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ROZPRAWA DOKTORSKA

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METODA ODSPAJANIA SKAŁ Z UŻYCIEM KOTEW

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ABSTRACT

The topic of the work stems from the need to find an alternative to the known and commonly used method of mechanical mining. In some geological and mining conditions, there is a strong need to reduce the negative effects accompanying traditional mining methods, such as: mechanical mining technologies in the vicinity of critical structures, industrial installations, foundations, or technologies based on explosives (blasting), which result in vibrations or the emission of gases harmful to health and environment.

A particular example of the need develop new technology is the problem of emergency tunneling in complex geological conditions in a way that does not cause the propagation of a zone of rock failure and/or their collapse.

No attempts have been made so far to describe the phenomenon of anchor pulling, in the context of the deliberate detachment of the largest possible fragments of rock from the rockmass.

Based on the analysis of existing solutions used in techniques for fixing metal structural elements in concrete engineering structures, it was concluded that there is an opportunity to adapt this technology, for the controlled pulling out of anchors, mainly undercutting anchors, in order to detach larger lumps of rock.

The assumptions of the method of rock detachment with the use of anchors and the analyses carried out on the failure mechanisms of the anchor joint, as well as the analytical models developed so far for concrete - especially in terms of determining the anchor pullout force (its load capacity) are described in the first chapters.

Both rocks and concretes are grain materials, and their behavior has some similarities due to their strength and deformation properties.

However, rock media often have, due to their genesis, different physical and mechanical parameters and structural characteristics than concretes. As written earlier, there has been no research to date on the phenomenon of anchor pullout in the context of obtaining an efficient method of excavation. Therefore, laboratory and in-situ tests were conducted, pulling out the undercutting anchors. The research was carried out at both rock mining sites and underground mines.

As part of this stage of work, samples were also taken for laboratory strength and deformation tests, determining material constants that characterize rock properties, including tensile strength f_t, compressive strength f_c, Young's module E, Poisson's ratio ν and cohesion c.

The doctoral dissertation presents the results of own tests of more than 120 pull-out tests of undercutting anchors, using the original instrument, with simultaneous measurement of the pull-out force. The tests were accompanied by optical 3D scanning of the failure cones and analysis of the propagation (trajectory) of the detachment crack. Detachment tests and failure cone interaction studies were also conducted for 2- and 3-anchor systems.

Based on the study, an empirical model was developed to: predict the value of the pullout force F, the extent of detachment Z and the volume V of rock detachment/destruction depending on the effective anchorage depth hef and the compressive strength of the rock f_c. In turn, the analytical model presents solutions and formulas that allow: predicting the extent of

the Z detachment depending on the compressive strength f_c, the anchorage depth hef, the head angle α and the coefficient of friction of the rock against the anchor head μ. Knowing the value of the force required for the detachment and the predicted extent of the propagation of the detachment crack, it is possible to implement the detachment process while maintaining the specified dimensions of the excavated tunnel.

The assumptions of an artificial neural network (ANN)-based advisory system for effective prediction of the parameters of de-anchoring process under field conditions, depending on the anchoring parameters used and rock properties, have been developed and described.

Numerical analyses were carried out using the Finite Element Method (FEM) for 2D models and axisymmetric 3D models for the anchorage depths used in the experimental studies and for the rock properties determined earlier, in laboratory tests. The numerical analyses carried out showed that for the anchorage depths and mechanical parameters of the tested rocks, the extent of the failure surface is much larger than that implied by existing calculation procedures used in concrete structures, e.g. CCD (Concrete Capacity Design), and its shape does not at all resemble the cone assumed in these methods. In the case of multi-anchor systems, the results of the FEA analysis showed the effect of cone interaction for certain ratios s/h_{ef} (s - distance between anchor axes). FEA-3D simulations show that the limit value of the s/hef ratio for which there is a failure cone interaction is of the order of 5.0-5.4. This is significantly higher than what is recommended by the CCD method ($\leq$3).

The results obtained coincide with the empirical results of field studies. They have important implications for the potential planning of hole placement in the rock stripping technique with the developed method.

The research and its results and the models presented were analytical solutions.

The purpose of this comprehensive research was also to present the possibility of their utilitarian application. In the last chapters of the work, a proposal is made for a modified method of pulling rocks out from the rockmass, using the bottom of the hole for stripping. This solution improves the implementation of the pull-out process. The directions of further work on this phenomenon have been defined, and the construction of a prototype, author's solution of the pull-out head, using a screw mechanism and a torque multiplier, have been presented.

The studies, their results, models and solutions presented in the doctoral dissertation of the work constitute a certain closed whole of the description of the phenomenon of rock detachment from the rockmass by the method of pulling out undercutting anchors. The results of these studies prove the possibility of precise and effective detachment of selected rock fragments in special conditions, for example: during rescue operations, removal of pillars or overgrowth of waste rock in the deck (longwall mining).