SLOPE STABILITY ANALYSIS

Božana Baćić[1]
Mato Uljarević[2]

UDK: 624.131.38:624.131.537
DOI: 10.14415/konferencijaGFS2014.051

Summary: Both, natural and slopes induced by human activity, created for different purposes, area permanent geotechnical problem. An important aspect in understandingthe complexity of mechanical behavior of the soil is the knowledge of all factors that cause slipping. In respect to this, more detailed laboratory and field research is needed. This will provide input to the calculation models in terms of physical and mechanical properties of the soil, as well as load on the ground and in the slope as a function of time. Only high quality research work can be a good basis for the analysis of natural and man-made slopes. Based on such analysis, it is possible to make an optimal technical solutions with respect to an acceptable risk level. Research in this area give an opportunity to review and improve the existing knowledge. This work provides insight into the general solution of moving sliding surfaces under the influence of the load. In doing so, general example of landslides is presented, taking into account the following: -soil parameters (soil cohesion, internal friction angle of the soil, the safety factor, the power functional relationship for the soil,) -load (groundwater, soil net weight, ongoing load on the surface, concentrated horizontal and vertical loads, seismic loads,). The main objective of this study is to present the problems of slope stability. In this regard, special emphasis is given to the sensitivity of the calculation model input parameters (soil, load), which should contribute to raising awareness about this issue, as a prerequisite to make the right decisions and optimal technical solutions in this area.

Keywords: Research, slopes, load, soil parameters

1. INTRODUCTION

Experience and observations suggest that the instability of slopes in most cases shows as sliding mass of soil, the sliding body, in a straight or curved sliding surface. Because of the stresses in the top and negligible soil strength, especially in the case of fine-grained soil, an opening crack occures, which due to the direction of motion, may be revealed as a scarp on the surface. The apperance of such crack is a clear sign of instability of the slope at an early stage of its occurence. Crack suggests that it may continue into the new sliding surface. The area of the sliding body and the environment around it, is called a

[1] Božana Baćić, dipl.inž.građ., Faculty of Civil Engineering, Technical University of Dresden, Mommsenstraße 9, 01069 Dresden, Germany, e-mail: bozana.bacic@gmail.com
[2] dr Mato Uljarević, dipl.inž.građ., Faculty of Architecture and Civil Engineering, University of Banja Luka, Stepe Stepanovića 77/3, 78000 Banja Luka, Bosnia and Herzegovina

landslide. Slip of the slope can occur rapidly with the advent of large displacements which is achieved in a short period of time, after which the sliding mass stays in the new equilibrium position. But, sliding can be a longtime and complex process, which sometimes influences changes in geometry of the landslide.

2. STABILITY ANALYSIS

Designing of buildings onto the stable slopes, similar to the design of any other building is implemented iteratively and progressively. The basic features of the structure are assumed, including the slope. And then critical estimating situations through which the construction of the building needs to pass, are being evaluated .
During calculation of geotechnical structures, according to Eurocode 7, "proof by method of partial coefficients " is being used. The method includes:
- design models ,
- effects, that can be given as loads or specific displacements ,
- properties of soil, rocks or other materials,
- geometrical data,
- deformation limit values ,
- crack width ,
- deformation ...

According to the regulations , the calculation model should describe the behavior of the soil for a given limit state and include a method of analysis which is usually based on the analytical model, and if needed, modification of the analysis results to ensure that the model results are accurate and on the side of safety .
The geotechnical analysis takes into account the effect of :
- weight of soil, rocks and water,
- current stresses in the soil,
- pressures of groundwater,
- constant load, and loads coming from structures in the region,
- displacements caused by earthquakes, dynamic loading,
- the effects of hydrostatic forces ...

The calculation is carried out with the partial safety factors. In the case of an abnormally high risk stricter values must be taken into account. For emergencies all numerical values of partial factors should be equal to 1.00.

3. METHODOLY OF SOLVING THE SLOPE STABILITY

Solving the slope stability, for a long time represented a hardly solvable problem because of the undevelopment of science and technology. However, today there are various calculation methods that are supported by programming software (GEO5, SLOPE/W). The methods can be divided into those which assume circular surface rupture (Bishop, Fellenius) and those which assume irregular surface rupture (Yanbu, Bjerrum).

Most of the fractures in the soil occure according to the model that describes fracture of continuum as shown in the Figure 1. Most of the sliping in the rock mass is a result of unfavorable orientation of discontinuities, where the fracture surface, in this case, follows the discontinuities. The stability of slopes that are not in the state of limit equilibrium is expressed using the safety factor Fs. Depending on the defined, the safety factor is defined as the ratio of resisting forces and disruptive forces.

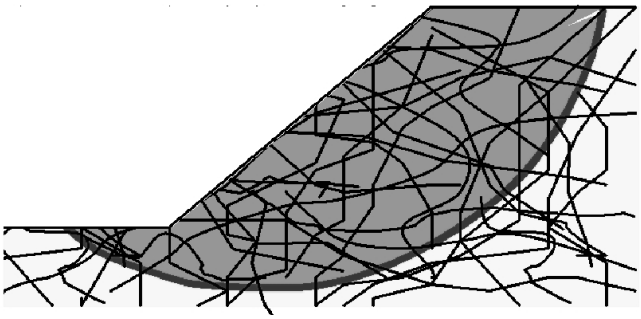

Figure 1. The instability of the soil mass that acts as an equivalent continuum

For computer programming and solving the general problem of slope stability, as well as for defining the fracture mechanisms, the most appropriate method of calculation is hypothetical division of the sliding body into slices. Allocated slice from sliding body with forces acting on it, is shown in Figure 2.

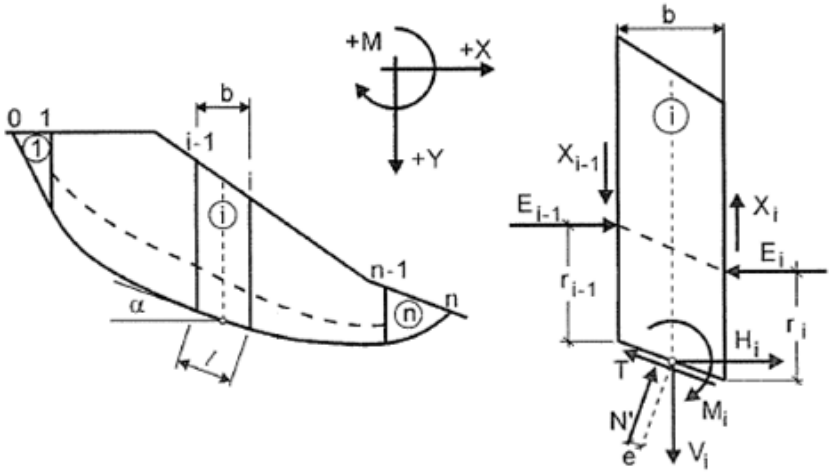

Figure 2. Force acting on an allocated slice

Forces acting on an allocated slice are:

- N'- normal effective forces in basis of each slice
- T - shearing forces in basis of each slice
- r - the positions of normal components of interslice forces

- E - the sizes of normal components of interslice forces
- X- the sizes of shearing components of interslice forces
- e - eccentricity of normal forces in basis of each slice

The safety factor, assuming a linear relationship between shearing stress and effective normal stress (Coulomb's law), is expressed by :

$$F_S = \frac{N' tan\phi + c' l}{T}$$

The safety factor greater than 1.00 indicates that the block is stable**.**

4. THE CHOICE OF SLOPE STABILITY CALCULATION METHOD

In practice, slopes usually occur in inhomogeneous and anisotropic material which results in the appearance of the sliding surfaces of arbitrary shape. All methods for determining the safety factor of slopes can be divided into exact and approximate. Exact methods are those that satisfy all conditions of equilibrium by introducing various assumptions without neglecting individual components of external and internal forces. Approximate methods are those that either ignore certain forces or ignore some equilibrium conditions .

The first one in a series of analytical methods that takes into account interslice forces, was presented by Bishop in 1954. on the Conference of Stability of Earth Materials in Oslo. This method is named after him, **Bishop's method**. Bishop's method assumes circular surface rupture. It represents the slice method, and so it is possible to analyze the stability of inhomogeneous slopes containing materials of different shearing strengths. Bishop 's method is graphically presented in Figure 3.

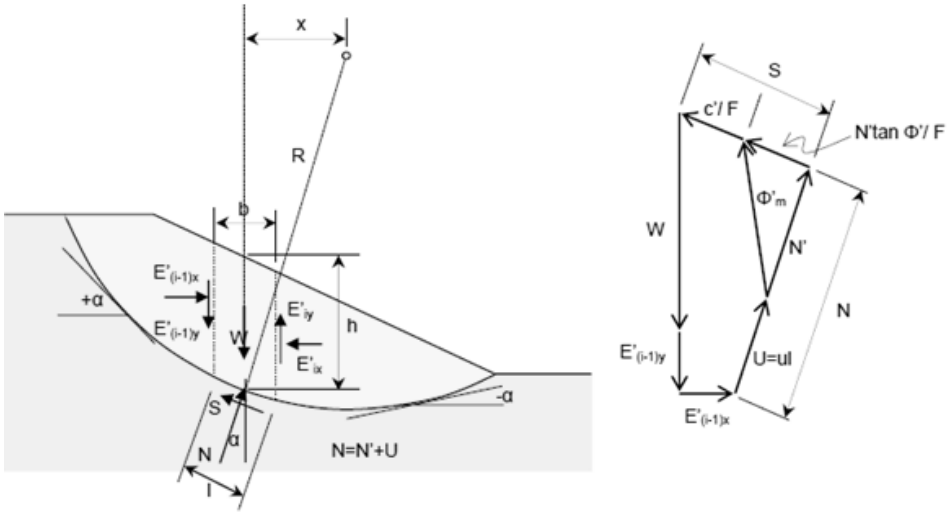

Figure 3. Bishop's method

The safety factor, according to Bishop's method can be calculated as:

$$F_S = \frac{1}{\Sigma W sin\alpha} \Sigma \left\{ [c'b + tan\phi'(W - ub)] \frac{sec\alpha}{1 + \frac{tan\phi' tan\alpha}{F_S}} \right\} \quad (1)$$

5. SOIL PARAMETERS

Cohesion (c) is the result of bonds between the particles. It has great importance is the cohesive soil, especially clay, while is negligible in cohesionless soil (sand, gravel ...). The **angle of internal friction** (φ) is the result of friction between the soil particles. It is higher in the sand than in clay. Shear stress state in any soil will cause the fracture of soil. Shear strength of the soil is the shearing stress that can be applied on the structure of soil in a particular direction. It directly depends on the cohesion and angle of internal friction of the soil. It is defined by the empirical expression which represents the Mohr - Coulomb 's law of breaking:

$$\tau_f{}' = c' + \sigma_n \, tan\phi' \quad (2)$$

As already stated, the problem of slope stability is defined by determining the relationship between the available shear strength and mobilized shear strength, which is needed in order to maintain the sliding body in balance. Safety factor is a number that is necessary to reduce the effective shear strength in order to achieve the state of limit equilibrium of the fracture surfaces.

$$F_s = \frac{\tau_f}{\tau_m} \quad (3)$$

The engineering methods of limit equilibrium imply that the safety factor, Fs, is a constant value along the sliding surface. Similar to the safety factor, the values of cohesion and angle of internal friction are defined. The stability analysis's task is to find the sliding surface, which gives the minimum value of the safety factor.

6. CONCLUSION

This paper presents a methodology of slope stability analysis and provides an insight into the basics of landslides and their general terms. Natural processes are constantly affected by change in the relationship of shearing stress and resistance, and the natural conditions often lead to the destabilization of slopes. Intensive construction of increasingly demanding buildings, as well as other actions, become an important factor in causing adverse conditions which may also result in the destabilization process of the field. In both cases, the consequences can be very harmful. In order to prevent their occurrence, the rules to avoid activities that could lead to a reduction of the degree of

stability of inclined surfaces should be followed. Larger unloading or loading of sloping surfaces should be performed only by qualitative identification of required geotechnical parameters and derived geostatic analysis. According to this, technical solutions can be chosen. These solutions should be designed as interventions in the soil in order to achieve the condition that won't lead to a destabilization of the field. In order to ensure desired, it is necessary that in addition to the previously mentioned, we follow the construction of building using measuring instruments, and beyond the projected measures further intervene when necessary.

REFERENCES

[1] Nonveiller, E.: *Kliženje i stabilizacija kosina,* Školska knjiga, Zagreb, 1987.
[2] Maksimović, M.: *Mehanika tla,* AGM knjiga, Beograd, 2008.
[3] Terzaghi, K. Peck, R.B.: *Soil Mechanics in Engineering Practice*, New York, 1967.
[4] Evrokod 7, Geotehički proračun, Beograd, 2009.

АНАЛИЗА СТАБИЛНОСТИ КОСИНА

Резиме: *Покретање како природних, тако и косина наталих насипањем за разне намјене, представља сталан геотехнички проблем. Битан аспект у разумијевању сложености механичког понашања тла представља познавање узорка клизања. У том погледу, неопходна су детаљнија лабораторијска и теренска истраживања, која ће обезбиједити улазне податке за прорачунске моделе по питању физичко-механичких особина тла. На основу анализе природних и вјештачких косина, могу се доносити оптимална техничка рјешења с обзиром на прихватљиви степен ризика. Радом је приказан општи примјер клизања тла узимајући у обзир основне параметре тла и разне врсте оптерећења. Основни циљ истраживања јесте приказ проблематике стабилности косина. У том погледу дат је посебан нагласак осјетљивости прорачунског модела на улазне параметре, што би требало допринијети повећању свијести о овој проблематици, као предуслову доношења правилних одлука и оптималних техничких рјешења у овој области.*

Кључне ријечи: *Истраживање, косине, оптерећење, параметри тла*