NEW APPROACH TO ASSESMENT OF SLOPE STABILITY ON WORKING BENCH IN OPEN COAL MINES

Zoran Panov[1], Sašo Jovčevski[2], Zoran Despodov[1], Dejan Mirakovski[1], Radmila Karanakova Stefanovska[1], Tena Ivanova - Šijakova[1]

[1]"Goce Delcev" University - Štip, Faculty of Natural and Technical Science, Štip, Macedonia

[2]ELEM AD Skopje, Electropower Company, Bitola, Macedonia

[1]zoran.panov@ugd.edu.mk

ABSTRACT

The main purpose of this paper is to analyze the stability of the open coal mine "Suvodol" in Southwest Macedonia, during the past two years (from April 2009 to December 2011), also to represent one new approach for assessment of slope stability of working benches on open coal mines.In the first half of 2009 the open pit mine had an alarming situation where the whole bed moved about 1 cm per day from the Southeast towards to the Northwest so that this situation be conveyed directly in the operation of this mine. To resolve this situation needed further analysis of the stability of the working benches, development of new work plans of method of excavation of coal and overburden in mine and very carefully monitoring the situation on the ground and monitoring the system of cracks that had occurred this time. In this paper will be performed comprehensive analysis of 8 distinctive profiles. We used the information from monthly reports of geotechnical stability of excavated blocks in the period April 2009 to December 2010. New analyses will be done with four regression analysis: linear, polynomials of second and third degree and logarithmic, obtained analytical expressions of the stability factor as a function of time. Overall, stability in the open coal mine during data were taken for analysis (the period provide with trend analysis), is with the value of ratio of stability to almost all sections, of under 1, and going month after month, with a slight increase up even above 1.3 (an increase by 40%). This trend coincided with the trend analysis of new approach made in research analysis in this paper.

KEYWORDS

assessment, regression analysis, slope stability, open coal mine

1. INTRODUCTION

Energy is the basis for any society. It is necessary for sustainability, development and progress. The energy balance in the Republic of Macedonia provides data that 80% of total electricity production accounted for just getting electricity from fossil fuels - coal. Keeping this trend and development, using of coals as the main energy resources are going to be the current and future drivers and stakeholders of the energy balance in the country in the next 20 - years.

Open coal mine "Suvodol" is the largest open pit of coal in Republic of Macedonia. In these conditions, provides at least 75% of the total needs of coal for to produce the electricity. From

this, and significance for energy balance of R. Macedonia is enormous in today's conditions as an energy resource is still irreplaceable.

The main potential risk in exploitation of coal is precisely the stability of slopes of the working bench. Monitoring of the stability of slopes, the appearance of cracks, changes in the level of groundwater, the occurrence of local landslides and continued analysis of stability, provide a development of new approach of planning the stability of slopes of the working benches. The primary idea of the research is in function of define a new approach of assessment of the geotechnical stability of working and final slopes of the open pit "Suvodol".

Methodology of research, mainly include research from the field and macroscopic assessment of the geotechnical stability of the pit and blocks, and with mathematical analysis and application of modern methods with equilibrium limit are analyzed geotechnical stability of the slopes of open pit. In analyzing were used modern methods to define the stability of slopes. When it was selected most characteristic methods in this area, for example: ordinary method, the method of Bishop, the method of Spencer and the method of Janbu. Finally, in the section for prediction and assessment of the stability of working slopes were used trend analysis in order to predict trend of moving of the factor for security in the period of several months required for the development of pit especially in the heating season (winter period). The period of the heating season begins in October and lasts for the April next year. It is a period when is necessary minimum daily quantities of 21,000 tons of coal and 100% work on 3 blocks on thermal power Bitola. Logically this requires continuous exploitation of coal from the pit "Suvodol" and the new open pit " Brod – Gneotino".

On the dump of coal is stored coal whose amount cannot be reduced below the minimum of 150,000 tons, which is enough for 1 week work of thermal power.

So in the mines, are possible only minimal delays during the heating season. The main cause of unstable and failure of the capacity of the mine and the appearance of delays, unless the planned repairs, moving equipment, etc., are the appearance of local landslides and other types of geotechnical instability in surface mines.

2. GEOMECHANICAL ANALYSIS OF STABILITY OF WORKING BENCHES

To get the most relevant and most characteristics results from the analysis of stability, the most important was to make the right choices and precise values of geomechanical parameters of materials were surveyed. Therefore, while solving this problem, were used all data by both current from previous investigations and trials, and geomechanical parameters adopted are shown in Table 1.

Table 1. Geomehanical parametars

No	Type of material	Geomechanical sign	G (kN/m3)	φ (o)	c (kN/m2)
1	Quaternary deluvial sediments	CL/CI	19	21	10
2	Tripoli	TR	15,64	17,90	31,83
2*	Tripoli - perturbed	TR	15,64	13,00	0
3	Coal	L	11,61	30,00	45,00

3*	Coal - perturbed	L	11,61	30,00	0
4	Coal clay	OH/OI	16,63	10,27	0
5	Floor sands and dust	SFs SFs/MI	21,2	20,77	0
5*	Perturbed material	SFs SFs/MI	19.5	10,60	0
6	Gneiss	Gn	22	50	200
7	Gravel material from break mother rock	SW/Gn	21,60	20,00	0
8	Mica dust	MI/MH	15,45	12,76	0

As can be seen (from Table 1) there are some affected parties in the coal seam that is also associated with fossil landslide, so the analysis of stability in this part of cohesiveness is considered equal to zero.

As already mentioned, the underground sediments almost entirely are water glut and incoherent, as that the spoiled, and in fresh material cohesion is zero and they are different by strength only by the angle of internal friction that is higher in double in unspoiled parties. Finally it should be noted and the impact of hidrogeological condition as a significant factor for the stability of slopes.

In zones where this condition is well defined and is real displayed as a parameter in the analysis of sectiones, output results are very concrete.

Perhaps, in the future research in this area should be directed to the observation of the changes in this parameter, during the dry and rainy periods, ie depending on whether they are affecting different parameters during the analysis of stability.

In the research were analyzed cross sections: P08 - 08 ', P09 - 09', P10 - 10 ', 49-49' 53-53 '55-55' 72-72 '76-76'.

In addition in this paper there is information about the most distinctive section 49-49'.

Section 49-49'

This section is analyzed in eight months in the period of research, in April, May, June, July, August, October 2009 and January and February in 2010. Section 49-49' is most analyzed primarily for the specific position, ie It covers the mass in the mine were excavate last year and where was concentrated the basic machinery for excavation of waste.

Because this profile was analyzed over a long time of period is concentrated excavation of waste that is the best indicator of movement of the slope stability in the open pit mine "Suvodol".

In the table 3 is given a tabular display of movements of the minimum coefficient of stability that is from 0.928 in July 2009 to 1.392 in October 2009, so it is seen that the stability of this profile is suspended and moves within the allowed parameters.

Table 2. Factor of stability of the section 49 - 49′

Mounts	April '09	May '09	June '09	July '09	August '09	October '09	January '10	February '10
Ordinary	0.935	1.107	1.069	0.935	1.003	1.269	0.997	1.253
Bishop	1.069	1.27	1.347	1.069	1.069	1.392	1.194	1.346
Janbu	0.929	1.22	1.199	0.929	1.002	1.214	1.063	1.249
Spencer	1.105	1.29	1.359	1.105	1.105	1.422	1.209	1.362

Table 3. Input table for analyses

Month	**X**	**Method**			
		Ordinary	**Bishop**	**Janbu**	**Spencer**
		Fs	**Fs**	**Fs**	**Fs**
April'09	**4**	0.935	1.069	0.928	1.105
May'09	**5**	1.107	1.27	1.22	1.29
June'09	**6**	1.069	1.347	1.199	1.359
July'09	**7**	0.935	1.069	0.928	1.105
August'09	**8**	1.003	1.069	1.002	1.105
October'09	**10**	1.269	1.392	1.214	1.422
January'10	**13**	0.997	1.194	1.063	1.208
February'10	**14**	1.253	1.346	1.249	1.362
MIN		0.935	1.069	0.928	1.105
MAX		1.269	1.392	1.249	1.422
X_{sr}		1.071	1.2195	1.100	1.245
.		0.131	0.138	0.136	0.131

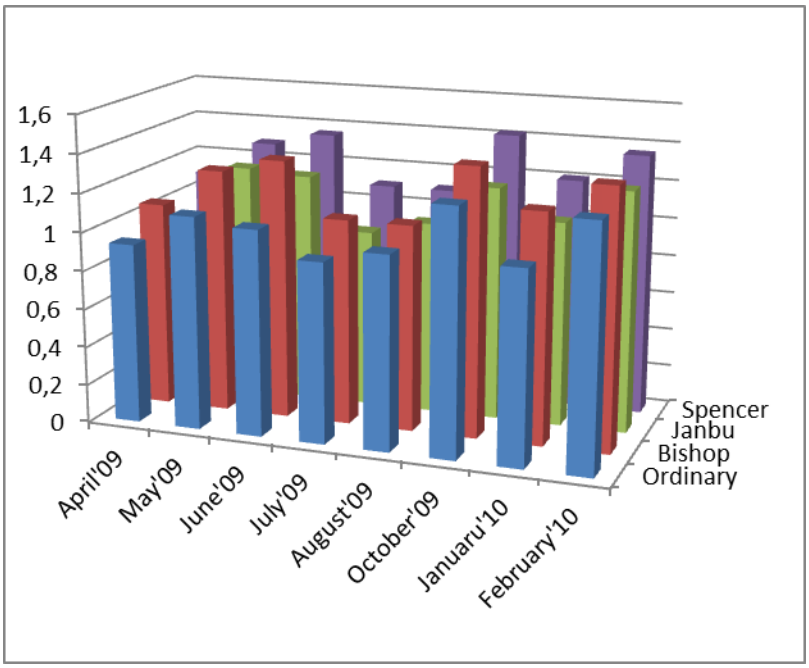

Fig. 1 The movement of the coefficient section 49 – 49′

Fig. 2 Real view of section 49 – 49′

3. TREND ANALYSIS

Considering the time interval and frequency of analysis data of the section 49-49 ', it is detail treated using the trend analysis for development planning and the dynamics of exploitation of coal mine "Suvodol".

Trend analysis was performed according to the following 5 actions:

1. choice of regression analysis;
2. establish the analytical dependence and the value of R^2 separately for each regression analysis;
3. ranking of obtained analytical dependencies according to the value of R^2;
4. calculation of values for y = f (x) for values of x from 4 to 19;
5. analyzing the values of x from 15 to 19, with step 1

In continue is given the explanation separately for each procedure with method of Bishop.

6. Choice of regression analysis

Taking the nature of the discrete function Fs = f (x), the number of data, the defined area of function (D.O. $\in$ N = $\{4, 5, \ldots 19\}$) value of the function ($V_f \in R = \{0.0, \ldots, 2.0\}$), as the most appropriate regression analysis for trend analysis to assess the stability of slopes of blocks were adopted:

- linear, y = ax + b;
- polynomial from 2 degree, y = ax2 + bx + c;
- polynomial from 3 degree, y = ax3 + bx2 + cx + d;
- logarithmic, y = a l_n (x) + b.

Determining the analytical dependence and the value of R^2 separately for each regression analysis. According to the analysis made in MS Excel, obtained the following analytical expressions for regression analysis (Table 3).

Method of Bishop

Table 4 Formulas derived by a Bishop for section 49 – 49′

Ordinal number	Regression analysis	Formula	R^2	Status
1	linear	y=0.0141x+1.1015	0,1399	3
2	polynomial from 2 degree	y=0.0001x2+0.0139x+1.1022	0,1399	3
3	polynomial from 3 degree	$y=0.0005x^3-0.0133x^2+0.1211x+0.8398$	0,1472	1
4	logarithmic	y=0.1159ln(x)+0.983	0,1401	2

According to the ranking in Table 3, we get the conclusion that polynomial from 3 degree (cubic) regression analysis has the maximum value for R^2, or R^2 = 0.1472. Although this value is very low (R^2 <0.3), cannot conclude a "more" analytical dependence between the projected factor of safety and time.

However, this regression analysis is adopted as a trend analysis to assess the stability of slopes of the blocks of this profile.

Based on analytical expressions for regression analysis was done calculating of the values for y = f (x) for values of x 4 to 19. After that is received data given in Table 3 and from them is made graph 3.

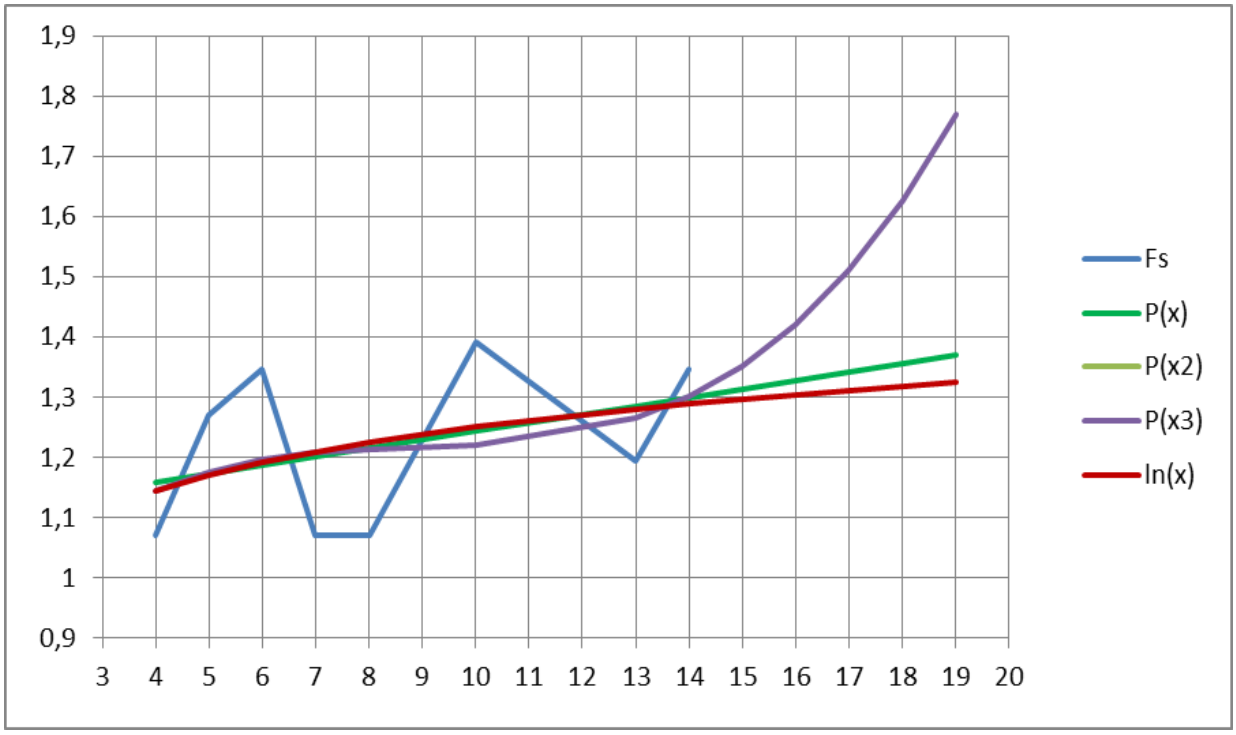

Fig 3. Graphic view by method of Bishop for section 49 – 49′

Table 5. Output table - trend analysis

Month	x	F_s	y			
			P(x)	$P(x^2)$	$P(x^3)$	ln(x)
April 2009	4	1.069	1.158	1.158	1.143	1.144
May 2009	5	1.270	1.172	1.172	1.175	1.170
June 2009	6	1.347	1.186	1.186	1.196	1.191
July 2009	7	1.069	1.200	1.200	1.207	1.209
August 2009	8	1.069	1.214	1.214	1.213	1.224
October 2009	10	1.392	1.243	1.242	1.221	1.250
January 2010	13	1.194	1.285	1.285	1.265	1.280
February 2010	14	1.346	1.299	1.299	1.300	1.289
March 2010	15	1.351	1.313	1.313	1.351	1.297
April 2010	16	1.421	1.327	1.327	1.421	1.304
May 2010	17	1.511	1.341	1.341	1.511	1.311
June 2010	18	1.626	1.355	1.356	1.626	1.318
July 2010	19	1.769	1.369	1.369	1.769	1.324

Discussion

The analysis of sections shows that there is a possibility of determination, ie prediction of the coefficient of safety for the next five to six months (heating seasons), and if compare the predicted with real coefficient of safety, it comes to accuracy and up to 90%, which is a very high percentage.

This proves that the purpose of this paper is justified, because it is get results that can be used in the manufacturing process.

Of all the reported information, with technology for development in open pit mine "Suvodol" for every six months, can get results for the development of the mine, i.e. to avoid unsafe situations and different activities, thus creating conditions for much safer operation of the mine.

From the general cross section of all analyzed 8 sections by different methods for:

- requires a geotechnical analysis for the longer period,
- requires more frequent analysis of the same sections
- need for more trend analysis to identify the one with the highest R2,
- predicting the value of the factor of safety of the shorter time period (not more than ½ the time of the analyzed period).

4. CONCLUSSIONS

The results in the paper gives a new scientific contribution to the assessment of the stability of slopes and their prediction in the future.

The elaborated models for assess the stability of slopes, using trend analysis - regression analysis provides an opportunity for defining new approaches of models for analyzing and predicting the stability of slopes of the blocks.

In this paper was performed a complete analysis on 8 characteristic profiles of which, according to the volume of available data, was selected 1 and that was 49-49 '.

It was used a number of information from monthly reports for geotechnical stability of blocks from the period of May 2009 until April 2010. With four regression analysis: linear, polynomials of second and third degree and logarithmic obtained analytical expressions of the stability factor in a function of time.

It is given appropriate tabular and graphs from these functions, and separately for each profile, i.e. each analyzed method for assessing the stability of slopes (ordinary method, the method of Bishop, Janbu method and the method of Spencer), separately.

Especially is abstracted method of Bishop.

The following conclusions are noted:

- according to trend analysis section 49-49 ", will be stable in the planned period of time in the next 5 months. These estimates coincide with the real (obtained from the relevant reports) after the expiry of a period;
- Stability in the open pit mine, "Suvodol" in the period for which data were taken for analysis, to the period to which provides trend analysis, is the coefficient of stability almost all accounts under one,
- This trend matches with the trend analysis done in this paper, especially in profile 49-49 '
- From the beginning of analyzing the stability of section 49-49 ", month after month, there is a slight improvement over 1.3, ie 40% increase.
- from a practical point, the situation on the ground in this period is very changed, that stabilizes all major landslides that were active in that time, except some local cracks and separate movements of the material;
- Generally, in mine "Suvodol" there is no report of the geological service for activity on the entire deposit;
- measures and monthly plans for work that were in function for stabilize the situation in the open pit mine "Suvodol" give results, so we came to a situation where we can talk about relaxation as regards the stability of slopes in general;

As suggestions for further research can be stated:

- Multiple analysis and evaluation, which involves using personal methods for assessing the stability of the same problem,
- Bring a collective reliable
- Bring a timely decision.
- Using reliable mathematical apparatus, ie regression analysis with higher values of coefficient of correlation;
- Using sophisticated methods to assess the stability of slopes, especially through the use of finite methods of elements.
- Using methods for making spatial analysis, analyzing and drawing diagrams for voltage condition in space, and using analysis for the time;
- implementation of modern measures and procedures for stabilize the working slopes.

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