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# Summary

Subject: doctoral thesis entitled: "Multivariate analysis of the segregation process and thickening of copper ore tailings in terms of their storage" developed at the Wrocław University of Science and Technology, Faculty of Civil Engineering and Water, Department of Geotechnics, Hydrotechnics, Underground and Water Construction, Wybrzeże Wyspiańskiego 27, 50-370 Wrocław. PhD student: M.Sc. Eng. Zbigniew Skrzypczak, supervisor: dr hab. engineer Adrian Różański prof. PWr, auxiliary supervisor: Dr. Eng. Irena Bagińska.

KGHM Polska Miedź S.A. is the largest in Europe and one of the largest copper producers in the world. It owns deposits in Europe and both Americas. In Poland, it exploits the largest copper ore deposit in Europe, and the technological process includes underground mines, ore enrichment plants and smelters. In the process of copper ore enrichment - flotation, a water suspension of finely ground rock (slurry) is created, which is waste during enrichment. It constitutes approximately 93% of the total output supplied by all three mining plants. The weight ratio of water to rock material is approximately seven to one. Therefore, the flotation process requires the supply of large amounts of process water. Both the water supplier and the post-flotation waste recipient are performed by the Hydrotechnical Plant Branch (O/ZH). A long-term perspective of the continuity of exploitation of copper-bearing deposits by KGHM Polska Miedź S.A. when the capacity of the currently operated tailings storage facility was exhausted, it led to the need to build a new place for depositing rock waste. In line with the development of deposition techniques, the new project includes the processes of segregating post-flotation waste in terms of the size of grains carried in the slurry and thickening both the part of the waste containing segregated coarse fractions and the remaining small fractions.

The paper deals with the implementation of planned technological changes in the field of waste deposition at the Tailings Storage Facility (TSF) managed by KGHM Polska Miedź S.A. O/ZH. The issue covers both the current operation consisting in depositing uncompacted waste at the Żelazny Most TSF, as well as the direction of changes including the implementation of segregation and thickening processes at the Kwatera Południowa TSF. The general aim of the work is to analyze the equilibrium state of the mutual growth of zones: the dam body and the canopy in the Żelazny Most and Kwatera Południowa TSF after the implementation of planned technological changes in the field of waste deposition. In particular, the considerations concern the development of a methodology for obtaining materials suitable for the construction of the static body and the distribution of waste streams between individual waste storage facilities in such a way that it is possible to ensure continuous operation of both facilities (Żelazny Most Storage Facility and Kwatera Południowa Storage Facility) over an appropriately long time horizon. A sufficiently long time horizon is understood here as a period of time during which it will be possible to store waste undisturbed and at the same time it will be sufficient to identify and implement improvements and modifications to ensure further continuity of operation in the event of difficulties occurring during the actual operation of the facility.

In order to achieve the above-mentioned goal of the work, it was necessary to carry out a multi-variant analysis of the process of segregation and thickening of copper ore post-flotation waste in terms of their simultaneous storage in both facilities, i.e. TSF Żelazny Most and Kwatera Południowa. Due to the high complexity of the process, it required the implementation of three separate issues constituting a related whole. Even though these tasks were considered separately, they lead to conclusions that can only be formulated taking into account their mutual influence. The following issues were identified as separate research problems:

i.) multi-variant parameterization of the hydrocycloning process,

ii.) the process of washing separated waste - verification of the possibility of using floating pipelines,

iii.) multi-variant analysis of the distribution of waste streams between individual waste storage facilities.

As a result of the analyzes carried out in the line, two calculation procedures were developed in the form of calculation files, allowing not only to preview the estimation of current operating parameters, but also to analyze potential changes.

The first procedure concerns the analysis of the operating parameters of the hydrocyclone. It was calibrated using comparative analysis with the results of work during the start-up of the "SSiZO" installation. It allows you to determine the main parameter of the hydrocyclone's operation, i.e. the size of the division grain. This parameter determines the quantity and quality of the segregated pour. The possibility of ongoing changes to hydrocyclone parameters, such as feed pressure or the diameters of replaceable pouring and overflow stubs, allows determining the required directions of modification of the hydrocyclone in order to achieve the required changes in material quality. Of the six analyzed formulas (models), the ones that best describe the current hydrocycloning process based on the type of hydrocyclone built into the "SSiZO" installation were indicated. For the equations selected in this way, constants were determined individually for the existing process parameters, allowing for minimizing the deviation of the calculated values from those recorded in the actual technological process. At the same time, other formulas have not been removed from the analysis procedure, which may describe the process more precisely in the future in the event of changes in the type of hydrocyclone used or changes in the range of the feed stream.

The second analysis, concerning several dozen years of operation of the Żelazny Most TSF, made it possible to determine the relationship between the growth rate of the beaches and the amount of waste directed to them, along with determining the parallel increase in the elevation of the internal part of the facility, represented by the elevation of the water table of the reservoir. Thanks to the approach proposed by the author, it was possible to obtain the required amounts of waste masses for deposition, resulting in an increase in the beach elevation by 1 meter individually for each of the 26 sections of the TSF without the need to analyze the volume density of the soil skeleton in individual waste deposition zones. This is important because the variability of the size of these zones over time, as well as the variability of the bulk density of the soil skeleton in the area of the beach and body zones, limit the possibility of rounding the parameter values for the entire zone. Linking the relationship between the deposited masses and the increase in zones together with the design data of the Kwatera Południowa TSF allows for the prediction of the increase in the elevations of individual areas of the facilities during their mutual cooperation and allows for predicting the effects of managing individual waste streams between the facilities. Using a simple calculation tool for this purpose, available to the operating staff, allows for both estimation of decisions regarding the scheduling of inflows and supplementing current data. It also allows for the refinement of calculation parameters and future optimization in terms of the accuracy of estimated data. The ability to edit the adopted formulas and dependencies also gives the opportunity to modify them in line with changes introduced in technology, which should make them more flexible compared to the closed analysis of current data.

Based on a multi-variant analysis of the distribution of waste streams, a problem was demonstrated regarding the shortage of coarse-grained material during operation involving both cooperation of both facilities and in the case of maintaining the current technology of independent operation of the Żelazny Most TSF. The author proposed one of the potential solutions to reduce these shortages, consisting in processing the Polkowice waste stream.

The study demonstrates the positive impact of such a procedure on the facility operation process. The problem of shortage diagnosed in the work, as key to maintaining the continuity of waste deposition, turned out to be so important that in parallel with the development of this pipeline, two independent, external institutions analyzed its potential impact. These studies confirmed the validity of the problems posed here, as well as the validity of the solutions proposed by the author. This is important because it confirms the utilitarian nature of these analyses.