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A comparative multi-criterion analysis of possible technologies used for selective mining, conveyance and dumping of solum at coal open pit mines of the electric power industry of Serbia

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ABSTRACT. Selective mining of fertile soil – solum from the overburden at the coal open pit mines of the Electric Power Industry of Serbia, is of great significance for land-reclamation, revitalization and management of dumping space. For the purpose of the Coal Production Department of the Electric Power Industry of Serbia, the researches related to this problem have recently been carried out, with participation of the authors of this paper. The researches have encompassed five applicable technological solutions of selective mining, conveyance and dumping of solum. The paper presents both short reviews of technological solutions and multi-criterion approach in selecting the optimum solution.
KEY WORDS: OPEN PIT MINING, COAL, SELECTIVE EXCAVATION, OVERBURDEN, SOLUM, LAND-RECLAMATION, REVITALIZATION, MULTICRITERIA OPTIMIYATION, ELECTRIC POWER INDUSTRY OF SERBIA.

СРАВНИТЕЛЕН МНОГО-КРИТЕРИАЛЕН АНАЛИЗ НА ВЪЗМОЖНИТЕ ТЕХНОЛОГИЧНИ РЕШЕНИЯ ПРИ СЕЛЕКТИВЕН ДОБИВ, ТРАНСПОРТ И ДЕПОНИРАНЕ НА ХУМУСНИЯ СЛОЙ ОТ ОТКРИТИТЕ ВЪГЛИЩНИ МИНИ НА ЕНЕРГИЙНАТА ПРОМИШЛЕНОСТ НА СЪРБИЯ

РЕЗЮМЕ. Селективното изземване на плодородни почви – хумус от откривката на въглищни мини, част от топлоенергийната промишленост на Сърбия, е от изключително голямо значение за рекултивацията, възстановяването и управлението на отвалите. Отделът по въгледобив към топлоенергийната промишленост на Сърбия, с цел изясняване на този проблем, наскоро извърши изследвания, в които участваха и авторите на настоящия доклад. Изследванията обхващаха пет технологични решения за селективно изземване, транспортиране и депониране на хумусния слой. Докладът представя както кратки описания на технологичните решения, така и много-критериален подход за избор на оптималното решение.

1. Introduction

Land reclamation of waste dumps of coal open pit mines represents a series of works for preparing the stockpiled overburden masses for returning the original natural functions aimed for agriculture, forestry, recreation and other useful purposes. To be successful, the land-reclamation should fulfill both functional and economical criteria, should be technically-technologically and biologically feasible, aimed at arrangement of space and formation of land for useful purposes. Technical land-reclamation, preceding the biological one, comprises:

- Levelling and shaping the surfaces at waste dumps;
- Moderating inclinations and shaping waste dump slopes;
- Mining, loading, conveyance and overlying fertile soil – solum or appropriate (fertile or potentially fertile) soil from overburden at the open pit surface;
- Levelling the deposited solum at the waste dump;
- Removing the effects of eventual subsidence at the waste dump.

Considered from economical and technological aspects, the technical land-reclamation should be, in principle, coordinated with the mining works at open pit mines, namely should be carried out synchronized with the works of overburden mining and dumping. It may be carried out:

- Amalgamated or simultaneously with the technical process of mining, conveyance and dumping of overburden at the highest open pit level;
- Separated or divided from the technological process of mining the overburden at the open pit. Mining, conveyance and dumping of solum is carried out separately, prior to mining of overburden (waste) at the highest open pit level.

Hereinafter are given the reviews of the analysed both united and separated solutions of selective mining, conveyance and dumping of solum at waste dumps of coal open pit mines of the Electric Power Industry of Serbia.

2. The analysed technological solutions

A united technological process of selective mining, conveyance and dumping of solum understands utilization of the existing ECS (**E**xcavator-**C**onveyance-**S**preader) equipment operating at the highest open pit level. The bucket wheel excavator selectively excavates solum within the height block. The first cut of the height block, having the height equivalent to the solum thickness, the excavator mines fertile soil that is later conveyed by the existing belt conveyors to the spreader.

The spreader overlays solum over previously deposited masses of overburden, thus forming the surface of fertile soils required for biological land-reclamation. Upon completion of one operation at solum mining (down to the full cut depth), the excavator mines the rest of overburden-waste at the level. The spreader deposits these masses on the waste dump as a foundation for the subsequent dumping of solum. The deposited solum masses are smoothed and levelled by bulldozers. Figure 1. illustrates a schematic plan of technological process of amalgamated selective mining, conveyance and dumping of solum and waste.

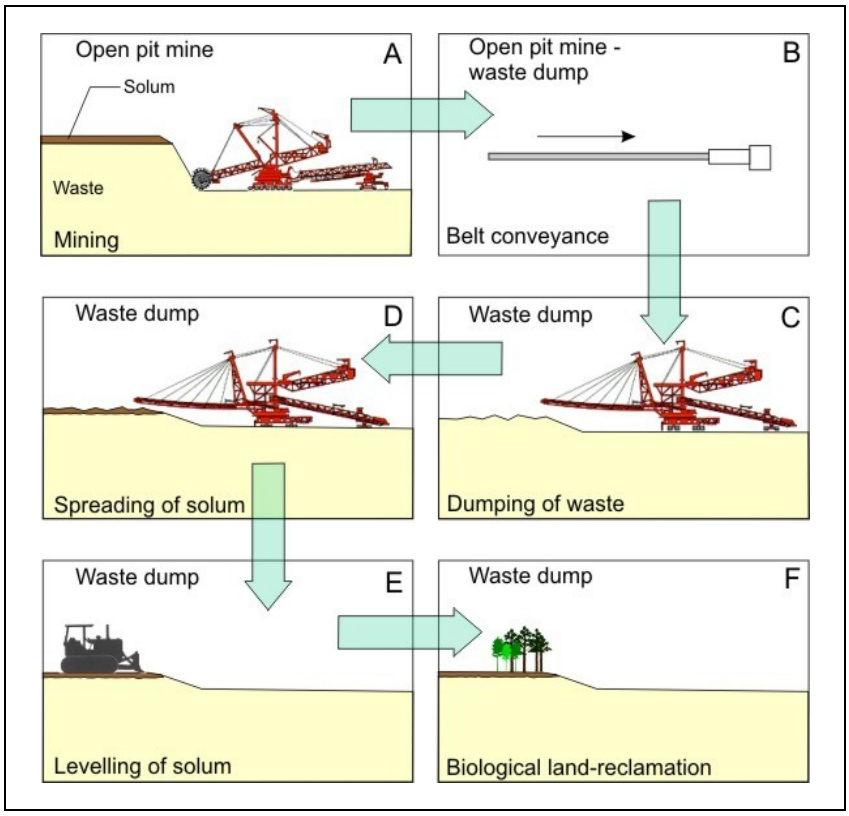

Fig 1. Technological process of amalgamated selective mining, conveyance and spreading of overburden, variant ECS

A separated technological process of selective mining, conveyance and dumping of solum, is carried out by specific equipment, namely the equipment not representing a part of the equipment existing at open pit mines. In principle, it could be with:

- Discontinuous equipment (analysed three variants);
- Continuous equipment (analysed the variant: excavator SM, belt conveyors and spreader).

Four variants of separated technological systems are analysed:

- Variant **A**: System SM excavator (Surface Miner) – dumpers – bulldozers;
- Variant **B**: System SM excavator – conveyors – spreader – bulldozer;
- Variant **C**: System of scrapers;
- Variant **D**: System of bulldozer with ripper – loader – dumper– bulldozer.

Figures 2, 3, 4 and 5 illustrate technological processes of the analysed variants of separated systems of selective mining, conveyance and dumping of solum.

Taking into consideration the objective of this paper as well as its limitations, we shall not dwell on topology and detailed structural presentation of technological variants.

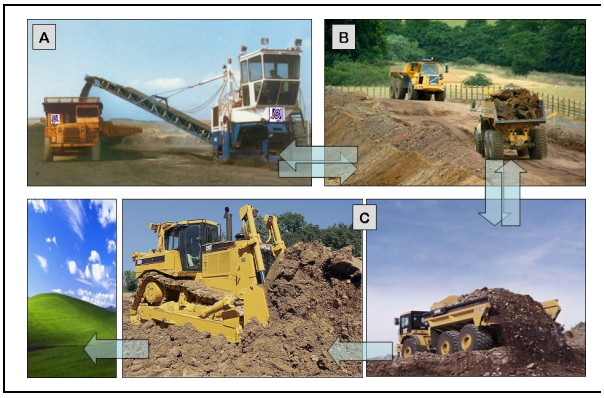

Fig. 2. Technological process, variant A

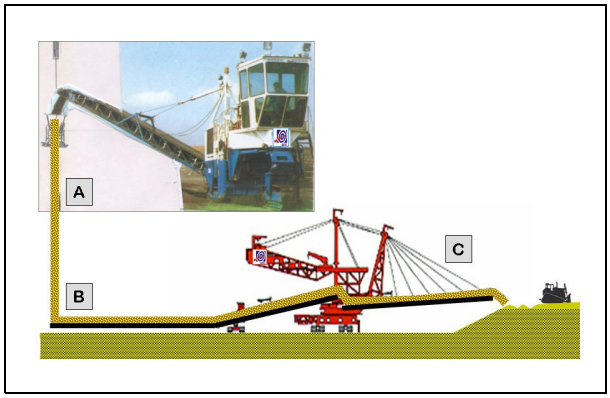

Fig. 3. Technological process, variant B

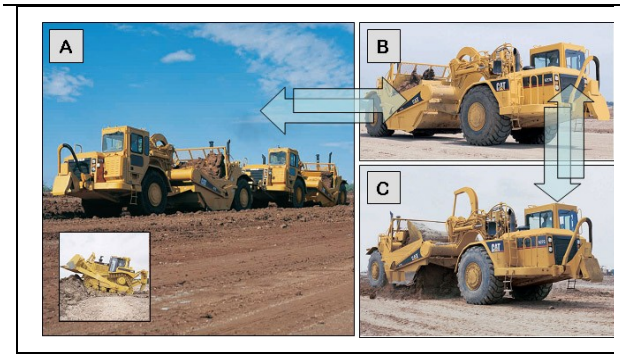

Fig. 4. Technological process, variant C

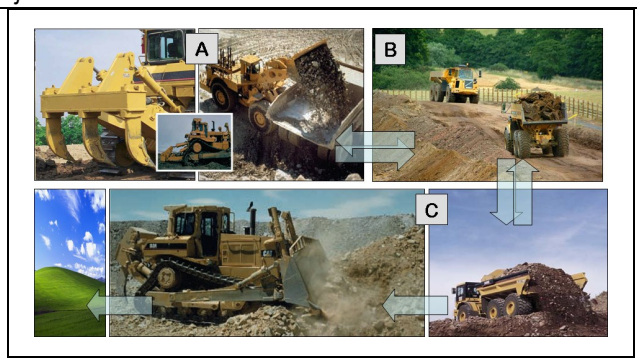

Fig. 5. Technological process, variant D

The decision making on selecting the most advantageous suggested technologies is exposed to several factors: economical (investments, exploitation costs), technological adaptability of the system, training of the existing and requirements for engagement of new labour, necessary logistics, qualification and state of equipment, ecological effects, etc. It is obvious that a typical multi-criterion problem is concerned.

3. A multi-criterion analysis

The purpose of a multi-criterion analysis represents the most optimum selection among the considered technological variants of selective mining, conveyance and dumping of solum at coal open pit surfaces of the Electric Power Industry of Serbia.

The Promethee method, as well as the following criteria, are used in the analysis:

- K1 - Investments in technological system;
- K2 - Specific costs per m^3 of deposited solum;
- K3 - Technological adaptability of system;
- K4 - Technical training for adopting and maintenance of system;
- K5 - Necessary engagement of new labour;
- K6 - Ecological effects.

Table 1 shows the matrix containing the initial parameters for multi-criterion analysis, and Tables 2, 3 and 4 give interphase calculations.

The graph of the final rank of the five analysed technological solutions of selective mining, conveyance and dumping of solum, is given in Figure 6.

Table 1.
Initial matrix

Criterion	K1	K2	K3	K4	K5	K6
Estimation	min	min	max	max	min	min
Type	1,000	1,0	2,0	2,0	1,0	1,0
Weight	1,000	1,0	0,7	0,3	0,8	0,5
ECS	0,015	0,5	0,7	1,0	0,1	0,1
Variant **A**	0,201	6,5	1,0	0,5	0,7	0,8
Variant **B**	0,455	9,8	1,0	0,5	0,8	0,3
Variant **C**	0,169	4,7	1,0	0,5	0,5	0,6
Variant **D**	0,160	5,0	0,8	0,7	0,7	0,8

Table 2.
Correlation matrix

Criterion	K1	K2	K3	K4	K5	K6
K1	1,000					
K2	0,964	1,000				
K3	0,705	0,789	1,000			
K4	-0,720	-0,835	-0,968	1,000		
K5	0,802	0,919	0,696	-0,825	1,000	
K6	0,043	0,294	0,397	-0,564	0,615	1,000

Table 3.
Phi indication preferences

Technology	ECS	Variant **A**	Variant **B**	Variant **C**	Variant **D**	Phi+
ECS	0,000	0,837	0,837	0,837	0,837	0,834
Variant **A**	0,163	0,000	0,651	0,000	0,163	0,244
Variant **B**	0,163	0,116	0,000	0,116	0,279	0,169
Variant **C**	0,163	0,767	0,651	0,000	0,698	0,570
Variant **D**	0,163	0,535	0,721	0,302	0,000	0,430
Phi -	0,163	0,564	0,715	0,314	0,494	

Table 4.

The course of ranking according to the Promethee method

Technology	Phi+	Rank	Phi -	Rank	Phi	Rank
ECS	0,837	1	0,163	1	0,674	1
Variant **A**	0,244	4	0,564	4	- 0,320	4
Variant **B**	0,169	5	0,715	5	- 0,547	5
Variant **C**	0,570	2	0,314	2	0,256	2
Variant **D**	0,430	3	0,494	3	- 0,064	3

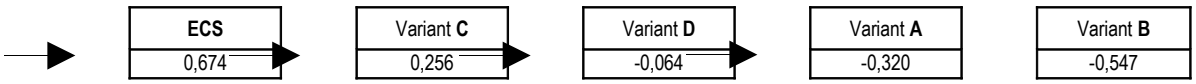

Fig. 6. A graph of the final rank of the analysed technological variants

4. Conclusion

According to the results of multi-criterion analysis, the highest rank (0,674) is characterized by the amalgamated technological solution, namely by the technology of selective mining, conveyance and dumping of solum based on the existing ECS systems. Then the separated, namely new technological solutions follow being ranked as:

- Variant **C**: Scraper system;
- Variant **D**: System of bulldozer with ripper – loader – dumper – bulldozer;
- Variant **A**: System of SM excavator – dumper – bulldozer;
- Variant **B**: System of SM excavator – conveyors – spreaders – bulldozer.

On the grounds of this analysis, the optimum technological solution of selective mining, conveyance and dumping of solum at coal open pit surface of the Electric Power Industry of Serbia, is represented by the existing ECS systems with the corresponding organizational adjustments for selective operating.

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