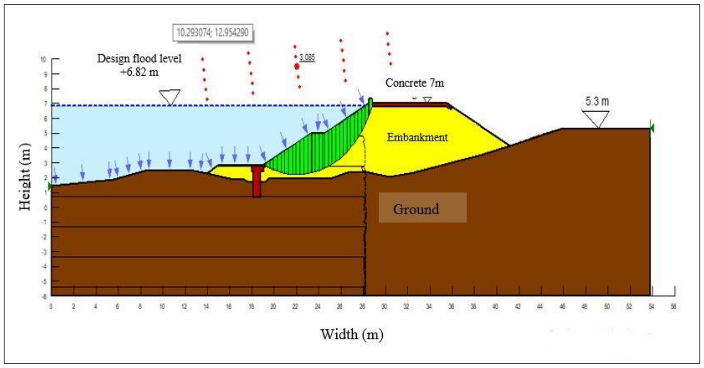


Figure 5: The location of dangerous sliding surface (Concrete revetment), when having load (Geoslope)

The most dangerous sliding surface depth was +3.2 m. These simulation in Plaxis and Geoslope showed the correlation. The location of dangerous sliding surface concentrated at the foot of the embankment satisfying the stability conditions. Therefore, the concrete revetment against erosion of the southern areas of the Ha Thanh river became a reliable solution for the construction of revetments.

3.3.2 Soft embankment

Soft embankment is a type of watertight construction (through revetment) to reduce the flow rate, cause sedimentation and prevent erosion. Soft embankment construction is a new solution to replace the current traditional method of concrete revetment with its superior advantages in construction and economy. To prove the effectiveness of this solution, it was decided to use soft embankments instead of concrete revetments in the actual simulation using Plaxis.

Scenario 1:

This scenario is quite similar to the simulation of concrete revetments, the input data was applied same as the simulation of soft embankment as follows: material parameters of Soft Rock R601, material design & parameters of Vetiver and data of water level. The water level applied for calculation in this scenario was designed water level with h= +6.82m. The dangerous sliding surface occurs on the upstream of the soft embankment, the maximum dangerous surface depth is in the riverbank. Sliding surface width is relatively large compared to concrete revetment scenario. The result shows that the coefficient k is 1.28 compared to the permitted stability coefficient according to Vietnamese standard TCVN 9902-2013 (Table 3) is good. The stability coefficient M_{sf} is 1.28 for the simulation with the design water level h = +6.82 m and the stability coefficient in the simulation in Geoslope is 2.31. When comparing two cases, it is realized that they have difference and this difference comes from the material used in separated scenarios. However, its parameters still satisfy the stability requirements. The authors continue to conduct the simulation for scenario 2 with the dry water level h = +2.5 m.

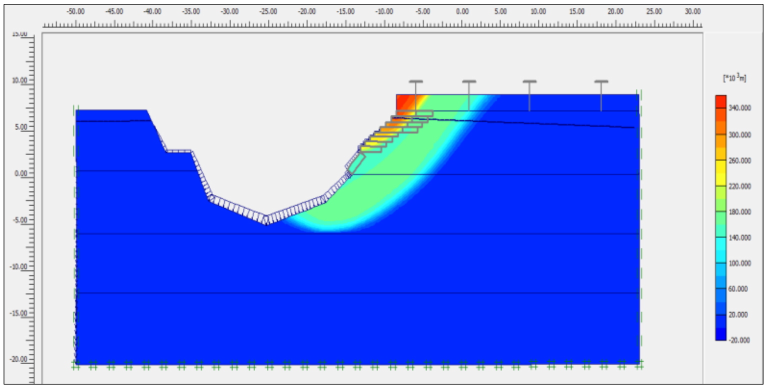


Figure 6: The location of dangerous sliding surface (soft embankment/scenario 1), when having load (Plaxis)

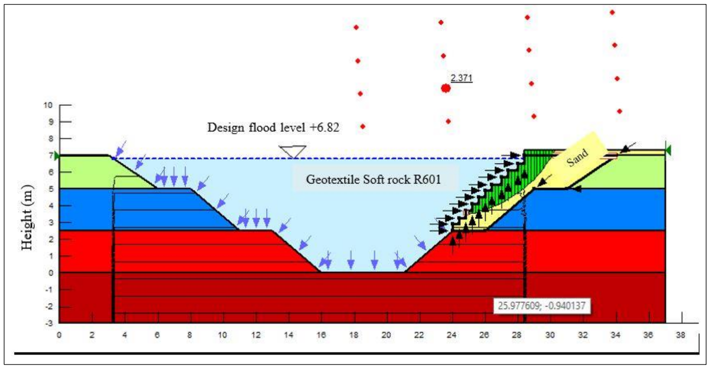


Figure 7: The location of dangerous sliding surface (soft embankment/scenario 1), when having load (Geoslope)

Scenario 2:

The authors used the Soft-concrete embankment section with the same input data and the dry water level h = +2.5m. The simulation results in Plaxis gives the stability coefficient, in case of the dry water level with h = + 2.5m, M_{sf} is 1.45 when compared with the simulated scenario in Geoslope with stability coefficient k = 1.43. There is a correlation in both cases using Plaxis and Geoslope respectively. Besides, Table 3 is a summary for all of scenarios conducted in this research. The authors found that the solutions of concrete embankment resulted in a higher stability coefficient K than that of soft embankments with the same categories. However, using Plaxis and Geoslope for stability calculations of soft embankment solutions also shows relatively good results and ensure stability when compared to Vietnamese standard TCVN 9902-2013 (Table 3). Therefore, soft embankment with Geotextile Soft Rock and Vetiver grass is also a feasible solution for construction nowadays. With regards to practical implementation in the industry, this study could be considered as a useful source for the Ha Thanh regulations. Its results could be used for construction projects in this area together with similar areas in central Vietnam.

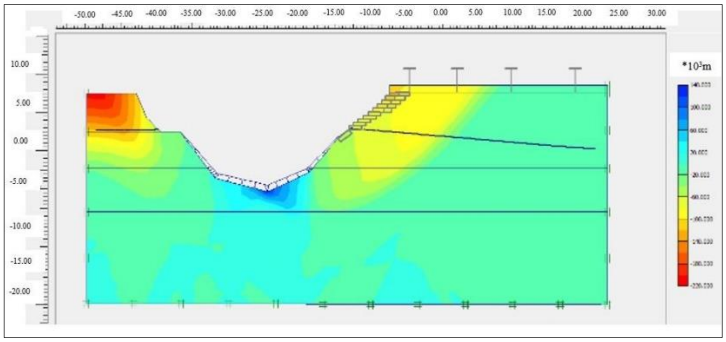


Figure 8: The location of dangerous sliding surface (soft embankment/scenario 2), when having load (Plaxis)

Table 3-The stability coefficient in different scenarios

Construction	Case	M_{SF} (Plaxis)	K (Geoslope)	[K]
Hard-concrete embankment	Scenario 1: +6.82m	3.2	3.10	1.20
	Scenario 2: +2.50m	2.95	2.82	1.20
Soft embankment	Scenario 1: +6.82m	1.28	2.37	1.20

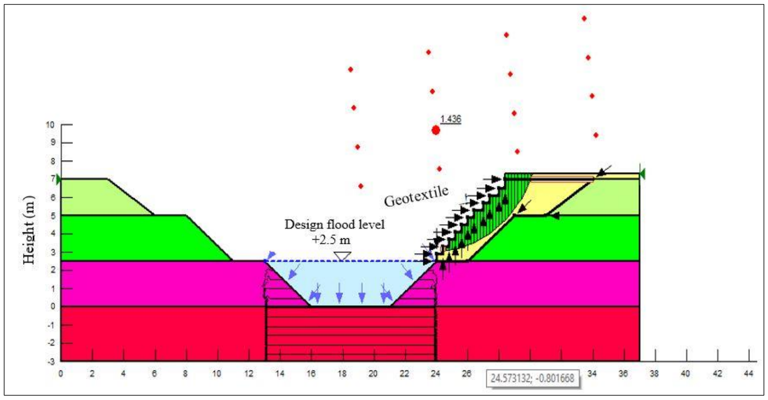


Figure 9: The location of dangerous sliding surface (soft embankment/scenario 2), when having load (Geoslope)

4 CONCLUSION

The study has simulated scenarios in order to assess the stability for the revetments of the southern bank of Ha Thanh and Binh Dinh rivers based on the physio-mechanical properties of the soil and designed water level using Plaxis. The stability parameters of calculations have been extracted for comparison with the stability coefficient [k] from calculations in Geoslope. Revetments with soft material such as Geotextile Soft Rock and Vetiver grass is feasible and brings good economic efficiency as well as practical efficiency. As a result, the expansion of soft embankment to similar embankments is feasible and brings optimal efficiency.

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