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Stress-strain and stability analysis of tailing dam Toranica – Kriva Palanka

Analyse de contrainte-tension et de stabilité du barrage de produit de queue Toranica - Kriva Palanka

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ABSTRACT

This paper deals with stress-strain and stability analysis of tailing dam Toranica – Kriva Palanka for specific stages of construction. In the technological concept of the mine for lead and zinc Toranica - Kriva Palanka (north-east of Republic of Macedonia), a tailing dam for disposal of flotation barren soil which remains after the processing of the mine material had been constructed. This tailing dam exists in the past 20 years. On the upstream side there is an embankment retention dam for diversion of river Kriva Reka into drainage tunnel. The tailing dam is on the down stream side made by fine sand and silt as products of flotation process.

The works in the mine Toranica had been stopped for some years. Stress-strain and stability analysis has been made for the existing conditions of the tailing dam and for the design conditions with upgrading of the tailing dam. The crucial parameter was defining of the need of the drainage carpet to the toe of the down stream slope of tailing dam. The calculations have been carried out by finite element method using geotechnical software package PLAXIS and by limit equilibrium method using software package GGU Stability.

RÉSUMÉ

Ce document traite l'analyse de contrainte-tension et de stabilité du barrage de produit de queue Toranica - Kriva Palanka pour les étapes spécifiques de la construction. Dans le concept technologique de la mine pour le fil et le zinc Toranica - Kriva Palanka (nord-est de la République de Macédoine), un barrage de produit de queue pour la disposition du sol stérile de flottaison qui reste après que le traitement du matériel de mine ait été construit. Ce barrage de produit de queue existe pendant les dernières 20 années. Du côté amont, il y a un barrage en remblai pour la déviation du fleuve Kriva Reka dans le tunnel de drainage. En aval, le barrage de produit de queue est composé du sable, vase fine et des produits du processus de flottaison.

Les travaux dans la mine Toranica avaient étéarrêtés pendant quelques années. L'analyse de contrainte-tension et de stabilité concerne les conditions existantes du barrage de produit de queue et les conditions de conception avec développement du barrage de produit de queue. Le paramètre crucial était la définition du besoin du tapis de drainage au point le plus bas de la pente en aval du barrage de produit de queue. Les calculs ont été effectués par la méthode d'élément fini utilisant le logiciel géotechnique PLAXIS et par la méthode d'équilibre de limite utilisant le logiciel GGU Stability.

Keywords : tailing dam, stability analysis, drainage, FEM.
For creating the first accumulation, initial dam with height of 12 m with crest on the embankment on peak elevation 945.00 m asl was created. The volume of the retention dam is approximately 11.150 m$^3$ with material from the river alluvium of Kriva River with removing of bigger blocks and installation in layers with mechanical compacting. Central clay core has been constructed to provide impermeability of retention dam.

The transferring of the water from Kriva Reka was made through outlet deviation tunnel, which was placed on the left side of the valley of Kriva Reka.

Because the space of the tailing dam is constructed for depositing only of the hard phase of the pulp, separated and clear water from the tailing dam as well as the atmospheric water is transferring through the outlet collector. The outlet collector is with circle cross section with diameter of 800 mm, performed by reinforced concrete.

3 SITE AND LABORATORY INVESTIGATIONS

Site and laboratory investigation works are performed for providing geomechanical parameters for the strain-stress and stability analyses of the tailing dam “Toranica”.

Six investigation wells with depth of 0.70 - 1.20 m are performed and it is concluded that up to the depth of 1.00 m on the middle of the tailing dam, on the place where previously the river bed of Kriva River was placed, appears a layer of silt gravel (alluvium), while on the hill sides silt gravel (diluvium) is appearing.

A number of samples were taken for the necessary laboratory testing in order to define geomechanical parameters.

4 METHODS OF ANALYZE

Taking in consideration the geomechanical parameters obtained by geomechanical investigations and laboratory tests, are adopted representative geomechanical parameters enclosed in the Table no. 1

<table>
<thead>
<tr>
<th></th>
<th>cohesion C [kPa]</th>
<th>Angle of internal rupture [°]</th>
<th>Volume weight [kN/m$^3$]</th>
<th>Modulus of compressibility [kPa]</th>
<th>Coefficient of filtration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flotation mud</td>
<td>0.00</td>
<td>15.00</td>
<td>14.10</td>
<td>15.40</td>
<td>2.70</td>
</tr>
<tr>
<td>Sandy dam</td>
<td>0.00</td>
<td>28.00</td>
<td>17.50</td>
<td>18.10</td>
<td>4.50</td>
</tr>
<tr>
<td>Alluvium in river bed</td>
<td>0.00</td>
<td>38.00</td>
<td>21.40</td>
<td>/</td>
<td>44.45</td>
</tr>
<tr>
<td>Dried rock</td>
<td>0.00</td>
<td>38.00</td>
<td>23.00</td>
<td>/</td>
<td>230000</td>
</tr>
</tbody>
</table>

5 ANALYZE OF RESULTS

5.1 Stress-strain analyze with finite element method

Stress-strain analysis of the hydro tailing dam in the mine Toranica, with finite element method with the software Plaxis was made for 2 characteristic cases: without drainage and with drainage.

With analyze of the condition for normal operation of the tailing dam without drainage, it was concluded that the filtration line is on the downstream too of the dam, which could cause potential instability and the factors of safety for certain sliding surfaces drops to the value of 1.0.

The analyze made for the designed conditions without drainage, presents that if the tailing dam works with full capacity, the water level inside will form a filtration line the stationary regime of work in the embankment sandy dam (appearance of water near the downstream too–Figure 2). Conducted filtration flows and piezometric line will appear at the slope which could cause washing of the tiny material from the slope close to the too of the embankment with local instability which can cause disturbing of the global stability of the sandy dam on longer period of time (Figure 4).

Two cases were analyzed for the condition of the hydro tailing dam with drainage in the middle lowest part (the part of the former river bed of Kriva reka). First case is during normal work of the tailing dam and the second case is if the collector is not in function, which will rise of the level up to the peak elevation 987.5 m asl. In both cases the drainage is in function, it decreases the piezometric line under the slope of the sandy dam for a distance that will disable the capillar raising and freezing of the water (Figure 3). The factors of safety of the global stability is higher than 1.5.

Figure 2. Filtration line during normal regime of work without drainage
The analyze made for the level of the water up to the peak elevation 987.5 m asl without drainage (case of termination of the collector work or appearance of upstream flooding wave) shows that the filtration line is appearing on the downstream slope of sandy dam (Figure 6), which could cause some instability problems as mentioned before for the case without drainage.

5.2 Slope stability analysis by limit equilibrium method

The slope stability analysis of the sandy dam with the limit equilibrium method was carried out with the computer program GGU - Stability, with circle sliding surfaces with Bishop method. The slope stability analysis was consisted of determining of the global and local stability of the highest profile of the sandy dam for most unfavorable case of ground water (piezometric line).

With the slope stability analysis performed for the actual condition of the tailing dam with piezometric line adopted according to piezometers monitoring, the factor of global stability is \( F_s = 1.54 \) (Figure 7), which is higher then the minimal allowed according to the regulations for this kind of slopes \( F_{min} = 1.3 \). It points out that the sandy dam in these conditions is stable. It should be pointed out that during the analysis local shallow sliding surfaces are appearing on the slope of the sandy dam because of the variable inclination of the downstream slope, which could affect the global instability on long term.
For long term and active use of the hydro tailing dam, it is strongly recommended performance of drainage blanket (Figure 10);

The stability of the sandy dam in conditions of active use and appearance of flooding wave or termination of the collector operation is not satisfying;

The results of the slope stability analysis for the designed case for the level of 990 m asl without drainage show that the piezometric line is appearing on the downstream slope close to the too which could cause slope erosion and long term instability;

In the process of active use of the hydro tailing dam and exceeding the existing height of the sandy dam, it is strongly recommended to achieve and to respect the designed downstream slope of 1:3, as a condition for stability of the hydro tailing dam.

Continuous monitoring of the water level in the piezometers and in the accumulation has to be conducted;

It is recommended ABA leaching test to be conducted, as a measure for preventing possible environmental impact.

REFERENCES


Eurocode 7 Geotechnics, commission of the European Communities, 1989;
