The influence of the second row of piles in double-row pile retaining walls with the stabilization of landslide

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Abstract. In the practice of designing anti-landslide pile structures along with the single-row walls find use in General multi-row two-row and retaining walls. This assumes that the second row of piles will greatly enhance the bearing capacity of retaining structure. The joint work of the piles in the rows and methods of their calculation are presented in a number of works of domestic and foreign. At the same time conditions the most effective use of the second row in the double row pile retaining walls remain to be studied. Since double-row pile retaining wall, the combined grillage represents a frame of flexible piles on an elastic Foundation, the load distribution between the piles from the existing on the wall of landslide pressure will depend on the flexibility of the piles, the ordinates of the load from the landslide pressure on the first row, the soil properties of landslide slope. To determine the valid picture of the work of anti-landslide pile structures was tasked to establish the role of the second row in the work of double-row pile retaining walls. The article presents the results of analytical studies frame construction flexible piles, the combined grillage hard, perceiving landslide pressure. Effective capacity utilization of the second row of piles was assessed using the utilization of the bearing capacity of piles second through 4,000 different designs double row of walls made of piles of various cross-sections, length, their reinforcement, the depth of application of landslide pressure, as well as with different variants of soil conditions. Due to the significant complexity of the implementation many variants of the analytical calculations were carried out with the use of computers.

1. Introduction

The theory and practice of strengthening of landslides piles have been numerous studies both in our country and abroad [1-20]. Mostly they dealt with the issues of calculation of stability and load-carrying ability of anti-piles under the action of landslide pressure. The effective application of anti-landslide constructions are particularly relevant for regions with complex geographical terrain and abundant precipitation.

In the practice of designing anti-landslide pile structures along with the single-row walls find use in General multi-row two-row and retaining walls[6-12]. This assumes that the second row of piles will greatly enhance the bearing capacity of retaining structure. The joint work of the piles in the rows and methods of their calculation are presented in a number of works of domestic and foreign researchers [5-12, 15-16, 18-20]. At the same time conditions the most effective use of the second row in the double row pile retaining walls remain to be studied.
2. The purpose of the research
Since double-row pile retaining wall, the combined grillage represents a frame of flexible piles on an elastic Foundation, the load distribution between the piles from the existing on the wall of landslide pressure will depend on the flexibility of the piles, the ordinates of the load from the landslide pressure on the first row, the soil properties of landslide slope.

To determine the valid picture of the work of anti-slide pile structures was tasked to establish the role of the second row in the work of double-row pile retaining walls.

The study was conducted on the basis of 4,000 options calculations and analysis of the results of piles of various cross-sections, length, their reinforcement, the depth of application of the horizontal load is below the surface of the soil, and also by different types of soil conditions. Due to the significant complexity of the implementation many variants of the analytical calculations were carried out with the use of computers.

3. The results of the research
The design scheme is shown in Figure 1. Piles first and second row arranged one against the other, and United by a grid-type frame construction. Load R (total resultant landslide pressure) acts on the first row of piles. The point of application of this load is at a depth "a" from the surface of the soil and depends on the type of landslide plots of pressure acting on a retaining structure.

With the aim of establishing General laws was considered theoretically possible a wide range of options changes to this ordinate.

The load from the first row of piles is passed through the grid in the second row. The redistribution of the total load between the piles of both series occurs with regard to their flexibility. Piles are seen as long flexible conditional pinching below the surface of the slide in place of the maximum bending moment at a depth of L. Its presence is in most theoretical methods for calculation of piles for horizontal load, for example, in [14].

The effect of the second row is evaluated by the reaction of \( R \), perceived the second row and the coefficient of capacity utilization \( \eta \) of the second pile. The reaction is determined in fractions \( A \) (Equ. 1) from the total load on the recessed \( P_u \) construction.

Calculation formula:

\[
R = \frac{Sh\lambda l \cdot \cos \lambda a Ch \lambda b - \sin \lambda l Ch \lambda a \cdot \cos \lambda b}{2(Sh\lambda l \cdot Ch\lambda l - \sin \lambda l \cdot \cos \lambda l)} \cdot P = AP. \tag{1}
\]

\[
\eta = \frac{R}{P - R}. \tag{2}
\]

Here:
- \( P \) – load (landslide pressure) acting on the double row retaining wall;
- \( R \) - response, perceived second row of piles;
- \( A \) - proportion of the total load \( P \), per second number of retaining walls;
- \( \eta \) – the coefficient of use of the bearing capacity of piles second. The indicator of flexibility of the piles \( \lambda = 0.635 \frac{E_o}{(1-\mu_o^2)EI_{pr}} \) [14], (3)

where
- \( E_o \) - the module of total deformation of the soil;
- \( \mu_o \) - is the Poisson's ratio of soil;
- \( EI \) – given the stiffness of the reinforced concrete cross-section;
- \( L \) - is the length of the pile;
- \( a \) – ordinate the application of the resulting landslide pressure \( P \);
In Figure 1 shows the results of calculations of changes of the coefficient $\eta$ depending on the depth of application of the horizontal load $P$ (landslide pressure). Its values fall rapidly with the depth of the point of application of force. Uniform load distribution between the piles of both series is observed at $a=0.1$ L.

![Graph](image)

Figure 1. A graph of the ratio $\eta$ of use of the bearing capacity of the second row, $a$ - the depth and application of the horizontal load $P$ (landslide pressure), and total module of deformation of soil $E_o$. $R$ – reactive resistance of the second pile.

With the increase of the ordinate "a" the effectiveness of the second row of piles is reduced, as in the first row accounts for a large part of the load from the landslide pressure.

For the purpose of uniform redistribution of the load between the rows in this case, it is advisable to increase the spacing between piles in series and piles in the second row to install the extension against the piles of the first row [7, 16]. Then the part of soil, not kept in the first row and forced between the piles of the first row, it will be perceived the second row.

The analysis shows that the efficacy of the second row of piles is higher in weaker soil of the landslide massif (Figure 1). This fact is confirmed by studies of the effect of the thinned row of piles on the velocity of landslides-flows [15, 17-18].

From Figure 2 and 3 shows that most efficiently used the bearing capacity of the second row of piles in soft soils and greater rigidity of the cross section.
Figure 2. Graph of the ratio $\eta$ of the deformation properties of the soil $E_0$ and geometric dimensions of the cross-section piles.

Figure 3. A graph of the ratio $\eta$ of the stiffness of the cross-section piles $EI$ and deformation properties of the soil $E_0$.

4. Conclusion

Thus, the analysis of piles in landslides allows to draw the following conclusions:

The second row of piles with a stable array below the pressure of the wall on the slope of the landslide is advisable to apply at the location of the point of application of the resulting landslide pressure from the bottom of the pile cap on the value of $0.2 \ldots 0.3 \, L$, where $L$ is the length of the pile.
At a deeper location of the point of application of landslide pressure the efficacy of the second row of piles reduces.

It is recommended to use double-row pile wall on the landslides, the body of which is composed of relatively weak soils.

Composed of double row of walls with great effect work short piles with a greater transverse rigidity.

The first row of piles, it is advisable to design more durable in comparison with piles of the second row.

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