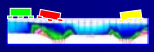
FIG Working Week 2007

SURVEYORS SURVEYING SERVICES

Geodetic inspections of mining areas in regions affected by the storage of waste in underground mining pits



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FEM

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 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 - FINITE ELEMENT METHOD 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.

FEM

Coal mining disturbs a primordial equilibrium of the mass of rock and leads to rising of high stresses, strains and deformations.

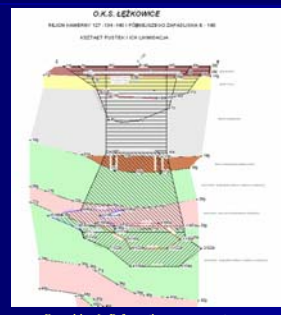
The deterministic model of the mass of rock based on the FINITE ELEMENT METHOD provides full picture of the stress distribution across the rock mass.

Due to such detailed information, enabling determination of deformation indices for all points, it is possible to predict changes and hazards caused by exploitation.

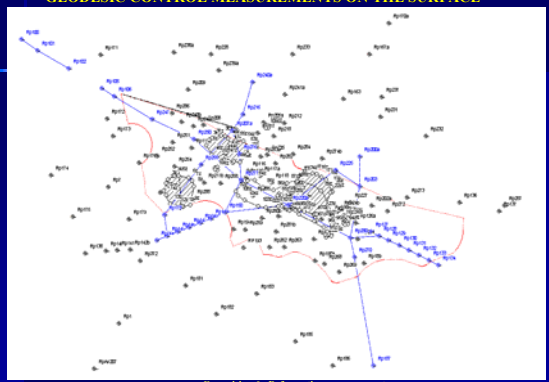
It was proved that the ABAQUS software package designed, among other things, to solve the geotechnical problems, can be used as a very useful tool for the rock mass research. The possibilities and practicability of the ABAQUS programs were tested for a sample Polish coal mine.

As a result of the research on possibility of using a numerical rock mass modelling it was confirmed that the ABAQUS system can be applied to the case of longwall coal mining with cavings.

This is a result of the exploitation in the Salt Mine in Poland



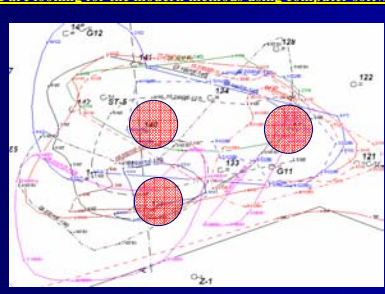
GEODESIC CONTROL MEASUREMENTS ON THE SURFACE



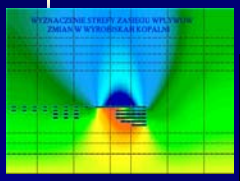
Results of the measurements taken with the use of the echo sounder in the sections on the levels inside the rock mass.

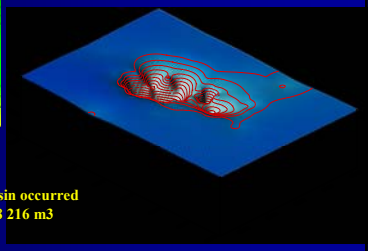
Interpretation of the measurements presented at the picture is very difficult

So we are looking for the modern methods using computer software



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.





The capacity of the subsidence basin occurred as a result of salt exploitation is 88 216 m3

FEM

My proposition is:

APPLICATION OF THE ABAQUS PROGRAMS TO RESEARCH ON THE ROCK MASS DEFORMATIONS IN THE EXAMPLE OF A POLISH MINE

The ABAQUS system is a set of professional programs which use the Finite Element Method and due to using of special program modules can be applied to solve geotechnic problems.

The ABAQUS system can be divided into three main modules:

- ABAQUS / PRE - interactive graphic pre-processor
- ABAQUS / STANDARD, EXPLICITE, AQUA, USA
- ABAQUS / POST - interactive graphic post-processor.

GENERAL CHARACTERISTICS OF THE ABAQUS SYSTEM

Preprocessing Module	Analysis Modules	Postprocessing
ABAQUS/PRE	ABAQUS/STANDARD ABAQUS/EXPLICIT ABAQUS/AQUA ABAQUS/USA	ABAQUS/POST

Scheme of the ABAQUS system

- ABAQUS
- Define geometry
- Define the material properties
- Define the element properties
- Define the mesh
- Define the loads and boundary conditions
- define the steps
- ABAQUS Analysis
- ABAQUS POST

In Department of Mine Surveying and Environmental Engineering of the University of Mining and Metallurgy in Cracow the ABAQUS system is used due to its installation at the CYFRONET-KRAKOW Academic Computer Center through the network connectors.

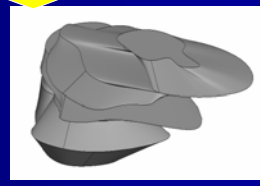
Software is installed on the CONVEX SPP 1000 computer

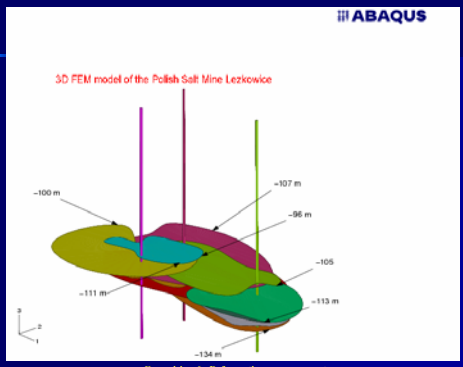
Also computers of the IBM PC class can be used as terminals after connection with the high power computers on which the ABAQUS system is installed.

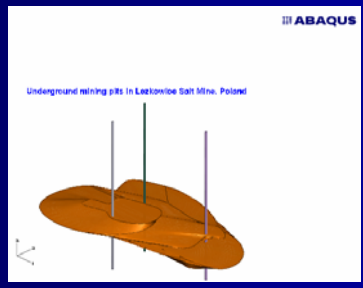
Horizontal sections were evened with the spline method in ABAQUS CAE

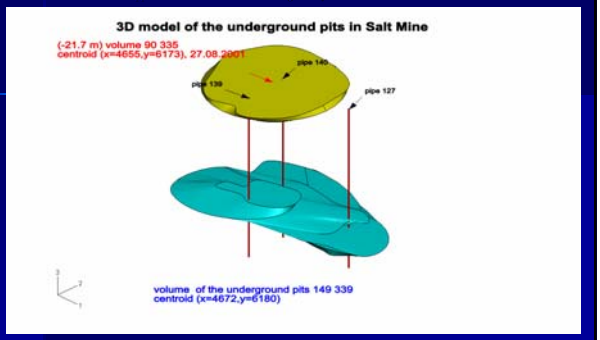
Graphic surveying results

FEM model

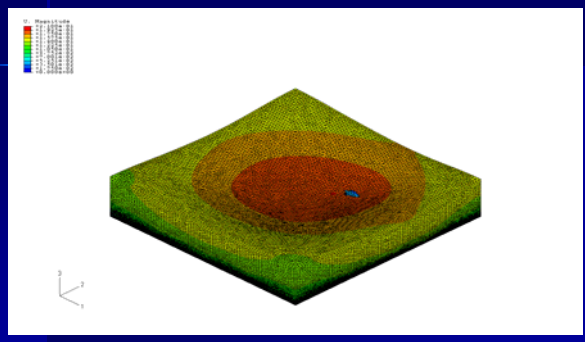




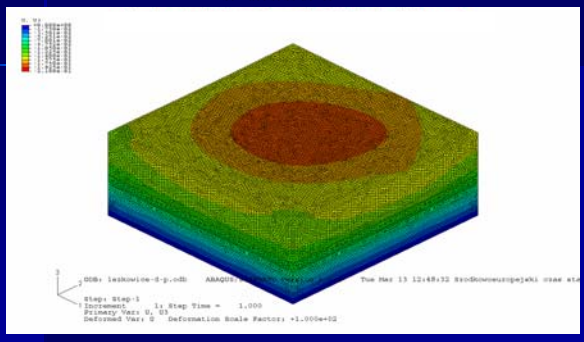




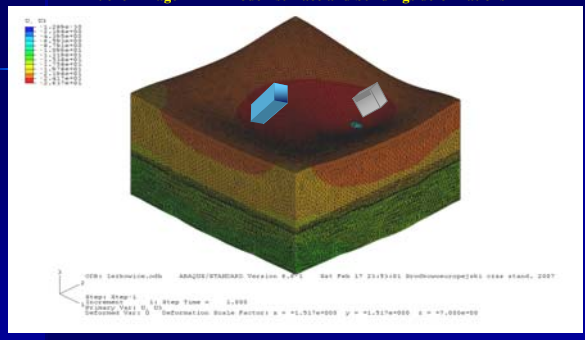
Thanks to the application of ABAQUS programs, it is possible to make calculations which allow balancing the capacity. Figure shows the move of the hollow axis with regard to the working axis and the comparison of the hollow capacity with the underground cavern capacity.



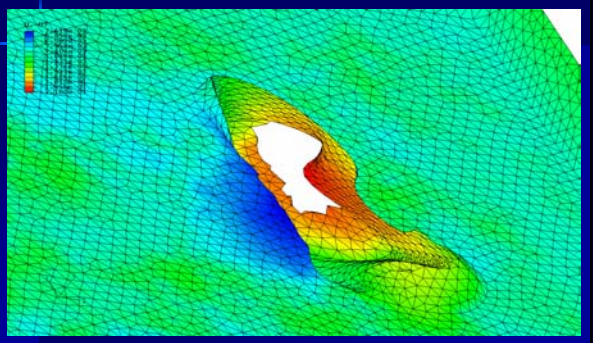
Surface subsidence



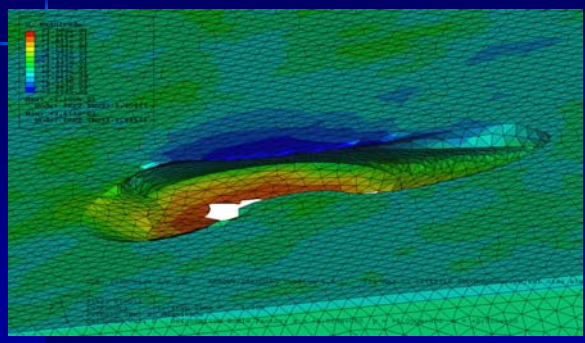
Drucker-Prager FEM model- surface and buildings deformations



Deformations in the rock mass



Magnitude Deformations in the rock mass



BUILDING OBJECTS DEFORMATION EXAMINATIONS.

Measurements on the surface elaborated with FEM method can be used for the forecasts, expedise 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.

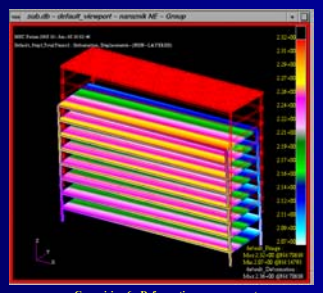
The examinations can be carried out on the basis of geodetic measurements and their analytical and graphical interpretation.

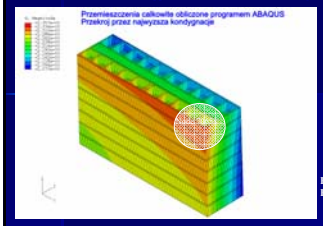
The changes on the surface are moved on building objects and the amounts which characterize the objects condition are calculated usually with the application of professional programs which make it possible for the detailed analysis of the object condition.

The article author 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 article author 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 shows also the results of the analysis of the building located on the mining area.





The results can be presented in the analytical or graphical form, what was shown on the example on figure

Probe Values Report, written on Thu Mar 22 16:34:46 2007
Probe values reported at nodes

Part Instance	Node ID	Orig. Coords X	Y	Z
PART-1-1	70558	0.	0.	32.
PART-1-1	67703	0.	14.	32.
PART-1-1	67904	50.5	14	32.
PART-1-1	70658	50.5	0	32.

Part Instance	Node ID	Elements	U: Magnitude
PART-1-1	70558	Elem-1	2.322
PART-1-1	67703	Elem-1	2.111
PART-1-1	67904	Elem-1	2.134
PART-1-1	70658	Elem-1	2.357
Minimum		Elem-1	2.111 at Node 67703
Maximum		Elem-1	2.357 at Node 70658

Probe Values Report, written on Thu May 03 11:19:14 2007
Source
ODB: c:/ABAQUS/OBLICZENIA/Lezkowice/lezkowice-d-p.odb
Probe values reported at nodes

Part Instance	Node ID	Orig. Coords X	Y	Z
PART-TEST3-1	39262	4.62579E+03	6.14375E+03	-96.6667
PART-TEST3-1	45572	4.65656E+03	6.16186E+03	-122.

Magnitude displacements in nodes

Part Instance	Node ID	Elements	U: Magnitude
PART-TEST3-1	39262	775273	191.628E-03
PART-TEST3-1	45572	465342	37.2612E-03

Strain components

Part Instance	Node ID	Elements	LE: LE11
PART-TEST3-1	39262	775273	127.187E-06

Part Instance	Node ID	Elements	LE: LE22
PART-TEST3-1	39262	775273	315.537E-06

Part Instance	Node ID	Elements	LE: LE33
PART-TEST3-1	39262	775273	-127.936E-06

Results of the calculations – components of the strain tensor

MSC.Patran 13.0.053 Thu Sep 23 22:30:58 PDT 2004 - Analysis Code: ABAQUS
Load Case: Default, Step3,TotalTime=3.
RESULT STRAIN, COMPONENTS - Layer (NON-LAYERED)
ENTITY: ELEMENT TENSOR

-Entity ID-	El. Pos. ID-	Location-Y	Location-Z	Location-X	Component-Y	Component-Z	Component-XY	Component-
19796	1	50.394344	0.105650	0.739550	-0.000911	0.000293	0.000990	0.000359
19796	2	50.394348	0.394350	0.739550	-0.000059	0.000157	0.000274	0.000391
19796	3	50.105637	0.105650	0.739550	-0.000714	0.000426	0.000660	-0.000135
19796	4	50.105644	0.394350	0.739550	0.000008	0.000160	0.000204	-0.000183
19796	5	50.394348	0.105650	2.760450	-0.000069	-0.000229	0.000670	-0.000170
19796	6	50.394348	0.394350	2.760450	-0.000077	0.000065	0.000384	-0.000121
19796	7	50.105637	0.105650	2.760450	0.000140	-0.000119	0.000351	-0.000019
19796	8	50.105640	0.394350	2.760450	0.000002	0.000045	0.000325	0.000031
22624	1	50.105640	0.105650	3.605650	0.000339	-0.000261	-0.000287	0.000027
22624	2	50.394348	0.105650	3.605650	0.000614	0.000091	-0.000913	-0.000272
22624	3	50.105637	0.394350	3.605650	-0.000159	-0.000160	0.000110	0.000065
22624	4	50.394352	0.394350	3.605650	-0.000136	-0.000061	-0.000012	-0.000233
22624	5	50.105637	0.105650	3.894350	0.000052	-0.000078	-0.000183	0.000036
22624	6	50.394348	0.105650	3.894350	0.000359	0.000211	-0.000778	-0.000022

SUMMARY INFORMATION
Min/Max Values

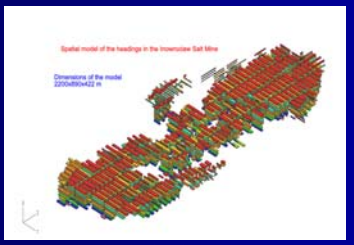
	-Source ID-	-Entity ID-	-Sub ID-	----X Component--
Min:	1	44052	7	-0.001215
Max:	1	46880	5	0.018979
	-Source ID-	-Entity ID-	-Sub ID-	----Y Component--
Min:	1	44052	6	-0.001218
Max:	1	46880	8	0.020676

Underground exploitation of the Salt Mine Inowroclaw

Figure 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 measurements are presented by means of ABAQUS CAE program on the basis of the file written by the author of the article in the ABAQUS STANDARD software convention.

The problem will be presented on the example of the Salt Mine in Inowroclaw.



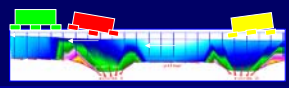
CONCLUSIONS

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.

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.

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.

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.



Thank you for your attention

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