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USE OF SOFTWARE FOR THE ANALYSIS OF LANDSLIDE STABILITY AT NATIONAL AND INTERNATIONAL LEVEL

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Abstract

This article is intended to highlight the input of the field stability software and its monitoring programs to implement the best technical measures to prevent and combat the occurrence of landslides. The best software programs at national and international level will be presented briefly, based on the principle of limit equilibrium method and the finite element method. This article will also describe the technical work resulting from the analysis of the implementation of the various programs in Romania, Spain, Algeria, and Iran. In Romania at present time, among the most used software for analysing the stability of slopes are: Geo5, Geostar, Geo-slope, MidasGTS NX, Midas SoilWorks, Plaxis 2D, Plaxis 3D, Phase2, Abaqus, Cosmos. Moreover, the article will mention other programs developed in Romania, following the research outlined in the PhD theses. There are more than 50 programs at world level that can be used in such analyses, of which in this article we mention Plaxis V 8.2, SPSS 18, FLAC slope.

Key words*: slope, landslides, micropilots, software, stability slope, monitoring landslides.*

INTRODUCTIONS

The modeling of geotechnical structures through computer programs, especially slopes and embankment, has seen a rapid development in the last decade. The calculation programs are divided into two main groups:

- calculation programs that have incorporated the principles of limit equilibrium (MEL),
- computer programs that have incorporated numeric analysis procedures, especially the Finite Elements Method (MEF).

It is known that the yielding of massifs of land, slopes and embankment, is similar to a process of shearing on a natural scale, in which the knowledge and evaluation of strength and shearing efforts play a decisive role. Shear strength, characteristic of soils dependent on a multitude of factors, is also dependent on the stage of deformation-displacement recorded at the level of yielding areas, assimilated as potential breaking surfaces in a problem of stability analysis.

Therefore, the accuracy of the methods for determining the parameters of shear strength, analysis and evaluation of the stability of land masses have evolved a spectacular evolution in recent years.

The methods based on the limit equilibrium admit a common hypothesis, according to which the safety coefficient has the same constant value for any point of the yield surface, the stability conditions being characterized by an average value of it. The main purpose of the method is to estimate the size of the safety factor for the "free body" delimited by the sliding surface. Shear stresses are calculated based on the applied forces, and shear strength is calculated based on the normal forces acting on the sliding surface and the shear strength parameters of the earth.

Methods based on numerical calculation procedures that considers the stress-strain relationship, are represented by MEF. The safety factor is determined by the technique of reducing the shear strength, which helps to estimate the stresses and strains that occur in the supporting elements, such as: piles, micropiles, anchors and geotextiles. The technique of reducing shear strength is systematically used to determine a stress reduction factor (safety factor) that brings a slope to the yield point (Luca et al., 2016).

Following the comparative analyzes performed between the two methods, it was found that there is a difference between the research conducted by MEF between 0.88% - 1.93% when the calculations used the parameters of shear strength with maximum values, and between 1.78% - 1.90% when the parameters with residual values were used, instead, the differences between the analyzes performed with MEL are higher, between 5.49% - 5.26% for the parameters considered with residual values.

From the different results it is observed that the finite element method offers a high degree of confidence, which can highlight the vectors of maximum and minimum displacements in vertical and horizontal direction, in different stages of work, effective and total efforts, water pressure in the pores and degree of saturation. The analyzes performed, both in the hypothesis of a soil mass with homogeneous and stratified stratification, show that the volume of mobilized soil is higher with increasing the parameters of the shear resistance (Chirila et al., 2021).

MATERIALS AND METHODS

Within the researched works at national and international level, a review will be made primarily of the programs used in Romania for calculating stability, landslide monitoring, as well as technical measures applied to prevent and combat the occurrence of natural disasters caused by landslides.

A first approach to solving land stability situations is the kinematic elements method, which involves dividing the earth mass into rigid (non-deformable) finite elements that can only move by sliding against each other, based on the breaking criterion Mohr-Coulumb, in the form of forces and not efforts, to have a discreet solution to the problem and not a continuous one. With the help of a program developed in the Matlab platform, stability graphs are presented for slopes with different slopes and heights, as well as their consolidation measures (Muresan, 2013).

In addition to the classical methods of determining the movement of land and buildings, the use of a new method of monitoring them, represented by the "Reflectorless Method", allows full automation of the entire process of measurement, data processing and provision of information without operator intervention the magnitude of displacements with determination errors of ± 2,3 mm can be provided. The "Detect" calculation program, based on which the "Reflectorless Method" operates, implements a new and simplified statistical approach to tracking movements. The program is accessed only through internet browsers without the previous installation of other programs and represents in short, the use of several points per unlimited object, not being materialized physically, without costs, the movement of points being in one direction (the accuracy offered by this program is 6 times higher than the classic ones).

In order to monitor landslides, the Golden Surfer 9 program, which uses Freyssisol technology by placing monitoring marks, offers the advantage of being able to obtain information of the influence of rainwater, soil moisture, water infiltration on the slope with great ease in 3D format, without the need for knowledge of this format (Trifan, 2014).

In the case of analyzing the stability of communication areas, unstable roads, where the phenomenon of frost-defrost has a great influence especially on soils with a composition of dusty sand, sandy clays, you can use the program Plaxis 2D which uses the finite element method by reducing shear-resistant parameters of the land until surrender. This process, called Phi-c reduction, identifies areas of instability on road sections where the main cause is the presence of surface water that has seeped into the body of the road and for which the stability factor can be calculated (Valceanu, 2014).

In Spain, the Slide V5 program (Figure 2) was used, which considers water pressure an infiltration, determining the degree of soil saturation as well as the slope of the land, cohesion, internal friction angle and density. The shear strength of the soil is the most important coefficient to be analyzed because it starts in application methods with differentiation of areas on landslides where the stability factor is greater than or equal to 1.5, and where the value is subunit 1.50 the implementation of the procedure for obtaining a supra-unit coefficient is applied. In a case study in the region of Malaga, the increase in shear strength increased the stability factor, which could be done by

inserting micropiles at 45 cm between the axes and at a depth of 25 m below the endangered building.

Additionally, anchors were introduced at an inclination of 20 degrees with a diameter of 0.6 inches and a limit voltage of 60% of the balance limit. The case study described the steps and the beneficial solution that micropiles have through the Spencer method of limit equilibrium, following which it was established that the degree of safety increased from 0.907 to 1.504 (Alfonso et al., 2021).

In Algeria, to prevent landslides, a procedure has been proposed which involves, first, the identification of the breaking surface, from where there is the greatest risk of detachment of a sloping part from the slope. The identification of this area is done with the help of inclinometers later, to evacuate the water from the precipitations, drains are built located laterally on the longitudinal direction of the rupture with discharge in the lateral parts of the slope (Sellami, 2014).

Once the water is drained, reinforced concrete micropiles are inserted right in the risk of rupture. The evolution of the stability as well as the exact identification of the possible rupture is followed through the Plaxis V program 8.2. As the possible slip is sectioned by a road, the loads exerting pressure on the ground were also considered, studying two hypotheses in which micropiles can be introduced depending on the length of the road and the corresponding pressure expressed in tons/m2. The program was able to express what load can be assigned to each armed micropilot and depending on the maximum moment of rupture of the slope (KN*m) and at what distance they will have to be drilled. One of the calculation examples highlighted that at a specific weight of 140 t, distributed over 36.6 m, a load of 3.86 t or 38.9KN / m2 results, for which the stability check, as well as the related graphs showed that the land will be in perfect safety, the risk of slipping being almost 0. What gives more confidence to this complete system of monitoring and technical implementation is that it can adapt to any type of soil substrate and on slopes with different degrees of inclination.

In order to assess the volume of landslides following landslides, the SPSS 18 program (Figure 3) was applied in Iran on the surface of the Baqi River basin, which helped to calculate the volume of land for 44 localities. For the beginning, the depth of landslide production was determined, this being between 3.3 m and 4.6 m and of the total soil displaced in this river basin, 35% is represented due to landslides. The aim of the study was to find a relationship between the surface and the volume of landslides, their surfaces were identified longitudinally and latitudinally using SPSS software 18 (Abolghasem et al., 2016).

The formula VL = ɛ x AαL was used, based on which the volumes of land were calculated and compared with other models from previous years, finding that the values are quite close. Like the parameters used to estimate the displaced volume, the coefficient of determination (R2) and the mean square deviation (RMSE) were calculated to indicate the efficiency of the model.

The equivalent volume was calculated with VL=2.482 x AL 1.024 and R2=0.99, which led to the estimation of a volume of 922658.42 m3 and an average sliding depth of 4.06 m. Based on the values extracted from the calculations, correlation diagrams were made between the volume and the landslide surfaces, as well as between the calculated depths, resulting in a significant increase in the displaced volume in relation to the monitored areas (example: at 1000000 m2 is 3.9 million m3).

$\bar{O}$ = average of the observed volumes; = average volume calculated; oi = the value of the observed volume; pi = calculated volume; n = number of variables; pi = estimated slop volume.

$$R^2 = \left(\frac{\sum_{i=1}^{n} (p_i - \overline{p})(o_i - \overline{o})}{\sum_{i=1}^{n} (p_i - \overline{p})^2} \right)^2$$

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n} (o_i - p_i)^2}{n}}$$

(Abolghasem et al., 2016).

In the Qinghai region of Tibet, which is prone to landslides due to frequent rainfall, the stability of a road section was analyzed, on the surface of which 3 geological drillings were carried out to

identify the soil stratification and the groundwater level. In this sense, the obtained samples were introduced in the Flac 3D calculation program (Figure 1), based on the finite difference method, after which the parameters of the earth could be determined. Following these analyzes, it was possible to find out where the landslides and the values of the shear coefficient at different depths occurred. As a technical measure, a numerical simulation of an introduction plan for micropiles capable of retaining and reducing landslides was performed (Hu-Tiang Fei et al., 2016).

RESULTS AND DISCUSSIONS

All the cases presented above are important, but for a practical highlighting of the technical works performed based on the analyzes provided by the calculation programs, those projects with significant technological impact were chosen for detailed presentation.

1) Program Flac 3D:

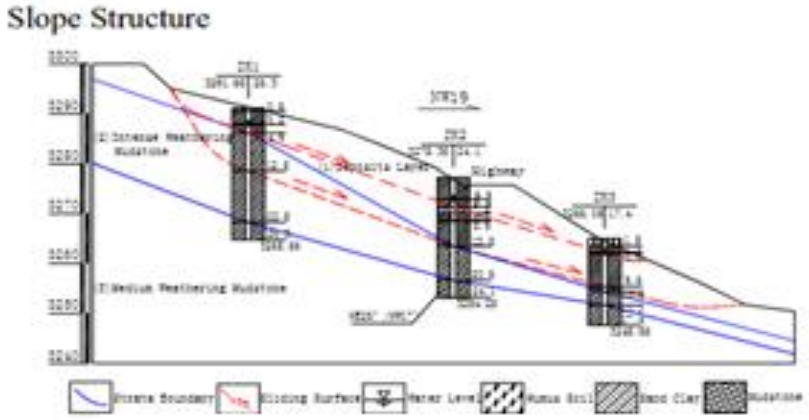

Figure 1. Geological section of colluvial landslides (Hu -Tiang Fei et al., 2016)

2) Program Slide V5:

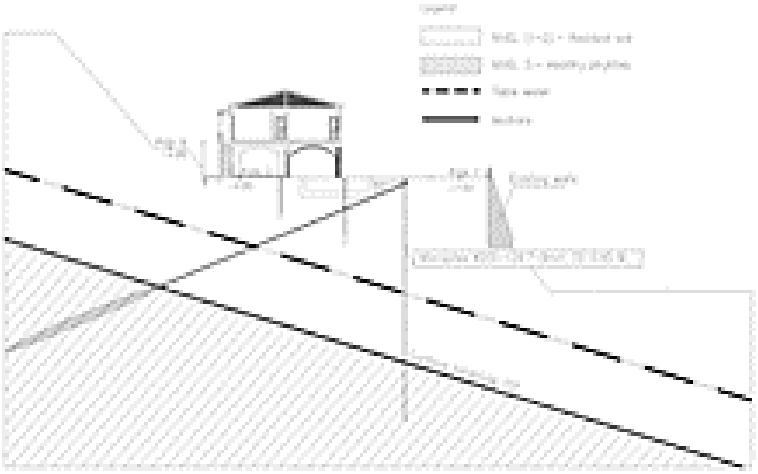

Figure 2. Study example cross section (Alfonso et al., 2021)

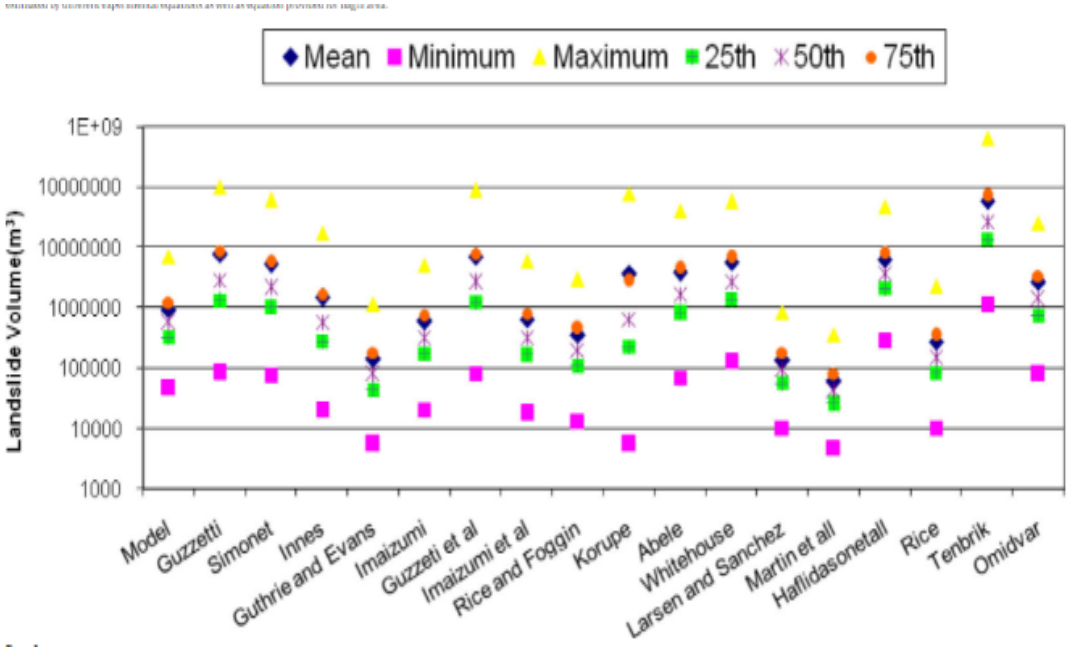

Figure 3. Evaluating the Model SPSS 18 (Abolghasem et al., 2016)

CONCLUSIONS

Relief has a dominant role in the outbreak and development of processes of erosion and mass movement of land. Landslide's intensity is directly proportional to the slope of land, the energy relief or fragmentation density hydrographic network (Constandache et al., 2015).

Following the analyzes performed in the presented projects, the degree of stability of the works has increased significantly in terms of safety and improvement of measures taken to prevent and combat landslides. These high values of the stability factor could be increased due to the calculation programs, which facilitated the accuracy of the calculation of safety in different risk situations as well as the volumes of earth that can be displaced in case of landslides to prevent loss of human lives and material damages.

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