ASSESSMENT OF SLOPE STABIILITY IN OPEN PIT MINES IN CORRELATION OF SPECIFIC ELECTRICAL RESISTANCE IN ROCKS

Zoran Panov, Risto Popovski and Radmila Karanakova Stefanovska
GoceDelcev University – Stip, Faculty of Natural and Technical Science,
email: zoran.panov@ugd.edu.mk

ABSTRACT
The problems resolving the slope stability of the open pit mines are one of the most treated in the surface exploitation of the mineral resources. The determination of safe and stable slopes, is really a complex and painstaking process that requires a large knowledge of the physical - mechanical and structural - tectonic characteristics on the terrain and using sophisticated methods to determine the stability. Having in mind that in the geomechanic in the input data has a number of ambiguities and approximations, and so the output - the result is always accepted with a degree of certainty. In this paper an experiment is made for assessment of the slope stability in the open pit mines just depending on the apparent specific electrical resistance of the rocks.

INTRODUCTION

Today, geoelectrical methods are used for exploration of horizontal and vertical changes of the electrical resistance of the rocks, from which it can be obtained data for geological composition, structure of the rocks, their layers and possibility for fracture from self - loading or coerciveeffectofload.Theresult is aclearerpicture oftherockymassifanditsposition inspace. Electric measurement of specific resistivity of rocks is used to identify existing or potential sliding plane. Sliding plane that occurs often can't be accurately defined and possible errors in the calculation of stability on the ground are present. Using shallow geo-electrical and 2D profiling can successfully make models that can be used to determine the site of the sliding plane. Following the apparent specific electrical resistance of the rocks, provides an opportunity to develop a discussion about changing the resistance or the level of ground water, or change the voltage condition in the rocks.

1. MEASUREMENT OF THE APPARENT SPECIFIC ELECTRICAL RESISTANCE OF THE ROCKS

The observations were performed with an interval of two year research of geoelelectrical characteristics of the rocks, the measurement of apparent geoelectrical resistance on the location on the Mount Plackovica (on the east side of the R. Macedonia). The terrain which according to the geological composition or mineralogical - petrological characteristics and structural - tectonic characteristics of the rocks generally corresponds to the conditions in neighboring mines already developed with surface mining (open pit "Bucim", open pit "Vrsnik", open pit "Bunardzik").

For monitoring the deformations of the terrain is made geodetic network of eleven points (Figure 1.), Two static points, one of which is the place of observation, the total station and the other is a control point, Target (electric transmission lines) and nine points from static measurement which is composed testing ground trigonometric network through which followed the moving.

The points are marked using the movement of the steel poles made with a length of 50 cm, and that way thus forming a trigonometric measurement network. The steel poles are placed on the ground on which the movement was monitored from late 2010, during the whole 2011 and early 2012 year. The given sketch (Fig. 1) is given a place to set two geoelectrical profiles.

The place where appear land slide is given on Fig. 2. This is the control area for comparative analyze of the measurements.

Fig. 1.1 Schedule of the geoelectrical profiles and measurement points

Fig. 1.2 Place of landslide (defined)

2. MEASUREMENT RESULTS AND MODELS OF INVESTIGATED AREA

In tables 2.1 and 2.2 are given some representative values from the daily measurements which apparent resistivity and for each measurement was made 2D electrical tomography with model of apparent resistivity. Measurements started in september 12 2010 and finished in april 10 2012. 500 measurements are selected as representative

Table 2.1 Date: 12.09.2010

	Measured apparent geo-electrical resistance ρ_a, (Ωm)				
H=AB/2 (m)	S-1	S-2	S-3	S-4	S-5
3	835	692	870	630	1108
5	1361	1127	1416	1028	1805
7	1888	1562	1961	1428	2503
9		1987	2494	1820	
11		2404	3017	2207	
13		2813	3527	2587	

Table 2.2 Date: 05.12.2011

	Measured apparent geo-electrical resistance ρ_a, (Ωm)				
H=AB/2 (m)	S-1	S-2	S-3	S-4	S-5
3	1200	1114	1573	1155	1506
5	1241	988	1227	897	1270
7	1055	942	1153	681	1399
9		902	1089	554	
11		833	1015	500	
13		736	924	496	

Table with coordinates of profiles PR-1, PR-2 and PR-3on placed probes with measured apparent electrical resistance at different depth.

Table 2.3

PR-1 Coordinates		Probe	Apparent electrical resistance, ρ_a (Ωm)					
X	Y		H=3m	H=5m	H=7m	H=9m	H=11m	H=13m
619985,06	626762,76	S-1	1200	1241	1055			
619991,02	626762,07	S-2	1114	988	942	902	833	736
619996,99	626761,37	S-3	1573	1227	1153	1089	1015	924
620002,97	626760,96	S-4	1155	897	681	554	500	496
620008,94	626760,55	S-5	1506	1270	1399			
PR-2 Coordinates X	Y							
619988,31	626772,4	S-1	2058	2140	2037			
619994,26	626771,7	S-2	1592	1679	1585	1433	1305	1226
620000,23	626771,01	S-3	1904	1790	1771	1751	1692	1598
620006,22	626770,6	S-4	1855	1694	1538	1398	1276	1174
620012,2	626770,2	S-5	1635	1500	1619			

From the research were received gradient maps of models of apparent electrical resistance at different depth of the terrain. In the next two figures are separated only 2,the deepest and the shallowest modeled.

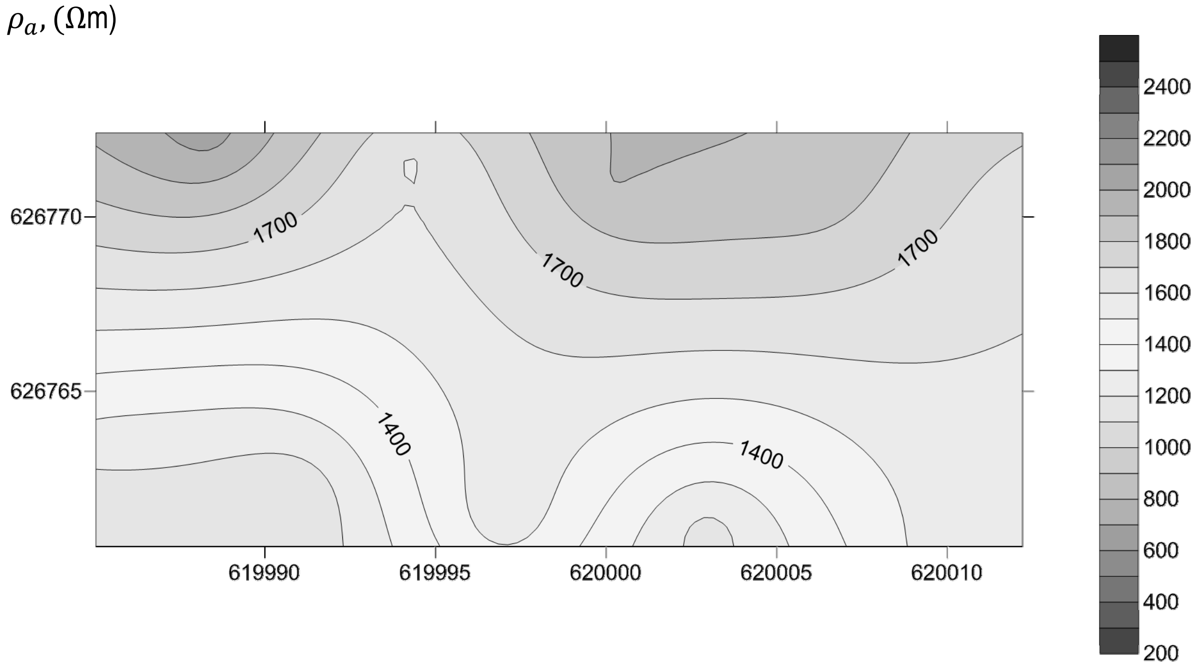

Figure 2.1. Gradient map of iso-ohms H = 3 m

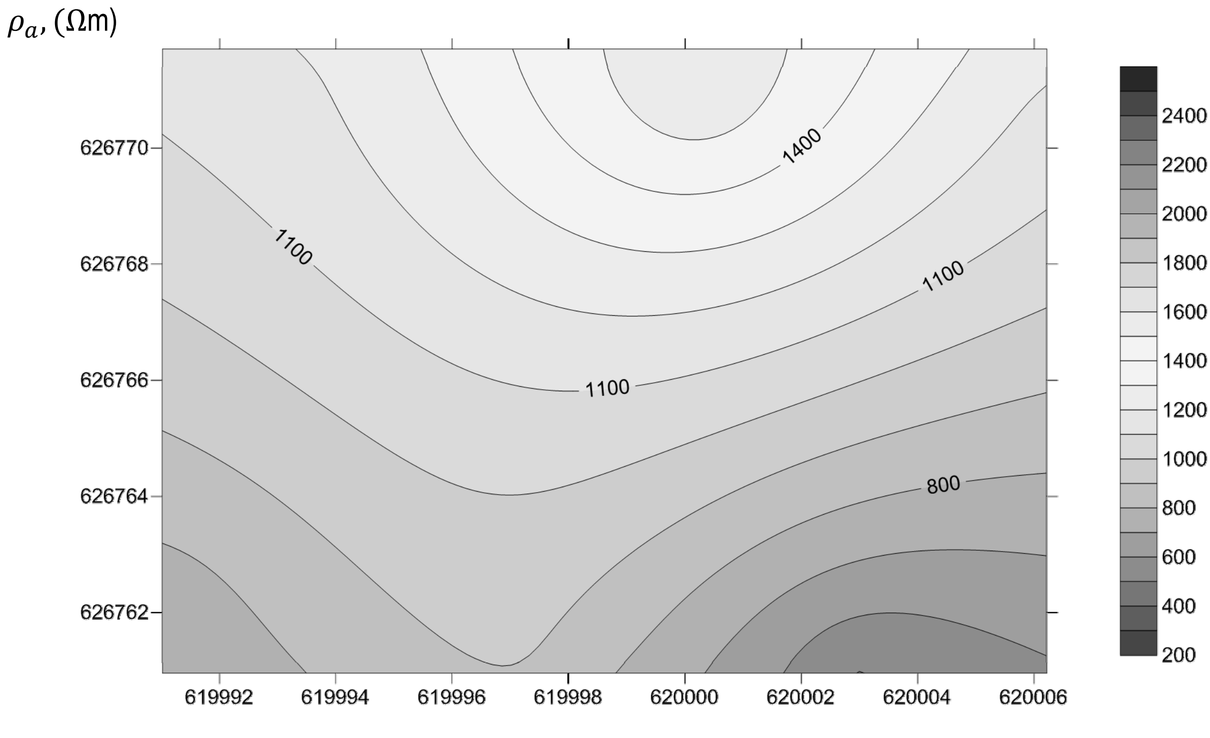

Figure 2.2. Gradient map iso-ohms H = 13 m

Model of the specific elecrical resistance on the profiles PR-1 and PR-2 is given on fig. 2.3. layers are separated according the calculated resistance.

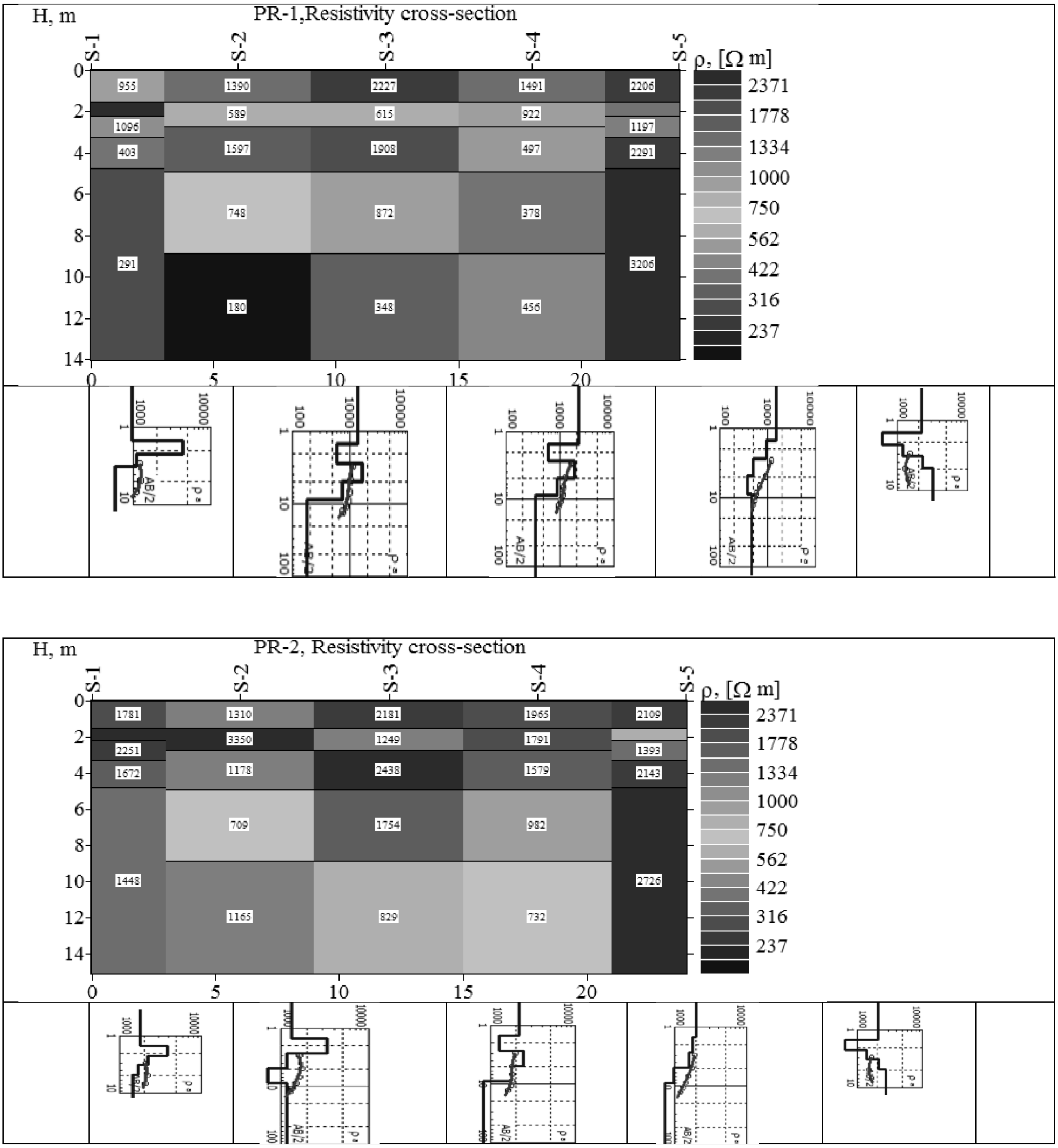

Figure 2.3 Models of the specific electrical resistance of PR-1 and PR-2

For analysis the dependence of slope stability and change of apparent specific electrical resistance is made geomechanical analysis for slope stability using three (3) distinctive methods of limiting balance.

The analysis is made with given levels of underwater and defined values of Ru, in conclusion from the level of the water in four control piezometers (are set in analyzed area, line profiles, for each two). The following values are obtained on the safety factor.

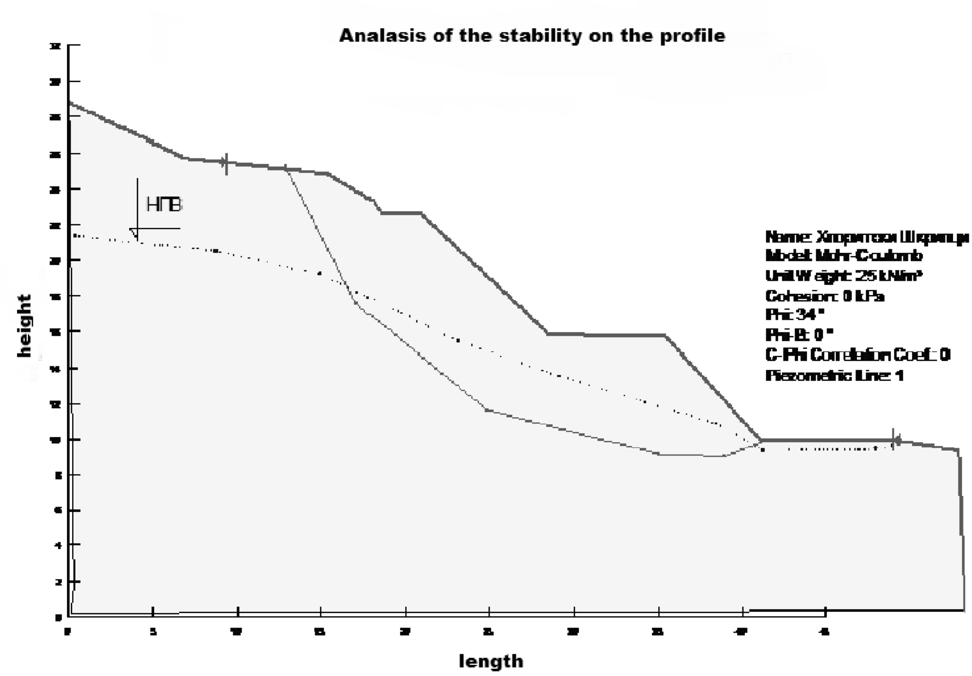

Fig. 2.4. Input parameters for the calculation of stability

Table 2.4 Safety factors

Safety factors	Ru=0		Ru=0.2	
	F	M	F	M
Bishop	1,405		1,075	
Janbu		1,306		0,955
Spencer	1,339	1,337	1,034	0,974
Minimum value (Fs)	1,306		0,955	
Mean value	1,347		1,026	
Condition for stablity (Fs>1.3)	yes		no	

DISCUSION

The analysis from the research showed that, during the two year period, it comes to a change in the apparent specific electrical resistance of the rock material. Increasing the level of groundwater, especially in the late autumn and late spring is causing an increase in the level of groundwater (measured by piezometres) with a slight decrease of the apparent specific electrical resistance. The measured deformations of the terrain (displacement and subsidence), over time, point to the fact that they have a higher intensity while changing from smaller to larger electrical resistance of rock material (the phase of lowering the underwater level) than the deformations that occur while reduction of the apparent specific electrical resistance., or increasing the level of groundwater. This especially is noticeable in the cases of short (in time) or fast chances from one state to another. In the time of the analysis a case was encountered whom in a long period of time it came to a drastic decrease on the apparent specific electrical resistance of the rock masses, who are causing a far bigger deformations (even a local fracture). All this, provides an opportunity to analyze the possibility to assess the slope stability by monitoring the change of the apparent specific electrical resistance. This measurements are relatively simple and inexpensive, without the need for major preconditions of execution. For these reasons, at least experimentally, in many open pit mines could be accessed to monitoring, which in turn if not more would certainly give more reliable data for the level of groundwater.

CONCLUSION AND RECOMMENDATIONS

The research in this paper showed a certain degree about dependence between the changes of the apparent specific electrical resistance of the rock material and the appearance of deformations in it. These analyzes were confirmed by daily measurements of the apparent geoelectrical resistance, compared with the level of measured groundwater (from piezometres) and ensuing deformation of the field (from the network of geodetic points).

That means that is made a attempt to think about the possible depending of the assessment of slope stability with the changes of the apparent specific electrical resistance. Having in mind that these measurements are simple, cheap, they could be subject to further far more comprehensive and serious research and analysis.

We hope that this our research will contribute to further research, in definition of a scientific approach to determining the reliability of slope stability, or the occurrence of deformations with the apparent changes of specific electrical resistance of the rocks.

REFERENCES

Поповски, Р., 2013, МОДЕЛ НА СТАБИЛНОСТ НА КАРПЕСТ МАСИВ КАРАКТЕРИСТИЧЕН ЗА ИСТОЧНО МАКЕДОНСКАТА ЗОНА, Докторкса дисертација, Универзитет "Гоце Делчев" – Штип, Факултет за природни и технички науки

Griffiths, D.H. and Turnbull, J.: 1985, 'A multi-electrode array for resistivity surveying', *First Break* 3(7), 16–20.

Griffiths, D.H., Turnbull, J. and Olayinka, A.I.: 1990, 'Two-dimensional resistivity mapping with a computer controlled array', *First Break* 121–129.

Kurahashi, T., Watanabe, S., Ohtani, T. and Inazaki, T.: 1998, 'Fracture imaging behind a rock surface for the slope stability assessment', *4th SEGJ International Symposium Fracture Imaging*, Tokyo, Japan.

Li, Y. and Oldenburg, D.W.: 1992, 'Approximate inverse mapping in DC resistivity problems', *Geophysical Journal International* 109, 343–362.

Loke, M.H. and Barker, R.D.: 1996, 'Practical techniques for 3D resistivity surveys and data inversion', *Geophysical Prospecting* 44, 499–523.