

# **Geodetic Inspections of Mining Areas in Regions Affected by the Storage of Waste in Underground Mining Pits**

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**Key words:** geodetic surveys, waste material deposit, deformation mining areas

## **SUMMARY**

Storing waste materials in mining pits is a very extensive subject and has also become the focus of a specialised field of research. Many such studies are based on geodetic surveys, which are a source of important information about changes on the surface. Mining technologies making use of waste materials should be monitored by means of geodetic methods, both with regard to the scale of the waste materials stored and their impact on formation and surface. The formation, as a centre with a very complex structure, requires special care in terms of geodetic measurements as far as the selection of measurement methods is concerned, as well as when it comes to analysis and the interpretation of results. The present article discusses one particular way that model analyses of the finite element method can be used to examine geometric changes resulting from the use of waste materials in liquidating underground pits. The article describes the application of model methods in studies of rock mass deformation and infrastructure on the surface based on the example of borehole salt extraction and the liquidation of underground pits by backfilling them with waste material.

# Geodetic Inspections of Mining Areas in Regions Affected by the Storage of Waste in Underground Mining Pits

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## 1. INTRODUCTION

The activities of many industrial domains lead to the production of the excess of redundant substances and wastes, what makes it necessary for their storage in the way which is not harmful for the environment. The existing mining pits might be brought into cultivation as redundant substances dumping ground, and the activity, by means of filling the after-exploitation empty spaces, will lead to the limitation of mining damages what is one of the priority tasks of mining plants. According to the regulations which are in force in Poland, wastes can be used in the so-called waste recovery process in the liquidation of the underground mining pits. Redundant materials can be deposited in the existing active mining pits in the liquidated mines as well as one can build the new containers, what shall be considered as an alternative solution depending on the economical aspects of the decision and the comprehensive evaluation of the results. Storing wastes in mines give a double result in the form of:

1. solving out the problem of redundant substances storage,
2. limitation of mining damages by means of the liquidation of after-exploitation empty spaces.

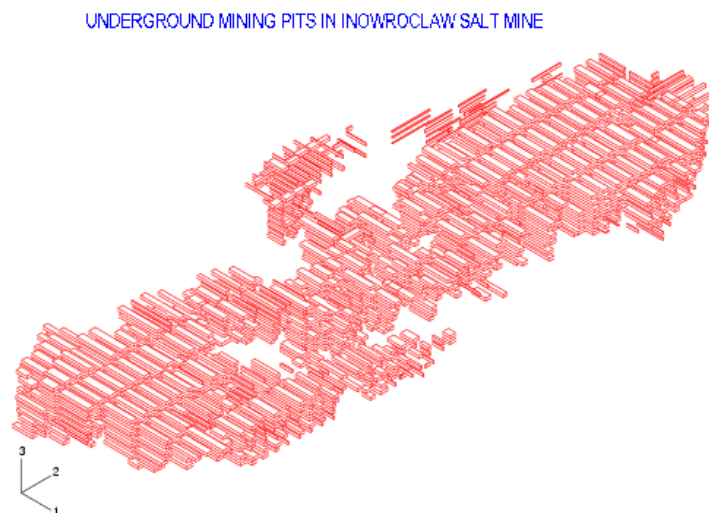
The way of treating the both factors as one, from the mining geo-engineers point of view, can be interpreted as the recovery of wastes by means of their application in mining techniques. A very essential and harmful effect of boring the mining pits is the creation of deformations of engineering objects on the ground. The underground mining pits are the disturbance to the equilibrium state in the rock mass and they cause the reaction of the rock mass, however the process shall be traced and as maximally as it is possible, the mining damages which occur in the region shall be limited. Filling the mining pits with the redundant substances in the liquidated mines will become its protection, so the limitation of mining damages on the ground. The process requires a careful control and geodetic measurements is one of monitoring activities. The measurements will be carried out in order to:

- to take stock of the mining pits intended for the liquidation by means of lifting them with the use of waste materials,
- geodetic control measurements on the surface
- control of the effects of storing wastes in the rock mass in geodesic examination of deformation of objects located on the surface of the mining area.

## 2. STOCKTAKING OF THE UNDERGROUND MINING PITS INTENDED FOR THE LIQUIDATION WITH THE USE OF WASTE MATERIALS

### 2.1. Underground Exploitation of the Salt Mine Inowrocław

Stocktaking of the underground mining pits, from the point of the view of the measuring methods, is not an engineering problem, if there is a direct access to the underground mining pits. Modern calculation methods create however great possibilities for the interpretation and analysis of the measurements results. The problem will be presented on the example of the Salt Mine in Inowrocław. Figure 1 presents the possibility of a graphical presentation of the measurement results taken by means of geodetic methods, in case of the access to the underground chambers. The results of the geodetic stocktaking are presented by means of ABAQUS CAE program on the basis of the file written by the autor of the article in the ABAQUS STANDARD software convention. Thanks to the elaborated concept of nodes numeration (FEM – Finite Element Method), on figure 1 a model was presented, which consists of 16 000 nodes creating the elements of FEM net in the spatial model showing the geometry of mining pits. The area presented on the figure, includes the mining pits located on the depth to -465m and on the area 2200 m long and 700m wide.



**Fig. 1**

Using the visualization program allows to perform the underground chambers stocktaking, which were filled with brine as a waste product in the leaching process.

The application of FEM programs for the presentation of stocktaking measurements is the initial stage for its further interpretation with regard to the occurred changes in the rock mass in model analysis. Figure 1 shows the results of such analysis indicating the zone of mine chambers brine filling influence.

## 2.2 Stocktaking of Underground Caverns in the Regions of Salt Exploitation with Leaching Method.

Salt exploitation in the Salt Mine Bochnia-Łęzkowice was carried out by means of an leaching method. The after-exploitation empty spaces which occurred as a result of it, lead to changes in the rock mass and their consequences are visible on the ground. Due to this, activities have to be carried out which aim at limitation of the harmful effects on the surface infrastructure. In order to prevent from the occurrence of such mining damages on the surface, one shall perform the stocktaking the occurred after-exploitation empty spaces and undertake activities which aim to minimize the mining damages. In the region of the exemplary salt mine, the measurements of the after-exploitation empty spaces were taken with the use of an echo sounder lowered via exploitation with leaching method. So, after finishing the exploitation, the caverns arose inside the rock mass shall be liquidated in order to fill it in before the harmful changes in the surface infrastructure occur. On the example of Salt Mine, the possibility of using MES and ABAQUS software as the pre-processing which allows for the spatial presentation of the working geometry was presented. Such an application of the method of computer modeling of the exploited surfaces is the stocktaking stage but also it is the basis for determinant forecasting of the empty spaces liquidation effect by means of filling them with the waste materials. This is how the after-exploitation empty spaces in the region of the Salt Mine Bochnia-Łęzkowice were liquidated, and the presented results of the underground empty spacer measurements are the concept of complex elaboration of their stocktaking and estimation of the liquidation with the application of waste materials effects. Figure 2 shows the results of the measurements taken with the use of the echo sounder in the sections on the levels inside the rock mass.

ABAQUS

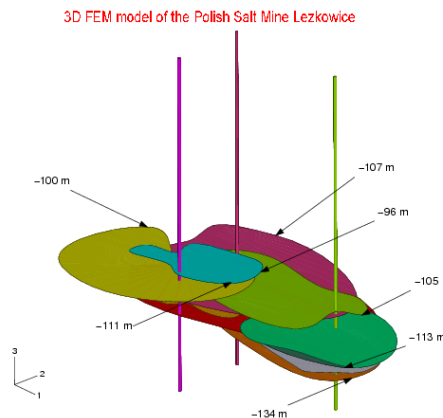


fig. 2

The presented horizontal sections were evened with the spline method in ABAQUS CAE program. The exploited area under the ground, in the given region of the exploited field was presented on the spatial figure 3. and so quite a geometrically complicated special system was created which is analytically described and prepared for further analysis with model analysis determinant methods.

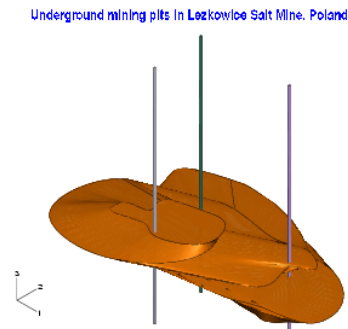


Fig. 3

Such a digital model is the graphical interpretation of stocktaking measurements and it is the basis for the registration of places and amounts of wastes collected inside the rock mass, which are the filling of the empty spaces and so their protection and at the same time the limitation of mining damages on the ground. In case of the Salt Mine Bochnia-Łęzkowice, despite filling the empty spaces with the waste material, it was not manager to prevent from the changes on the surface in the form of the area lowering. In the exemplary region, hollows occurred in the form of non-continuous area deformations. Such hollows which occurred on the surface might have caused mining damages in the form of destroying the surface infrastructure and so such situations shall be avoided and it is possible by means of the mining pits liquidation right after the exploitation is finished and such filling of them in order not to leave any empty spaces underground. Another figure no 4 shows the underground mining pits and the hollow which occurred on the surface.

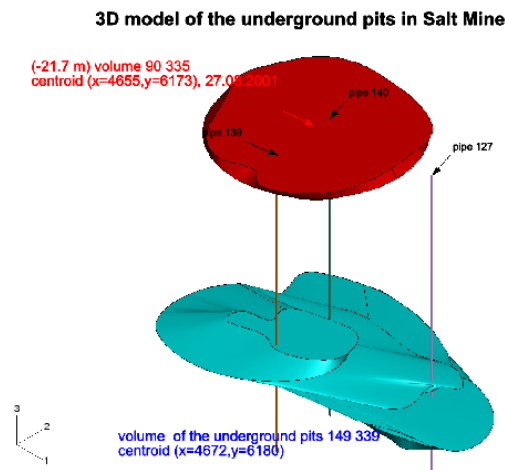


Fig.4

Thanks to the application of ABAQUS programs, it is possible to make calculations which allow balancing the capacity. Figure 4 shows the move of the hollow axis with regard to the working axis and the comparison of the hollow capacity with the underground cavern capacity.

### 3. GEODETIC CONTROL MEASUREMENTS ON THE SURFACE

On the mining area of the Salt Mine in Bochnia-Łęzkowice, periodical geodetic observations on the surface are carried out. The whole technological process is monitored by the topographical observations, the frequency of which depends on the foreseen changes on the surface. A geodetic net which includes bench marks and observation lines where the lowering and horizontal misshaping are measured, figure 5.

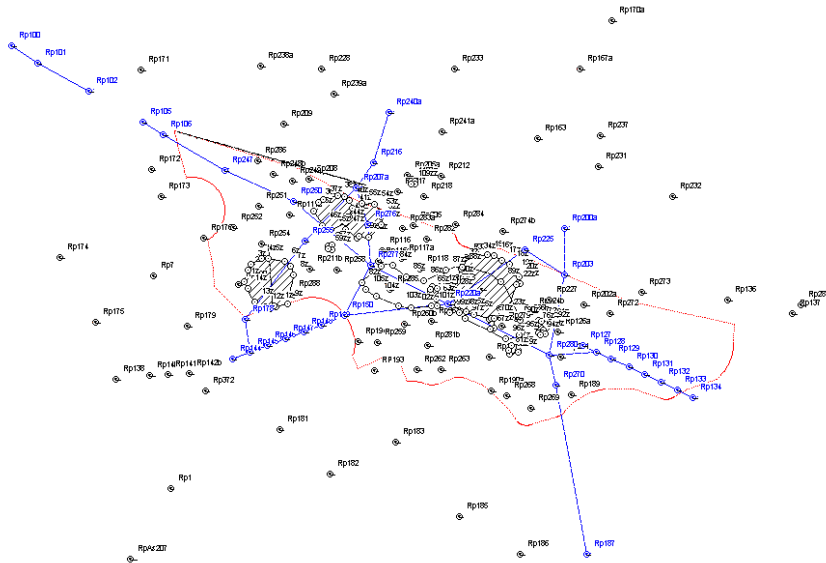
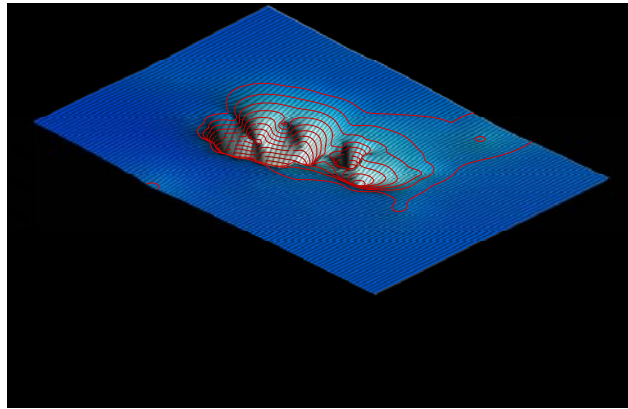


Fig.5

Figure 6 presents the spatial model of lowering occurred on the surface as a result of the salt exploitation with an leaching method in Salt Mine Bochnia-Łęzkowice



**Fig.6**

The capacity of the subsidence basin occurred as a result of salt exploitation is 88 216 m<sup>3</sup>. It is the total capacity of the subsidence basin as a result of the area lowering. Additionally, the hollows occurred presented on figure 5 and the capacity of only one of them is over 90 thousand m<sup>3</sup>, what was shown on figure 4.

#### **4. BUILDING OBJECTS DEFORMATION EXAMINATIONS**

Measurements on the surface elaborated with FEM method can be used for the forecasts, expertise and changes effects evaluation in the rock mass, and especially their consequences on the surface. All the building objects shall be monitored with regard to their deformation and so the evaluation of its functioning safety. The examinations can be carried out on the basis of geodetic measurements and their analytical and graphical interpretation. The changes on the surface are moved on building objects and the amounts which characterize the objects condition are calculated usually with the application of professional programs which make it possible for the detailed analysis of the object condition. The author of the article proposes the application of ABAQUS programs which give the possibility of sending the stage analysis of all the factors in different examined centers via the application of FEM supermodels and sub-models library. And so the results of the calculations for the rock mass as well as changes on the surface in one analysis cycle are send on the building objects on the ground. The figure 7 shows also the results of the analysis of the building located on the mining area. Deviations from the perpendicular, lowering the bench marks on the foundations as well as the deformations of the surface rock mass layers achieved from the model calculations are a complex set of information about the building condition. The results achieved in such a way can be presented in the analytical or graphical form, what was shown on the example on figure 7.

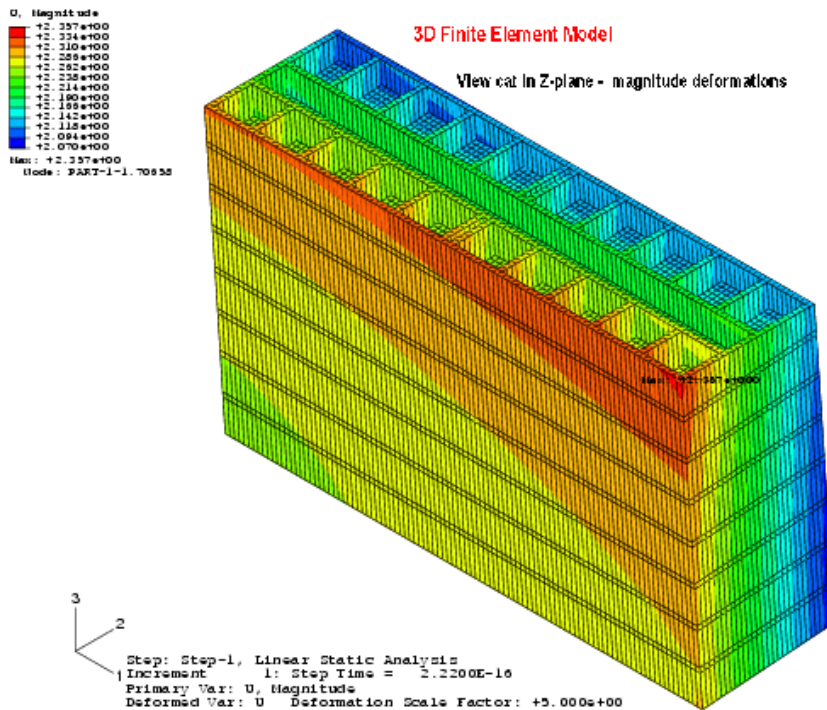


Fig.7

## 5. CONCLUSIONS

The possibilities of geodesic monitoring of using the wastes in after-exploitation empty spaces and hollows occurred as a result of underground exploitation were presented. In author's opinion, the amount of the material entered into the rock mass shall be undergone detailed estimation and the methods applied shall also consider the necessity of estimating the results of such activity. The applied of Finite Element Method as well as ABAQUS software, give large possibilities of evaluating the changes occurred in the rock mass is extremely useful for the complex evaluation and monitoring of the application of wastes in mining techniques influence. The subsidence basins, hollows and caverns which occur in such a way, can be used as the dumping site for the redundant materials however according to the valid regulations and under the supervision of the effects of such activity. It is not possible to avoid the area lowering during the exploitation, but after it finishes, filling the mining pits in, might bring important results by means of decreasing the surface deformation and especially the building objects that might be affected by mining damages, the removal of which is quite expensive. The whole cycle of operations which aim at monitoring the results of storing the



waste materials in the rock mass shall be the one common examination method of all the possible consequences. And so the application of the Finite Elements Method was proposed, which in the author's opinion gives the possibility of a comprehensive evaluation of the changes in the rock mass and on the surface.

## **BIOGRAPHICAL NOTES**

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