Global Monitoring of Changes in the Rock Mass Arising as a Result of Filling the Mining Workings with Wastes.

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Key words: rock mass deformations, FEM modeling, geoinformatics

SUMMARY

The article presents the concept of the application of the Finite Elements Method in the global monitoring of changes in the rock mass and on the surface of the area, arising as a result of filling the workings. Mining activities using waste materials in securing old workings, according to the Geologic and Mining Law, should be monitored to control the influence on the rock mass and surface. Mining workings are being measured with geodetic methods and the monitoring of their impact on the rock mass is carried out. In case of filling in workings with waste materials, such an action should be controlled with methods enabling to present the location and quantities of the materials deposited in the rock mass, as well as their influence on the rock mass and surface. In the monitoring of changes in the rock mass modern computer technologies are applied, based on the known theories of model studies, so that the results could cover the problem in a complex way and become comprehensive to many specialists in different areas connected with mining activities, geo-engineering and construction. Waste materials applied in mining technologies can have a strong influence on the rock mass and surface. According to the regulations, this process should be carefully monitored, especially in terms of the safety of surface objects and rock mass stability. The article presents the concept of an analytic and graphic presentation of the results of the measurements of old workings, applying the Finite Elements Method in model studies. The main purpose of such interpretation of the geodesic observations results in old workings is the application of methods providing wide possibilities to present the geometry of workings, their changes and the influence of the rock mass on the surface.

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1. INTRODUCTION

Constant growth in the quantity of the produced waste materials demands the application of environmentally safe methods of their disposal. In the European Union there are legal regulations about landfills. These regulations precisely define the requirements for the underground deposition of wastes. Mining activities, using waste materials in securing old workings, according to the Geologic and Mining Law in Poland, must be monitored to control the impact on the rock mass and surface. A very important factor of control and monitoring are geodesic measurements that in many cases are basic material to make important decisions about safety and the prevention of mining damage on the surface. Thus the studies on making the rules for geodesic monitoring in the areas of the waste deposition are carried out.

The application of waste materials in mining techniques is treated as the reuse of wastes. Wastes can be used in underground mining techniques for:
- the liquidation of unnecessary workings, including shafts,
- the enforcement and stabilization of mining workings.
- as a component of stowing,
- as a material for sealing workings formed as a result of the exploitation in caving system.

Waste materials used in mining techniques can significantly influence the rock mass and surface and this process, according to current regulations, should be carefully followed, especially due to the safety of the functioning of surface objects and the stability of the rock mass. Due to a specific structure of a medium such as the rock mass, the applied methods should be adequate to this complicated structure. The methods should:
- meet the needs, i.e. take into account a complicated structure of the medium,
- if possible, make progress in the development of numeric methods and their software.

In such cases a proper monitoring of mining areas should be carried out with such methods, so that it could be possible to define geometric shapes of workings filled with wastes, their localization in the rock mass and mining-caused deformations in mining areas, including effect on the objects on the surface. Analytic and graphic presentation of the measurement results should cover all these factors, thus the applied methods should give the full view on the impact, especially in the aspects connected with the safety of the infrastructure's work on the surface. For a problem put in such a way, numeric models of the Finite Elements Method are very useful, because all these problems can be thoroughly analysed in one algorithm and professional software. According to the author, one should apply modern computer techniques based on the known theories of model studies, so that the results could cover the problem in a comprehensive way and are understandable in wide circles of specialists in different disciplines related to mining, geo-engineering and civil engineering. The results of geodesic

measurements were given with the Finite Elements Method, with the application of the ABAQUS software. The ABAQUS software makes a very good tool giving wide possibilities of analyses in the geometrization of workings and the studies of deformations – both for the rock mass, making the initial cause - and for engineering objects on the surface, where the results are observed. In the studies, the segments of the ABAQUS software installed in the Academic Computer Centre CYFRONET AGH in Krakow were applied. In the calculations powerful computers were applied. The applied: programs were ABAQUS CAE and ABAQUS/solver as well as a special library for the studies in geotechnical analyses.

2. GEOMETRIZATION OF UNDERGROUND WORKINGS WITH THE APPLICATION OF GEODESIC MEASUREMENTS AND THEIR MODEL PROCESSING WITH FEM.

The base and fundamental source material in the monitoring of the results of filling post-exploitation cavities in the rock mass come from geodesic measurements. Thus such observations and methods should be used so that the results of the applied methods of the liquidation of workings could be assessed properly. In many cases classical measurement methods on the surface do not allow full and safe interpretation of the changes in the rock mass, and – consequently – the prevention of mining damage. Preliminary analysis of the impact of the applied methods of the liquidation of voids in the rock mass, will allow a proper planning of the geodesic observations and special measurements. The analysis of measurements was referring to the Salt Mine of Łężkowice, where post-exploitation voids were filled with slag from the waste heaps of the T. Sendzimir Steel Works in Krakow. In the Borehole Salt Mine Bochnia-Łężkowice the exploitation was carried out with the borehole method. Formed in the rock mass caverns were measured with an echo-sonar and then high-furnace slag was put to fill the rock mass to minimize deformations. The measurements were made in subsequent observation series on levels from 96 to 134-metre depth. Despite securing the underground working by filling the cavity with slag and regular geodesic observations, it was not possible to prevent the subsidence of over 20-m depth on the surface. According to the accepted concept of the model interpretation of results in the pre-processing of FEM, measurement results were given and their geometric visualization was presented. The applied program ABAQUS-CAE gives great opportunities in the interpretation of measurement result and makes a good tool allowing geometrization of voids and subsidence, and - at the same time – a good material for branch interpretation. The decisions related to safety and prevention of the negative exploitation impact could be made. The calculations of the volume of solids allowed the analysis of the quantity of the slag used to fill the voids and compare to the volume of the subsidence on the surface.
In figure no. 1 there is a graphic presentation of the results of measuring the chambers with an echo-sonar, and figure 2 presents a 3D model of chambers and the subsidence on the surface.

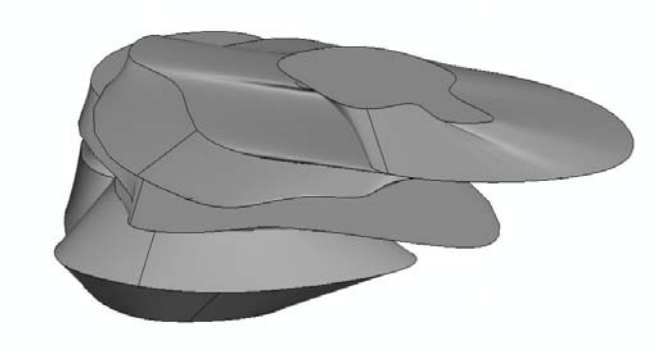

Fig. 1. Post-exploitation chambers measured with an echo-sonar

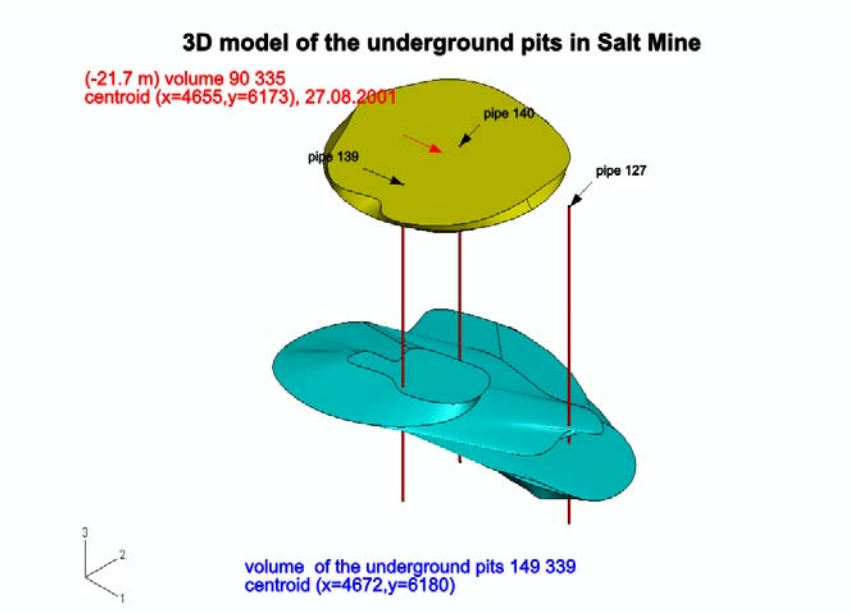

Fig. 2. 3D model of chambers and the subsidence on the surface

Differences of the co-ordinates of the geometric centres of solids indicate the dislocation of the subsidence in the relation to the working. The presented geometric model made base for further studies aimed at examining not only the shape of the voids, but also changes in their geometry, i.e. rock mass deformation resulting from the exploitation, as well as filling the voids with waste materials.

3. THE APPLICATION OF FEM IN THE STUDIES OF THE IMPACT OF LOCATING WASTES IN POST-EXPLOITATION WORKINGS.

To show the possibilities of the application of FEM models in the geometrization of workings and rock mass deformation studies, a 3D model was made, where the workings were voids made as a result of exploitation. The FEM Model consists of 1 300 000 elements and was

calculated in ACK Cyfronet. The calculations were made to determine the impact of mining activities on the surface in the region of chambers measured with an echo-sonar. The analysis of changes on the surface is a subject of a separate paper and requires the verification of model premises based on geodesic measurements. In figure 3, a fragment of the model in the region of chambers on the level of -100, -122 m is shown. The presented results show vertical deformations in the region of caverns, calculated for the Drucker-Prager model.

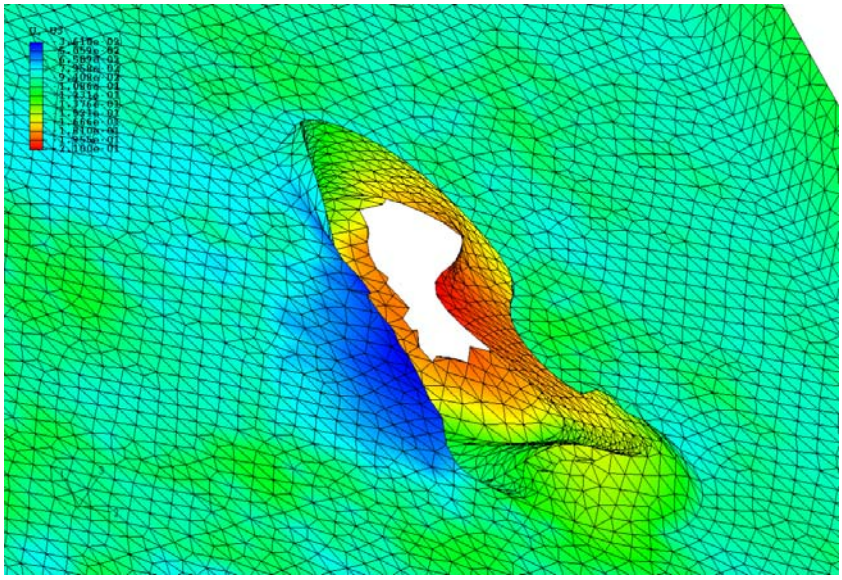

Fig.3. A 3D model of post-exploitation chambers on –100 to – 122-m level.

There is a possibility of calculating deformations made as a result of exploitation and the changes resulting from filling the chambers with high-furnace slag. In any indicated place of the model one can calculate deformation indexes and changes is shape, which can make valuable material in the interpretation of the results of the impact of the liquidation of post-exploitation chambers by filling them with slag – a waste product from the T. Sendzimir Steelworks in Krakow.

4. GEODESIC MONITORING OF THE IMPACT OF THE LIQUIDATION OF WORKINGS WITH THE APPLICATION OF WASTE MATERIALS.

4.1 Periodical levelling measurements on the surface of the mining area

As it was shown in the analysis of geodesic measurements carried out in the regions influenced by filling post-exploitation voids with waste materials, discontinuous deformations should not be expected. Despite filling underground chambers with slag from the steel works, there was a subsidence on the surface, which should be regarded as harmful impact of mining on the environment. In fig. no. 4 the localization of subsidence and isoclines of the subsidence speed in the period directly preceding discontinuous deformations. Levelling measurements did not indicate the situation making threat and dangerous situation on the surface.

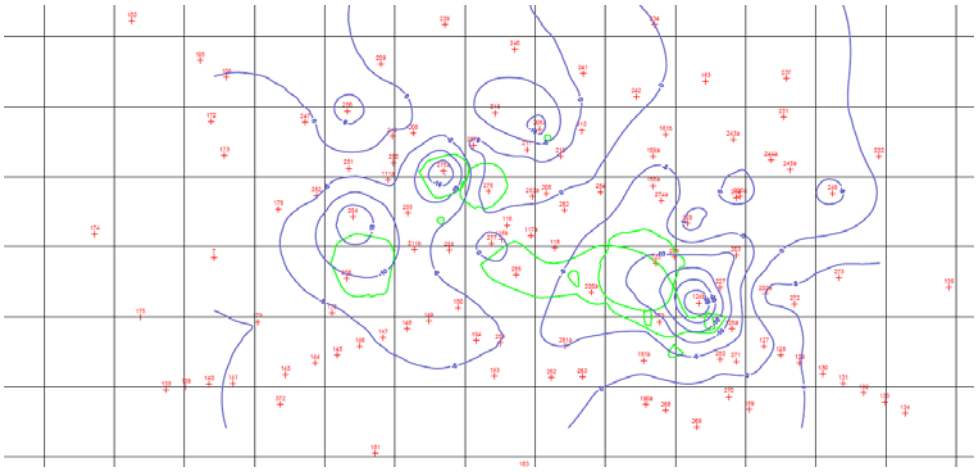

Fig 4. Isoclines of subsidence speed in the period between May and November 2001.

To avoid hazard on the surface special geodesic measurements in threatened regions should be made. The localization of places covered with special measurement and the applied technologies can be indicated based on the preliminary analysis based on model studies of the rock mass with FEM. A comprehensive analysis and geodesic monitoring of rock mass deformation in the regions of the use of wastes in mining techniques, with one method FEM, both design stage and the interpretation of results are covered.

4.2 Special measurements.

In regions particularly threatened with discontinuous deformations special geodesic measurements are necessary to assess deformations on the surface. Such measurements should be made in such a way that their analysis and interpretation give the possibilities for a global assessment of deformations. The point image of the changes on the surface, as a result of geodesic measurements, should be based on model studies making the approximation of the existing changes in the whole area covered by the measurements. In the places threatened the possibility of discontinuous deformations, local angular and linear networks can be designed, e.g. in the form of rosettes presented in fig. 5.

The measurement of such constructions does not make a problem, however the selection of equipment and the method of processing the results are important. The equalizing of the observations should be carried out in a free system, allowing the possibility of the displacement of all the studied points.

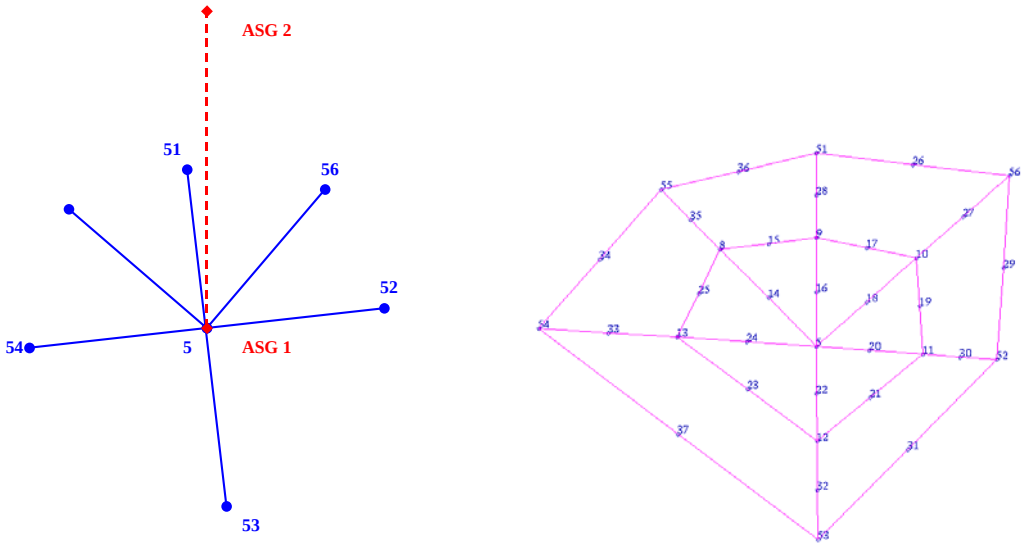

Fig. 5.Local networks of special measurements.

The application of FEM programs provides great opportunities of the calculation of the measurements of deformation indexes in the whole study area. The purpose of the carried out calculations was to mark the co-ordinates of strains tensors in the study area. Figure no. 6 presents displacements and a graphic image of the co-ordinates of strains tensors, based on the calculations made in FEM with the application of ABAQUS programs.

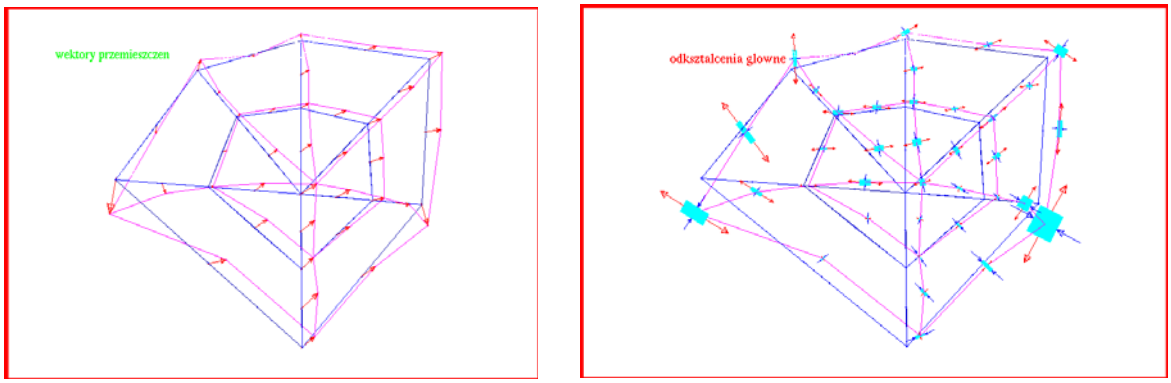

Fig. 6. Dislocation vectors and coordinates of the tensors of main strains

The obtained in such a way results make a significant extension of the information on the state of the rock mass deformation in the zone particularly threatened by discontinuous deformations. The results of the calculations allow significant conclusions and can make base for important decisions on the prevention of dangerous impact resulting from mining activities.

5 CONCLUSIONS.

A general concept of the monitoring of the results of using wastes mining activities was presented. The main idea of the method is the application of one calculation algorithm on different stages of the analyses, starting from the preliminary analysis, through the design and measurement stages, to the interpretation of results. Such studies are a comprehensive project and can make base for branch interpretations and decisions about putting wastes in the rock mass to minimize negative impact on environment and limit mining damage. Global geodesic monitoring and analytic processing of results allow a 3D localization of deposited wastes and detail analysis of the results in the form of geometric changes in the rock mass, especially on the surface, where a particular attention should be paid, due to the protection of environment and safe functioning of buildings.

REFERENCES

1. Cieślik J., Pietruszka K.: Analysis of the exploitation and disposal post-exploitation voids, in the region on chamber E140 in OKS Łezkowice, using MES and geodesic measurements, XII Mining Workshop 2008, Conference Baranow Sandomierski 18-20.06.2008.
2. Pietruszka K: Geometrisation of post-mining headings filled with waste materials. Polish Academy of Sciences – Cracow Branch, Proceedings of Geodesy and Environmental Engineering, Commission - Geodesy 43, p.17-28, 2007
3. Pietruszka K.: Geodetic supervision of construction facilities in the areas of mines using waste in underground headings removal. Reports of the 8th Scientific-Technical Conference „Current Problems of Engineering Surveying", Reports of Geodety, No 1(82), 2007, s. 259-267, Politechnika Warszawska, Polska Akademia Nauk, Białobrzegi 30.03.2007 –31.03.2007.
4. Pietruszka K: Geodetic inspections of mining areas in regions affected by the storage of waste in underground mining pits. FIG Working Week, International Federation of Surveyors, Hong Kong, 13-17 maj 2007.

BIBLIOGRAPHICAL NOTES

Main professional achievements :
– Ph. D. – 1981 University of Mining and Metallurgy, Krakow, Poland, on subject: Modelling a deformations of the constructions using Finite Element Method
– Supervisor of Grant in Polish State Committee for Scientific Research (1994-1996): 3-dimensional description of rock mass and surface subsidence deformations along with hazards during mining activities.
– Supervisor of Grant in Polish State Committee for Scientific Research (2005-2008): Geodesic Monitoring of filling the mining workings with wastes.
– Developer of a method of prediction and examination of the deformations in rock mass and subsidence at the underground architecture areas. GAMMA - Geotechnical Applications Method of Modelling Analysis
– Scientific research in Polish State Committee for Scientific Research on subject: Prediction of underground architecture influence at the infrastructure of rock mass and surface.

Position:
– academic teacher and scientific staff
– 1999-2002 - Vice dean of the Faculty of Mining Surveying and Environmental Engineering in University of Mining and Metallurgy in Krakow, Poland

Field of specialization :
– Surveying
– Engineering and Industrial Surveying
– Mining Surveying
– Using Finite Element Method in modelling results of the deformations in building constructions, rock mass and surface at mining areas,

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