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USE OF STRUCTURED PILES AS STABILIZING ELEMENTS OF SLIDING SUSCEPTIBLE SLOPES

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Abstract: *The paper proposes a principle of verification for increasing stability of slopes by structured piles. The principle is ilustrated by a case study of a building on a hillside of Dealul Melcilor in Braşov town.*

Key words: *piles, slope stability axial and horizontal loads*

1. Introduction

Frequently, in practice of construction design is, especially in hilly and mountainous areas, piles or columns are used as solutions for indirect foundations. Usually, at the base of slopes proluvial deposits is accumulating, deposits from the torrential, with cross bedding or even muddy lens material with high organic matter content. Therefore to avoid differential settling the question founding in a homogeneous soil, can be achieved by deep foundations.

Sometimes, in addition to the main problem of deformations uniformity of the soil it is necessary to check the overall stability, whether it is on a slope. Verification is generally done on virgin land without construction, or at most, taking into account the construction as a surcharge, representing an unfavorable factor overall stability.

The aims of this paper is to study reverse situation, the intake of stability that brings a network of piles who are destined axial loads.

2. Background Research

The problem o stabilize the slopes using strings piles in a row, several rows or groups of piles studied by different authors in different aspects [2], [3], [4], [5].

Sizing works with piles for slope stabilization involves three stages as follows:

Calculating the stability factor, Fs, of the slope by one of the known methods. The safety factor is defined as [4]:

$$F_s = \frac{\sum R}{\sum F_D}\ , \qquad (1)$$

meaning the ratio of:

$\sum R$ – the sum of the resistance forces along the critical slip surface;

$\sum F_D$ - sum of the forces destabilizing the slope.

As we assume piles, regardless of their size and disposition – have a stabilizing contribution to the safety factor, leading to the target size by ΔR, equality number

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(1) becomes:

$$F_T = \frac{\sum R + \Delta R}{\sum F_D} \quad (2)$$

Thus, from the equations (1) and (2) it results:

$$\Delta R = \sum F_D \cdot (F_T - F_s) \quad (3)$$

The second step involves calculating the pile – soil interaction. In this point of view there are several hypotheses proposed, assuming they generally two types soil, one with weaker mechanical behaviour near the surface features and the other more rigid more profound as in Figure 1.

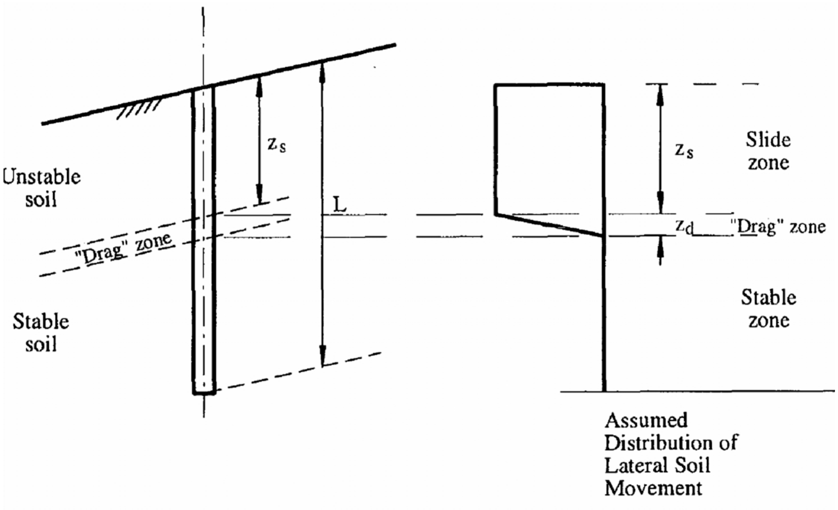

Fig. 1. *Basic problem of a pile in unstable slope: free field soil movement [4]*

The problem for the sliding zone that we intent to do is to rotate it in horizontal plane, so the calculation diagram may be reduced to two areas, one in which the soil is pushing piles and the other to the downstream. Actually piles have some displacements, so stresses transmitted in to the downstream of them varies depending on the hypothesis upheld. Size of the shadow behind the piles is also subject to these movements.

The third step comprises stabilizing the solution itself. Various assumptions are built different methods, but in principle they must indicate the spatial disposition and the depth of piles. The categories of factors that determine the final solutions of the nature of cohesive and non-cohesive of the soil, rigidity, or rather the difference in stiffness between the different layers, configuration, slope and pile's diameter.

Generally it is accepted that the greater light 4 diameters of the piles it will not exist the arch effect between piles also the displacement is proportional to the ratio of the length of the pile in the stable and sliding soil [1].

3. Modeling Soil Behavior Submitted to the Influence of Piles

This article aims is to study the issue of piles used only to pick a special axial loading overlaid horizontal pressure generated by movements of unstable ground surface.

We have adopted some simplifying assumptions as follows:

- Piles displacemenet are null;
- Horizontal movement of the soil does not change the status of efforts;
- Piles are distributed in rows;
- Piles are assimilate to plan shaped sectional;
- The slope is infinite.

To determine the status of efforts the problem of horizontal plane rotates vertically. Thus we can look at the overall efforts that are pushing the soil on first row of piles with the same value as volume weight of that soil has it. Given that piles are circular and the calculation is made in two dimensions, loads will be reduced or increased at a rate in proportion to the unit pile diameter. In this case it will add to the simplifying assumptions that the value of undisturbed soil pressure is constant for the whole length of the piles onthe first row and has a uniform unit thickness. Downstream the soil is lacking weight.

Efforts downstream piles are distributed complementary to a pressure bulb according to the uniform distributes loads (see Fig. 2).

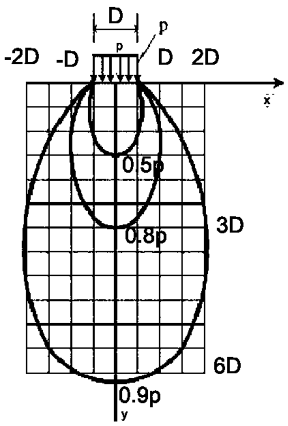

Fig. 2. *Complementary pressure bulb*

Lapping the entire field with these piles bulbs it will be found that their surface horizon interfere.

The values of the interfering depends on the spatial distribution, first of the distance between the piles on the y-axis (paralel to the slope), and the diameter D of the pile. Pressure distribution downstream of the piles efforts will have therefore form:

$$\sigma_y = p\cdot(1-\frac{1}{\pi}\cdot[(\beta_2-\beta_1)+\sin(\beta_2-\beta_1)\cdot\cos(\beta_2+\beta_1)] \quad (4)$$

where β_1 and β_2 are the angles under it is seen heads diameter's pile.

On the *y* axis direction $\beta_2 = -\beta_1$, so :

$$\sigma_y = p\cdot\left(1-(\frac{2\cdot\beta}{\pi}+\sin 2\beta)\right) \quad (5)$$

Assuming the distance between column piles, D_{iax} is constant, pressure in the middle of interax distance is:

$$\sigma_M = 2p\cdot(1-(\frac{2}{\pi}(\alpha_2-\alpha_1)+2\sin(\alpha_2-\alpha_1) \quad (6)$$
$$\cos(\alpha_2+\alpha_1)\cdot(\cos^2\alpha_2-\sin^2\alpha_1)))$$

The angles under which piles may be expressed in terms of diameter and distances between piles as follows:

$$\beta = \mathrm{atg}\frac{D}{2y}, \qquad \alpha_1 = \mathrm{atg}\frac{D_{iax}}{2y},$$
$$\alpha_2 = \mathrm{atg}\frac{D_{iax}+2D}{2y}$$

Considering a linear variation of the horizontal efforts on column piles and interax in the y direction it is:

$$F_x = n\int_0^{Ds}\frac{\sigma_y+\sigma_M}{2}dy, \quad (7)$$

where (see Fig. 3):

-n is the number of rows of piles.

- Ds is the distance between the rows of piles on y direction;

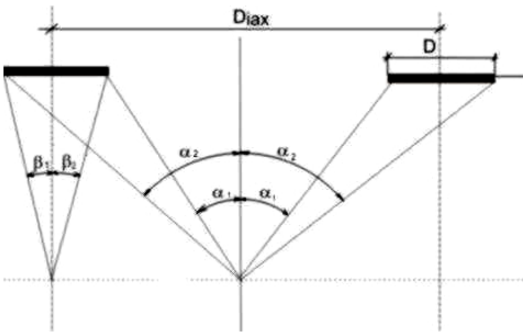

Fig. 3. *Angles and axes notation*

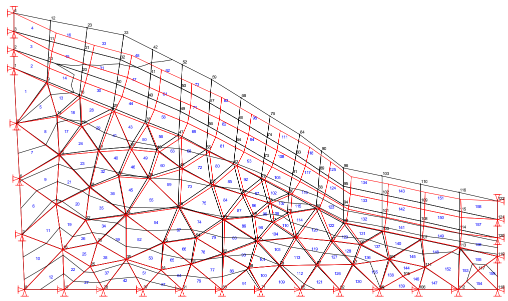

Fig. 4. *Meshing massive displacements due to its own weight*

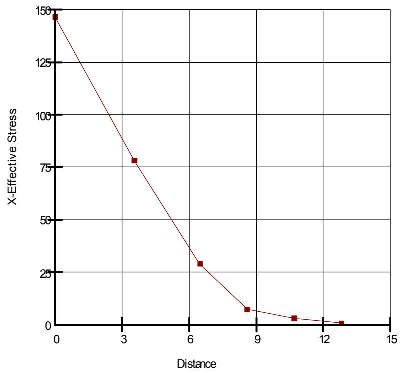

Fig. 5. Horizontal pressure & depth

- D_{iax} is the spacing between piles;
- y is the distance between piles on slope direction.

4. Case Study – an S + P + 6E Building Dealul Melcilor Braşov

The case study presented in this paper refers to a building developed on 4 levels with drawals height, built on a hillside susceptible to sliding [7].

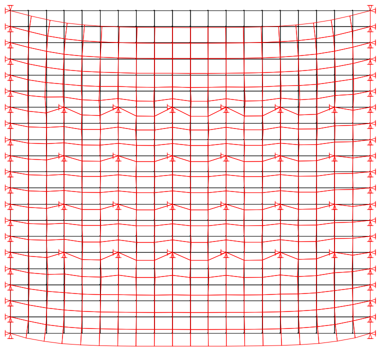

Fig.6. *Plane deformation of the soil, with fixed heads pilots*

The initial project was developed based on a geotechnical survey, with an insufficient number of boreholes at the site, leading to the adoption of a foundation system surface.

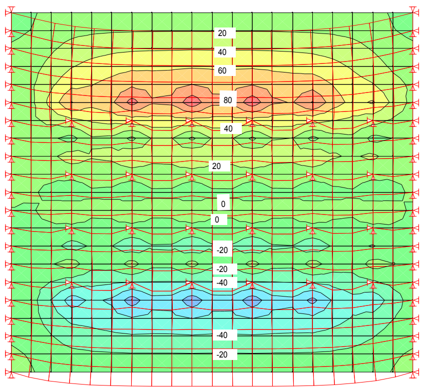

Fig.7. *Horizontal presssure distribution*

During excavation works execution in order to achieve foundations , downstream, on the SW side was found a improperly soil, different from that indicated in the geotechnical study.

After investigating in situ condition actually, it was decided to restore the geotechnical study, which indicated after computing the stability of the site, at risk major slip, the stability factor F_s was subunitary, with the proposal to adopt the system of deep foundation to ensure the differential settelment and slip the site. Computations carried out by MEF confirmed this situation, as illustrated in Fig. 4 and 5.

In this situation, the role of piles is to ensure the transmission to healthy soil taken from the building loads and eliminate the risk of slip of the site as ilustrated in fig. 6 and 7.

The foundation was done through the point bearing piles, with a diameter of 600 mm and a peak embedded up to 500 mm depth in rocky terrain.

Pile's sizing was made efforts to the maximum sectional data load assumptions being [8]:

• vertical forces transmitted by the construction

• Horizontal forces due to pressure of the soil due to the use of shear strength (f_{mob} = f), considering that pile's heads are rigid fixed in the slab and in foundation soil.

Geotechnical characteristics of the soil were considered those provided by 6 (six) boreholes conducted at the site. Following the computation is was established pile's composition:

• Pile diameter, f = 600 mm;

• longitudinal reinforcement arranged in the form of annular case (f = 20 mm);

• Cross reinforcement as helix-shaped fret (f 10 mm).

The lenght of the pile has been provided at least 500 mm to be embedded in stony ground recessed.

Based on the geotechnical characteristics of the soil contained in the borehole's statement the bearing capacity of the piles was found to be minimum 70 tf. The number of piles (NP) was established to take over from the condition of vertical loads transmitted from the building, based on the relationship:

$$N_p = \beta \cdot V_{Ed} / V_{Rd} + (1...2)$$

In which:

- β- coefficient depending on the size eccentricities resultaning from vertical forces;
- V_{Ed} - resultant designed vertical force transmitted to the building ;
- V_{Rd} - isolated vertical force capable pile.

It resulted by the calculation a total of 70 piles who were arranged to string axes intersections and main building and in an intermediate position for the larger openings.

Tests carried out on site on the testing piles have found maximum compressive force capable of 110 tf.

The foundation itself was established type "beam networks", thus ensuring solidarity at the level of heads piles and increase stiffness after building the foundation level both directions. Analysis of the structural capacity of the piles to prevent the sliding trend of the soil was modeled by the terrain configuration, geotechnical, static scheme and the actual spacing of piles.

5. Conclusions

Following processing and interpretation of data obtained was found that the spacing piles over 6d (d- pile diameter) horizontal efforts in the field diagram shows a concentration area located in the vicinity of their maximum extension is quantified at approximately 1,25d, a side axes piles most exposed.

With this size area enlargement active in efforts horizontal pile, based on simplifying assumptions for calculating the distribution and value the efforts of horizontal related to piles, it was established that the actual situation on the geotechnical characteristics of the terrain, number and arrangement plan of piles structural , their contribution to the prevention of the tendency to slip is in the range of percentage (20-30%).

For the situation of land once the site asigutrarea slip building was also supported by other complementary measures due to the presence of structural piles, namely:

• Downloading the massive weight of soil systematize susceptible to slip through the terraces of the site;
• foundation of the building directly downstream section, standing on a stable, solid foundation;
• Changes in the height of the building by successive withdrawals from downstream to upstream;
• Layout piles Structural downstream section of the building;
• Sizing and layout retention contour elements.

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