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Study On Calculated Methods of Slope Stability In Climate Change

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ABSTRACT

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Global climate change, sea level rise has been causing more and more serious saltwater intrusion, causing severe impacts on agriculture, transport, aquaculture, and biological environment. Riverbank erosion and erosion threaten the living and working areas of the people. The research of structural solutions to deal with this situation is an urgent problem not only for current load but also in the future. This paper focuses on calculating methods for calculating embankment slope stability under climate change conditions.

Keywords : Dyke, Climate Change, Erosion, Stability, Slope.

I. INTRODUCTION

Earth's climate change is the change of the current and future atmospheric, hydrological, biosphere, and lithosphere due to natural and man-made causes. The main causes of the earth's climate change are increased activities that generate greenhouse gas emissions, over-exploitation of sinks and storage of greenhouse gases such as biomass, forests, other terrestrial, coastal and marine ecosystems.

In Vietnam, according to a study by the Research Institute of Hydrometeorology, within 50 years, the average temperature has increased by 0.70C and the sea level at Hon Dau hydrological station has risen about 20cm. Climate change makes sea level rise, and droughts and floods occur with increasing frequency. Along with sea level rise, climate change is also a source of droughts. Sea level rise together with rivers depleting alluvium are factors that bring salt water from the sea to penetrate deeply into the mainland.

Evaluate the impact of sea level rise, on agriculture, and sea level rise affects the growth, yield of crops, planting season, and threatens to shrink agricultural land. For aquatic products, sea level rise and shrimp farming are most affected, due to changes in water quantity and quality, especially in estuarine and coastal production areas. In forestry, sea level rise will reduce the area of mangroves, adversely affect Melaleuca forests and planted forests on acid-contaminated soil, and increase in temperature and degree of drought will also increase the risk of forest fires. development of pests and diseases, epidemics, etc. For irrigation systems, sea level rise will affect the system of canals, of which mainly inland canals, canals of grades I and II. As for the transportation system, the road system will be inundated, especially when there are storms and storm surges, this number increases significantly. For houses, residents, sea level rise will affect households in different degrees.

Embankment works are generally built on soft ground and are often filled with poor quality soil, so when storms, high winds, and big waves, especially in climate change conditions are mostly destroyed. very serious. Therefore, it is necessary to study and apply technology solutions of embankments to ensure investment efficiency of the project and serve as a scientific basis for similar projects. This paper focuses on calculating methods for calculating embankment slope stability under climate change conditions.

II. CALCULATED METHODS OF SLOPE STABILITY

A. Use static equilibrium methods under critical conditions

Soil parameters for sand and clay and TBM is shown as Table I and Table II.

Static equilibrium under critical conditions (Limit Equilibrium Methods - LEM or also known as the method of partitioning, fragmentation). Up to now, the ingot distribution method has been recognized as a numerical method to analyze the calculation of soil slip, which is considered an ideal hard - plastic object in accordance with Coulomb's Law. The present analysis of soil slip computation is classified into the superstatic problem class. Therefore, to solve the problem, scientists have to use additional physical assumptions related to the interaction force between the pieces when dividing the shear block. If using this method, the engineer must make prior assumptions about the position and shape of the slip surface. Then write the static balance equations of force and torque for the assumed slip surface. The slip surface can be subdivided into sliding elements with the assumption that the factor of safety of the sliding elements is the same. The force and torque balance equations can be written and solved for each shear element. The interactions between the sliding elements are described by the forces between the sliding elements. This method is the earliest calculated slope stability calculation method. When they were born, authors such as Fellenius, Tezaghi, Tsugaev, etc. assumed to completely or partially remove the interaction force between the pieces. After that, other authors only revolved around the problem of intermolecular interaction force and to solve this problem they had to come up with many different assumptions. The LEM method started with Fellenius (1936), then developed into the sliding element method by Bishop (1955). After Bishop, a series of other authors have participated in the study such as Janbu, Spencer, Sharma, Morgenstern-Price, Fredlund ... The latter methods mainly complicate the relationship between the force between the shear factors. is still based on static equilibrium. But the first method like Bishop or Janbu's Simplified satisfies only one of two conditions of static equilibrium (For example, either a moment like Bishop, or a force like Janbu's Simplified). It is interesting to note that Bishop's method, which was born first and used fairly elementary assumptions, gave very impressive results (not much different from later complex methods such as Morgenstern- Price or GLE by Fredlund). Of the above methods Janbu's Simplified is quite large.

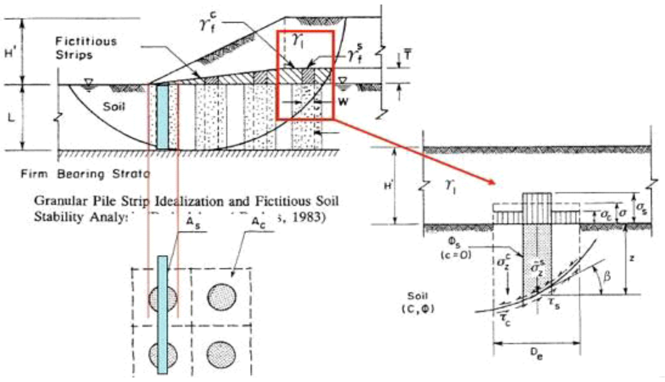


Figure 1. Determination of slip surface by static equilibrium method under critical conditions

In the past, when the calculation technique was rudimentary, it was necessary to assume that the whole or a component of the interaction force between the ingots was removed to have a solution for the design of the earth roof, slope; among these are simple Fellenius, Tezaghi, Tsugaev, Krey, Bishop ... Considering the physical factors related to the interacting force such as magnitude, inclination angle, set point, many scientists have been interested a lot for the development of the theory of Soil Mechanics and thereby clarifying the Incorrect errors are quite controversial when applied today. Among these, the following methods should be mentioned: Spencer method, Morgenstern-Price method, GLE-Canada method ... assumption of the slope angle of interaction force, Sarma method assuming the law of variation of vertical components. of the force, the Janbu method assumes the set point of the force. The above traditional methods have been programmed by many domestic agencies and foreign companies and commercialized their products. Among them, the Bishop method is commonly used in our country, the Janbu method is prescribed for use in Norway, with commercial software, recognized by the world as having a more reliable theoretical basis.

Currently, thanks to the application of modern plastic theory of the ideal hard - plastic object, the problem of analyzing ground roof calculation has been reset to a different format that is more suitable with the physical nature of a system of many elements. standing in the state of limit equilibrium and the obtained results have turned the problem, which is considered superstatic into a static problem without additional physical assumptions, so the solution is theoretically reliable. The two basic limitations of LEM are: - Ignore the relationship of soil stress and strain. - The results are very dependent on the experience of the engineer. Remember that solving the LEM slope stabilization problem is a trial and error process assuming the position and shape of the slip surface.

B. Use the finite element method to find the critical slip surface.

This method is very different compared to LEM. The reason for this is because if using the finite element method, the conditions of stress equilibrium, continuous strain, stress-strain relationship are all satisfied (LEM methods are completely unsatisfactory. stress balance - just force balance). LEM is completely ignored in terms of the distortion relation.

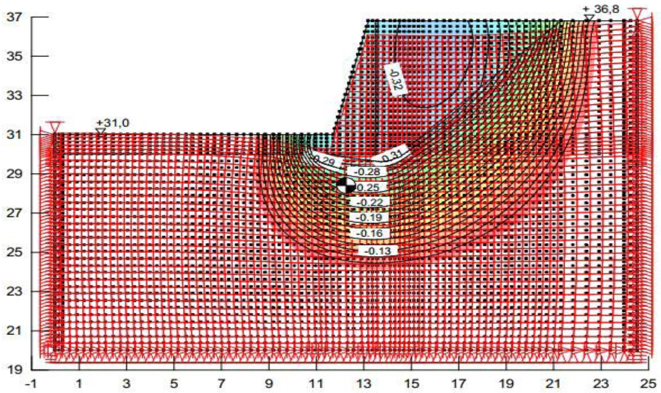


Figure 2. Using the finite element method to determine the slip surface

If the notion that the potential slip surface is a set of points with great shear strain where the ratio between shear strength and shear stress is minimal, the finite element method is used to find points. This is workable. The limitation of the finite element method is that if the input data does not truly reflect the soil behavior, the calculated deformation results are completely meaningless and this is the main reason to prevent the Wide application of finite element method in slope stability analysis. Compared with the finite element method, LEM only needs users to input parameters that are very easy to find such as c, φ, to ensure the results are solved.

C. Use dynamic planning

The method of using dynamic planning mainly aims to overcome the limitations of the two above methods. As follows: Compared with LEM, dynamic planning overcomes both of the above mentioned limitations. Specifically, the factor of safety is calculated from "real" stress by the finite element method rather than by static equilibrium (ie stress-strain relationship is satisfied). More importantly, there is no need to presuppose the position and shape of the slip surface. In other words, the sliding surface found by dynamic programming is unique. Compared with the finite element method, the limitation on input data has been overcome. Although E data is still required when analyzing, this E value is not so important (maybe even a constant) because the dynamic planning does not rely on strain field to find the slip surface.

D. General circular cylindrical slip surface method

According to the results of actual monitoring in cases of slipping of the ground and soil compression tests, when the ground loses its load capacity, the ground is pushed to slide along complex curves. The slip surface methods assume not to solve the problem of finding the shape of the slip surface but assign certain shapes to the slip surface to find their position and to determine the coefficient of safety and stability against slip for the ground.

The calculation methods based on sliding surfaces assuming that are different planes from reality are very rarely used at present. On the other hand, when choosing a more complex slip surface such as a logarithmic torsion surface or an irregular shape can give results close to the true value, but the analysis and calculation will become lengthy and complicated. Therefore, the method of assuming the circular cylindrical slip surface considering the sliding surface has a cylindrical shape will give the results consistent with reality without being too complicated.

Content of calculation of the method:

Assuming in front of a shear center, with a shear center assuming circular cylindrical slip surfaces, determine the coefficient of stability of the soil mass shear for each sliding surface, find the minimum coefficient of stability Kmin corresponding to this center of shear. Assume other shear centers and then determine the stability coefficients Kmin for each shear center. Compare the Kmin values, find the smallest Kmin. The slip center corresponding to the smallest Kmin is the most dangerous sliding center, the corresponding slip surface will be the most dangerous sliding surface.

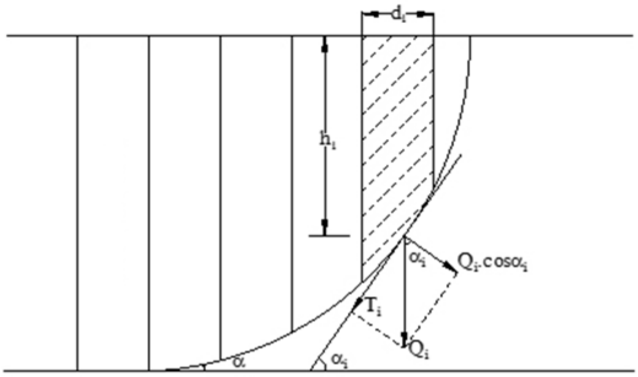


Figure 3. Diagram of mechanical equilibrium condition on its slip surface (The thickness of the soil mass is 1m)

E. Fellenius's method of division into prisms

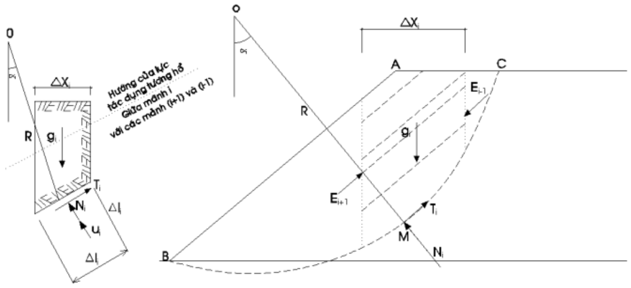


Figure 4. Diagram of calculation by W. Fellenius method

To simplify the process of calculating the problem, Fellenus proposed dummy it is assumed that only the weight of the prism itself W exerts the force exerted on the bottom of the piece, while the force components caused by the adjacent fragments are eliminated.

At that time, the normal force of the normal line was effective so the thin bottom N 'was recalculated as:

N '= Wcos - ul = bhcos - ubsec

In which: l = bsec

Set u = rugh, we have N' = γbh(cosα – rusecα)

Or

$$\sum N' = \gamma b \sum h(\cos\alpha - r_u \sec\alpha)$$

Replace the general equation for sliding mass balance:

$$F = \frac{c' L_{AC} + tg\varphi' \sum N'}{\sum W \sin\alpha} = \frac{c' L_{AC} + \gamma b tg\varphi' \sum h(\cos\alpha - r_u \sec\alpha)}{\sum W \sin\alpha}$$

Where: LAC = θR is the arc length AC.

F. Sequence calculation of fragmentation method according to Bishop (1955)

Bishop (1955) presented the self-computation of slope stability analysis fragmentation method based on arc slip theory.

Several types of slip surfaces are assumed to calculate slope stability, however the assumption of a circular cylindrical slip surface is widely used and gives a result that satisfies accuracy without the need for an over-analytical process. complex. An assumed slip surface passing through a slope foot with radius R will be considered as the most dangerous slip surface if the lowest factor of safety is calculated during the analysis. The circular cylindrical slip surface assumption is widely used in current computational software and in design documentation. Using a calculation tool using a computer tool will reduce computation time and complete the most dangerous sliding surface of the slope.

The computational principle of these methods is to find the most dangerous shear center with the arc slip surface, by dividing the sliding block into the prisms perpendicular to the ground of equal width, calculating the coefficient. stabilize F.

The smaller the division of prisms, the more accurate a result is given, but dividing these prisms too small will lead to a large computation. On the other hand, to find the most dangerous slip surface, it is assumed that the shear center O and the semi-shear R must be changed and the iteration calculated gradually to convergence.

The computation is based on a fundamental principle of considering the static equilibrium of the prism blocks to get an approximate result for each slip surface assuming the process is repeated until the values of the assembly parameters are obtained. converging and finding the slip surface is considered the most dangerous sliding surface.

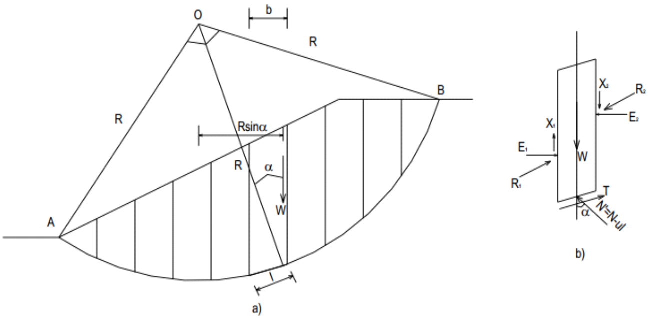


Figure 5. Fragmentation method a) Fragmentation of a sliding block b) Forces exerted on a piece

Considering a slip surface centered O, the slip radius R is divided into width fragments

b. The forces acting on a piece include:

The weight of the fragment: Wi = ybhi

The effective normal jets on the thin bottom: Shear force generated along the bottom of the piece:

T = Wsinα

Forces exerted by adjacent pieces: R1, R2

Normal force between pieces: E1, E2

Tangential force between the pieces: X1, X2

Additional loads acting on the sliding block are introduced into the sliding mass and other forces. At the critical equilibrium, the total failure moment is exactly equal to the moment of the total mobilized shear force along AB:

$$\sum \tau_m l R = \sum \frac{\tau_f}{F} l R = \sum W \sin\alpha R \leftrightarrow F = \frac{\left(\sum \tau_f l\right)}{\sum W \sin\alpha}$$

Under effective stress conditions:

$$\tau = c' + \sigma_n' tg\varphi' \leftrightarrow \tau f_1 = c' l + N' tg\varphi'$$

So:

$$F = \frac{c' L_{AC} + \sum N' tg\varphi'}{\sum W \sin\alpha}$$

With homogeneous soil:

$$F = \frac{c' L_{AC} + tg\varphi' \sum N'}{\sum W \sin\alpha}$$

In which: LAC is the AC length .

Calculation results depend on determining N values, to simplify calculations, Bishop (1955) has added assumptions about the correlation properties of forces acting between adjacent soil prisms.

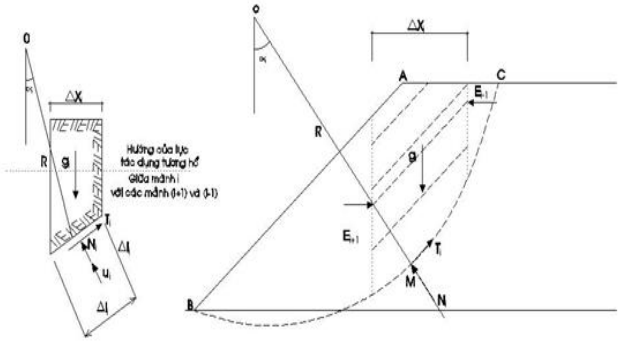


Figure 6. Diagram of calculation according to the method of W. Bishop

Under relatively homogeneous conditions and when ru is almost constant it can be assumed that the tangential forces between the pieces are equal opposite which means X1 = X2 and E1 # E2, with equilibrium along the bottom of the piece. will have:

$$0 = W \ \sin\alpha - \frac{\tau f}{F} l = w \sin\alpha - \frac{c' + N' tg\varphi'}{F}$$

So that:

$$F = \frac{\sum C' L_{AC} + N' tg\varphi'}{\sum W sin\alpha}$$

With vertical balance there will be

$$0 = W - N'cos\alpha' - ulcos\alpha - \frac{\tau f}{F} lsin\alpha = W - N'cos\alpha' - ulcos\alpha - \frac{c'}{F} lsin\alpha - \frac{N'tg\varphi'}{F} sin\alpha$$

$$0 = W - N'cos\alpha' - ulcos\alpha - \frac{\tau f}{F} lsin\alpha = W - N'cos\alpha' - ulcos\alpha - \frac{c'}{F} lsin\alpha - \frac{N'tg\varphi'}{F} sin\alpha$$

So:

$$N' = \frac{W - \frac{c'}{F}(lsin\alpha - ulcos\alpha)}{cos\alpha + \frac{tg\varphi'}{F} sin\alpha}$$

$$N' = \frac{W - \frac{c'}{F}(lsin\alpha - ulcos\alpha)}{cos\alpha + \frac{tg\varphi'}{F} sin\alpha}$$

$$F = \frac{1}{\sum W sin\alpha} \sum \frac{[c'b + (W - ub) tg\varphi'] sec\alpha}{1 + \frac{tg\alpha tg\varphi'}{F}}$$

The computation begins by assuming a test value for F and repeating to get a repeatable value for an initial hypothetical arc.

In this method the ru value is considered to be average and constant, the Bishop method is suitable for the slope calculated with a relatively large ru value, a deep sliding arc or a relatively small radius in the direction. The Bishop of Safety is calculated lower than the small errors.

The calculation according to the above methods should pay attention to the determination of pore water pressure during the construction process as well as the use of the work. The change of pore water pressure during construction and use can change the value of the ru coefficient in the above audit formulas.

III. REALISTIC CONSTRUCTION CALCULATION APPLICATION

A. Theoretical basis of simulation model

GEO-SLOPE is geotechnical software used to analyze the stability of soil-rock.

When calculating the stability of embankments on soft ground, most of the methods usually calculate on the slip surface assuming the arc and consider the equilibrium state of the sliding block. For simple calculation, the topic applied fragmentation method of W. Bishop (limit equilibrium state) with the assumption that the total interaction force is zero on the horizontal axis.

Calculation steps:

- Assume a shear center in advance, with that center assuming circular cylindrical slip surfaces. Determine the stability coefficient of the sliding soil mass according to each sliding surface. find the minimum coefficient of stability Kmin for this shear center.
- Assume different shear centers and determine kmin for each shear center.
- Compare Kmin values to find out the smallest Kmin which is the most dangerous sliding surface. Compare this Kmin value with the allowable stability

coefficient of the works according to the rules to get conclusions about the design sections.

B. Steps to simulate GEO-SLOPE

- Declare seep pattern:

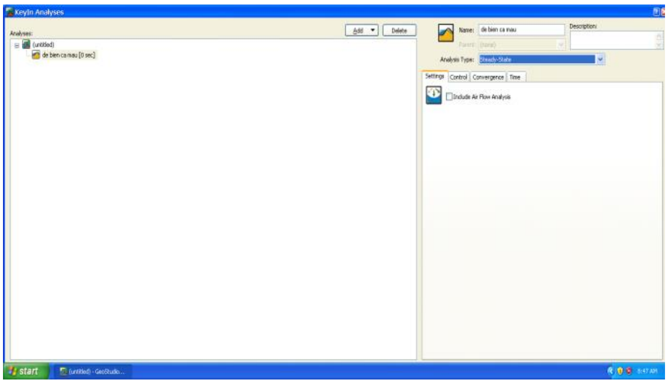

KeyIn Analyses
Analyses:
(untitled)
de bien ca mau [0 sec]
Name: de bien ca mau
Description:
Parent: (none)
Analysis Type: Steady-State
☐ Include Air Flow Analysis

Figure 7. Declare seep model

Set up the parameters for the problem such as page size, system of units, scale, grid, coordinate axis of the model:

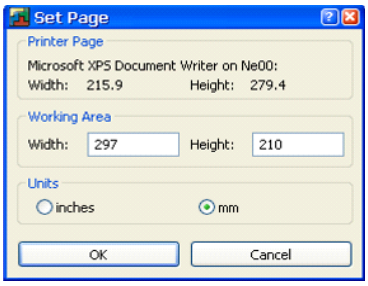

Set Page
Printer Page
Microsoft XPS Document Writer on Ne00:
Width: 215.9 Height: 279.4
Working Area
Width: 297 Height: 210
Units
○ inches ● mm

Figure 8. Declare the page size

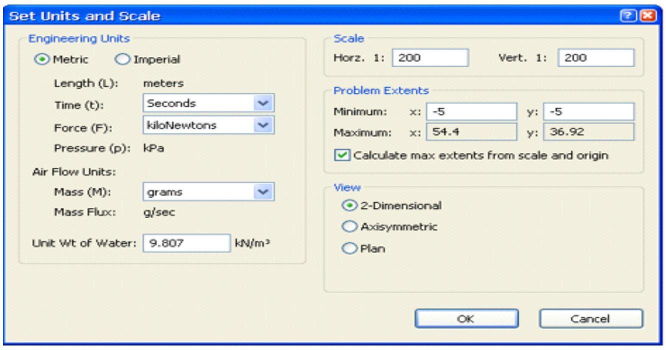

Set Units and Scale
Engineering Units
● Metric ○ Imperial
Length (L): meters
Time (t): Seconds
Force (F): kiloNewtons
Pressure (p): kPa
Air Flow Units:
Mass (M): grams
Mass Flux: g/sec
Unit Wt of Water: 9.807 kN/m³
Scale
Horz. 1: 200 Vert. 1: 200
Problem Extents
Minimum: x: -5 y: -5
Maximum: x: 54.4 y: 36.92
☑ Calculate max extents from scale and origin
View
● 2-Dimensional
○ Axisymmetric
○ Plan

Figure 9. Declare units and model rate

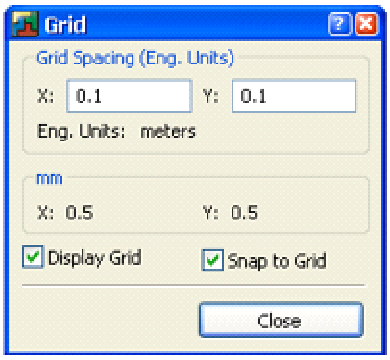

Grid
Grid Spacing (Eng. Units)
X: 0.1 Y: 0.1
Eng. Units: meters
mm
X: 0.5 Y: 0.5
☑ Display Grid ☑ Snap to Grid

Figure 10. Declare grid system

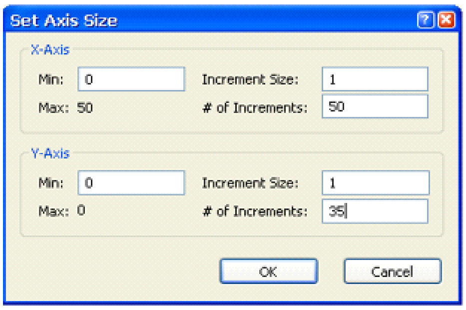

Set Axis Size
X-Axis
Min: 0 Increment Size: 1
Max: 50 # of Increments: 50
Y-Axis
Min: 0 Increment Size: 1
Max: 0 # of Increments: 35

Figure 11. Declare axes

- We will get the basic model:

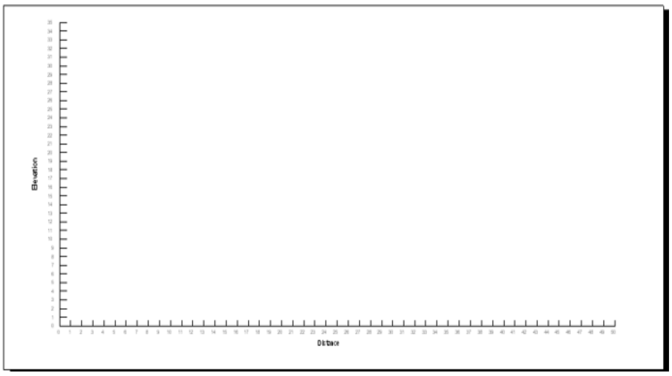


Figure 12. Working area after setting parameters

- Then we proceed to draw and perform various stages of model calculation

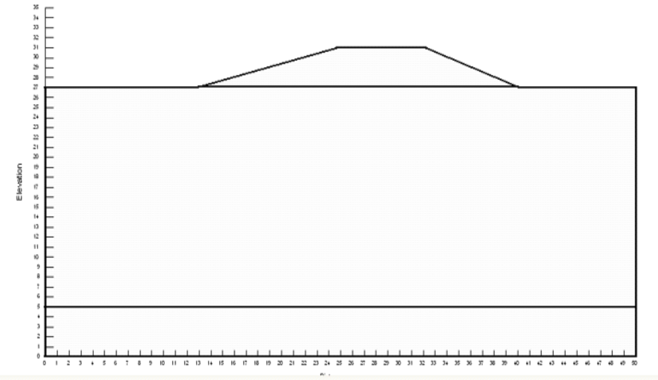
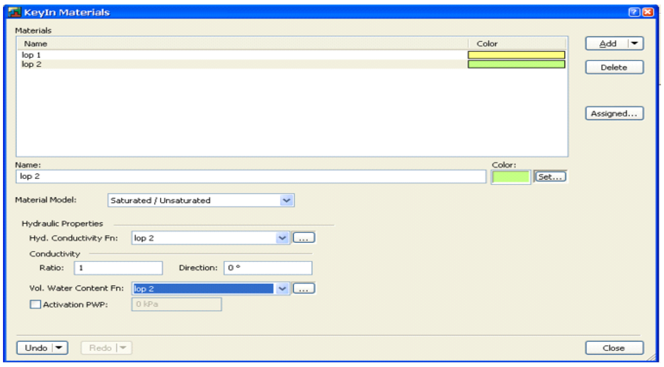


Figure 13. Drawing the model to be simulated



Materials

Name	Color
lop 1	🟨
lop 2	🟩

Name: lop 2

Color: 🟩

Material Model: Saturated / Unsaturated

Hydraulic Properties

Hyd. Conductivity Fn: lop 2

Conductivity

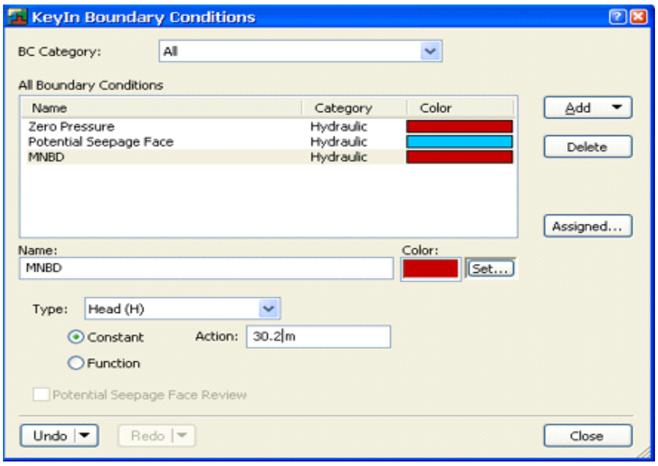
Ratio: 1

Direction: 0 °

Vol. Water Content Fn: lop 2

☐ Activation PWP: 0 kPa

Figure 14. Declare the soil layer parameters and assign them to the model



BC Category: All

All Boundary Conditions

Name	Category	Color
Zero Pressure	Hydraulic	🟥
Potential Seepage Face	Hydraulic	🟦
MNBD	Hydraulic	🟥

Name: MNBD

Color: 🟥

Type: Head (H)

● Constant

○ Function

Action: 30.2 m

☐ Potential Seepage Face Review

Figure 15. Declare boundary conditions and assign them to the model

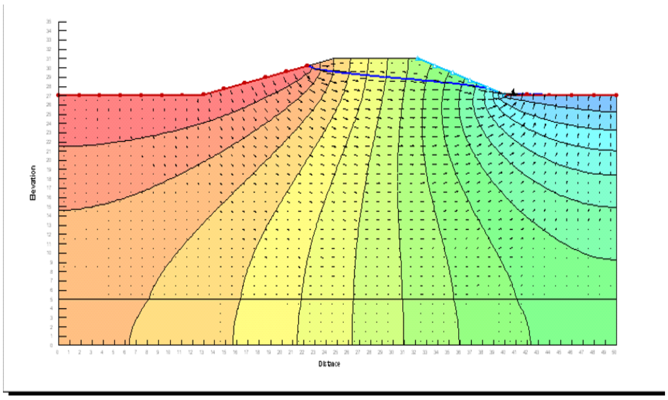
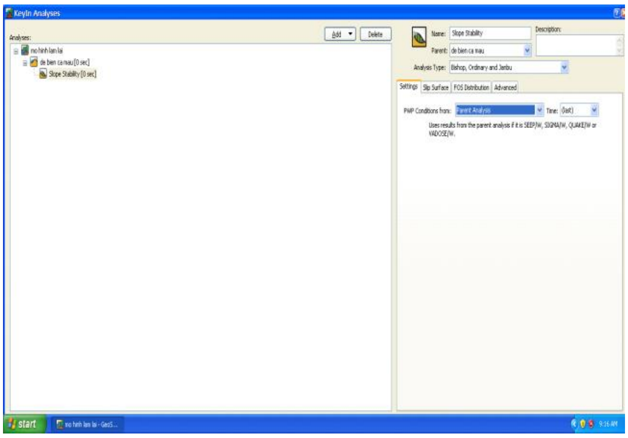


Figure 16. Simulation results after calculation

- Set up the model GEO-SLOPE W



Analyses:

mo hinh lan lai

de bien ca mau [0 sec]

Slope Stability [0 sec]

Name: Slope Stability

Parent: de bien ca mau

Description:

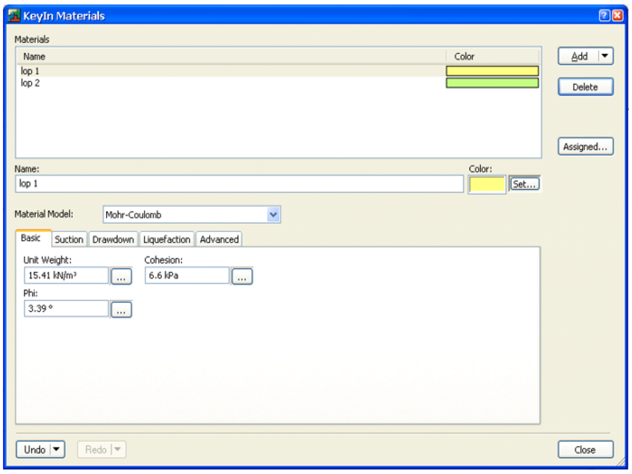
Analysis Type: Bishop, Ordinary and Janbu

PWP Conditions from: Parent Analysis

Time: (last)

Uses results from the parent analysis if it is SEEP/W, SIGMA/W, QUAKE/W or VADOSE/W.

Figure 17. Set up geo-slope stability model



Materials

Name	Color
lop 1	🟨
lop 2	🟩

Name: lop 1

Color: 🟨

Material Model: Mohr-Coulomb

Unit Weight: 15.41 kN/m³

Cohesion: 6.6 kPa

Phi: 3.39 °

Figure 18. Declare soil layer parameters

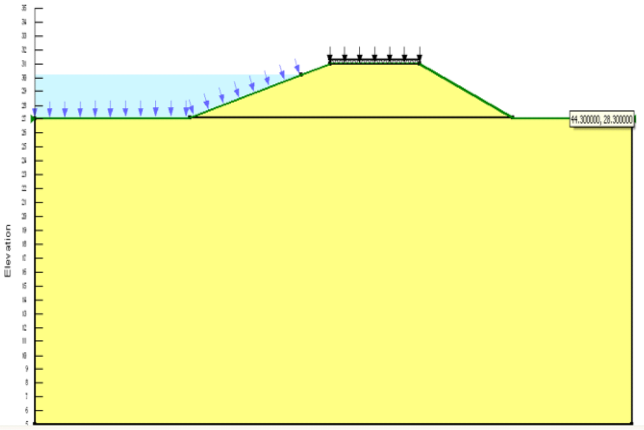


Figure 19. Assign the load to the model

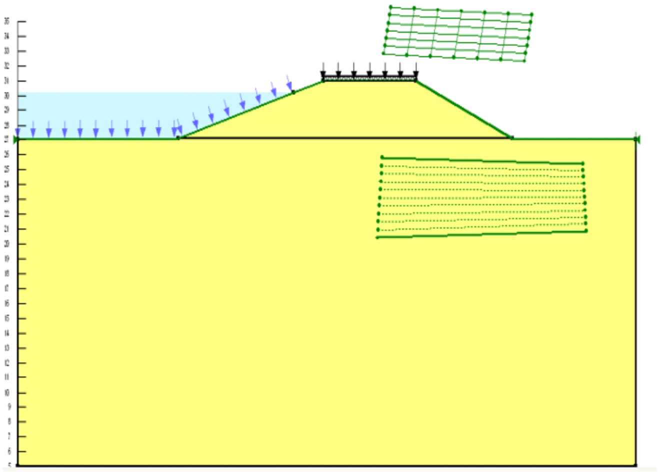


Figure 20. Setting up the stable slip surface

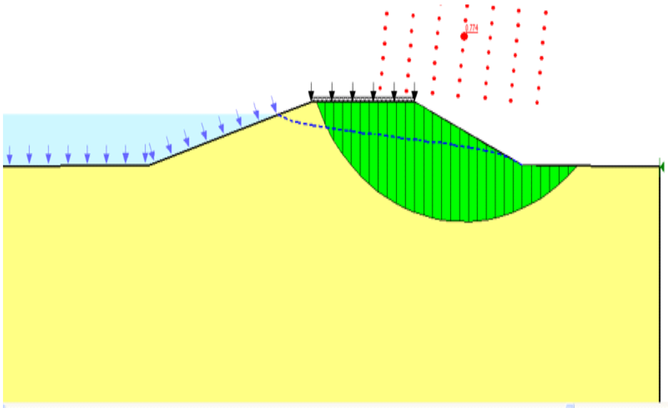


Figure 21. Results of the model

C. The parameters of the soil layers

Layer 1: Mud clay Mud clay, green gray. This clay layer is located just below layer 1a and distributed to a depth of 21.2m in borehole KM1, 27.3m in KM2, 26.0m in KM3 from the natural ground.

Layer 2: Clay, mixed clay, yellow brown, red brown, gray white Clay, yellowish brown, reddish brown, white gray, soft to hard plastic state.

This layer is located just below layer 1 and when the layer is drilled to the full depth of 30.0m, the bottom layer has not appeared.

The average physical and mechanical criteria representing the engineering geology of the project area are listed in the Table I.

TABLE I. MECHANICAL AND PHYSICAL PROPERTIES OF SOIL

No	Mechanical characteristics		Layer 1 Clay Mud	Layer 2 Clay
1	Number of test samples		28	8
2	Particle size composition, P,%	Gravel		
		Sand	10.4	23.7
		Dust particles	45.2	35.0
		Clay	44.5	41.3
3	Natural moisture	W, %	72.92	32.32
4	Unsaturated Unit weight	γ_{unsat}, kN/m^3	15.41	1.8.83
5	Saturated Unit weight	γ_{sat} , kN/m^3	15.59	1.9.04
6	Dry Unit weight	γ_d, kN/m^3	8.91	1.4.23
7	Proportion	Δs	2.657	2.740
8	Saturation	G, %	97.78	95.72
9	Porosity	n, %	66.46	48.05
10	Empty coefficient	e_0, %	1.982	0.925
11	Liquid limit	W_L , %	53.71	44.74
12	Plastic limit	W_P , %	32.84	25.65
13	Plastic index	I_P , %	20.87	19.09
14	Viscosity	B	1.92	0.35
15	Standard friction angle	φ, degree	$3^0 39$	$13^0 26$
16	Standard Cohesion	C_{tc} , kN/m^2	6.6	21.6
17	1st friction angle	φ_1, degree	3o10	11o31
18	1st Cohesion	C_{tc1}, kN/m^2	6.2	17.8
19	2nd friction angle	φ_2, degree	$3^0 21$	$12^0 15$
20	2nd Cohesion	C_{tc2}, kN/m^2	0.064	0.192
21	Compression coefficient, a, cm2/kG	$a_{0.0\text{-}0.25}$	0.682	
		$a_{0.25\text{-}0.5}$	0.472	0.068
		$a_{0.5\text{-}1.0}$	0.262	0.035
		$a_{1.0\text{-}2.0}$	0.161	0.022
		$a_{2.0\text{-}4.0}$	0.098	0.015
		$a_{4.0\text{-}8.0}$		0.010
22	Modulus	E1-2, kN/m^2	442	6270
23	Permeability coefficient	K , cm/s	8.7E-6	3.9E-6

The parameters of the dyke:

- Dike crest elevation: 3.9m
- Width of dike surface: 7.5m
- Converted load: 11.46kN/m

D. Simulate some typical dyke cross-sections.

1) Simulation of a high dyke with inclined roof does not withstand overtopping waves.

Simulation results of inclined roof dikes.

When not using geotextile, the stability coefficient of the dyke is very low and does not meet the anti-slip condition as shown in figure 21.

The dyke is most unstable when the water level is equal to the dike bottom elevation

Dyke after simulation using geotextile as Fig. 22.

Comment:

- The layers of geotextile are 0.3m apart.
- The dike roof uses geotextile with a length of 3m to increase the safety of the two roofs.
- Using 2 layers of geotextile stretching along the dike foot according to the standard 22 TCN 262-2000.
- The factor of safety is 1.938> [K] = 1.4 so that shear stability is satisfied.

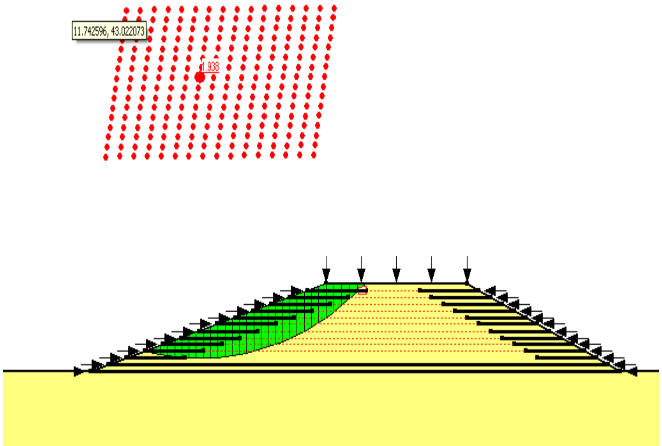


Figure 22. Slanted roof dyke

2) Simulation of a vertical wall dike

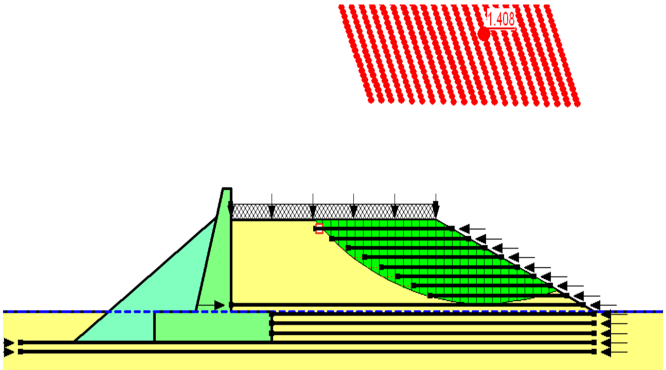


Figure 23. Vertical wall dyke

Comment:

- A dyke using retaining wall saves the amount of embankment soil, saves land clearance area than a dyke using sloping revetment. But it costs about the raw materials of reinforced concrete
- A vertical wall dyke when the geotextile is not used, the safety factor is very low.
- When using more geotextile, it is necessary to place the geotextile at the lower elevation of the dyke, so it has to be dig down about 1.3m, so it costs more than usual.
- The geotextile layers are spaced 0.3m apart according to the standard 22 TCN 262- 2000.
- The factor of safety is 1.408> [K] = 1.4 • Both sides of the dyke satisfy the condition of slip stability.

IV. CONCLUSION

The phenomenon of riverbank slide, river dykes will naturally occur when there are fluctuations in flow, wave speed or the exploitation of the riverbed is not planned, especially in the condition of increasing climate change. especially the estuary area connecting to the sea. Therefore, the slope stability analysis is a very important job, is the basis to assess whether the project is stable or unsafe, it is necessary to have measures to reinforce and handle in time.

The application of the principles of calculating basic stability of the foundation and slope has many differences based on different conceptions about the model of computational elements. Therefore, it is necessary to focus on analyzing and analyzing the currently applied slope stability calculation methods, commenting on the advantages and disadvantages of the calculation methods as a basis to be able to choose the preferred method. suitable for practical application to enhance slope stability.

However, along with the development of information technology, the introduction of soil calculation software such as Plaxis, Geo slope... the stability calculation becomes faster and more accurate. The most common method used to audit stability of embankment slopes, roadbeds ... is the Bishop method.

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