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SELECTION THE VARIANT TECHNICAL SOLUTION OF THE TRANSPORT AND SERVICE ROAD TO THE EASTERN EXTERNAL LANDFILL AND COLLECTIVE WATER COLLECTOR***

Abstract

This work presents the variant technical solutions for transport of waste to the external landfill of the open pit Gacko. The construction of road has several purposes and should ensure the stabilization of the outer landfill in the zone with deposited quaternary sediments as well as the waste transport to the external landfill by the high-capacity trucks. The selection of a more favorable variant was made from the aspect of unit costs for the waste transport and from the aspect of the costs of variant solutions.

Keywords: *technical solution of the road, open pit Gacko, unit transport costs, transport capacity*

INTRODUCTION

Coal exploitation works at the open pit Gacko are currently performed according to the Main Mining Design of the open pit Gacko - Central field for the capacity of $2.3x10^6$ t/year of run-of-mine coal. The coal exploitation is developed in two zones, the roof and central exploitation zone [1].

The exploitation conditions at the open pit Gacko are very complex and expressed through the mining-geological, mining-technical and techno-economic indicators [2]. The exploitation of coal at the open pit Gacko are developed in two zones. The Field C, which is the central exploitation zone and the zone of roof coal series [3]. In order to ensure the undisturbed development of mining operations in the roof coal zone and provide continuity in the coal supply, it is necessary to excavate the quaternary sediments. The quaternary sediments are deposited on the eastern outer landfill. Because of the poor physical-mechanical characteristics, due to the heavy precipitation, the stability of deposited quaternary sediments was disturbed. The road ramp must ensure the stability of external landfill in the zone where the quaternary sediments have been deposited, waste transport from the Central Field, waste transport from the roof zone, transport of equipment and maintenance of the collecting water collector located in front of the Central zone development [4]. A layout of the mining facilities is shown in Figure 1.

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Figure 1 *Layout of the mining facilities at the open pit Gacko*

The route of road (embankment) for waste transport and stabilization of the external landfill

For the needs of waste transport and the need for ongoing maintenance of the water collector, it is necessary to make the route of road from Field C. In addition to the road route, it is necessary to form a protective embankment in the north-eastern part of the external landfill. The main function of the protective embankment is to carry out the landfill stabilization in a part where the quaternary sediments and waste from the Roof zone are deposited, characterized by the poor physical-mechanical characteristics. In addition to the stabilization function of the external landfill, the protective embankment will have a function of the road. Just because of its function, the road and landfill must be built from the high quality marble material from the central exploitation zone of the Field C.

Variant 1

Two variants of the road route were considered. In the Variant 1, the road consists of three sections (Figure 2). Section 1 represents the road route to the protective embankment of the landfill; Section 2 represents the protective embankment, and Section 3, which will be a connection between the protective embankment and the old Kulski road.

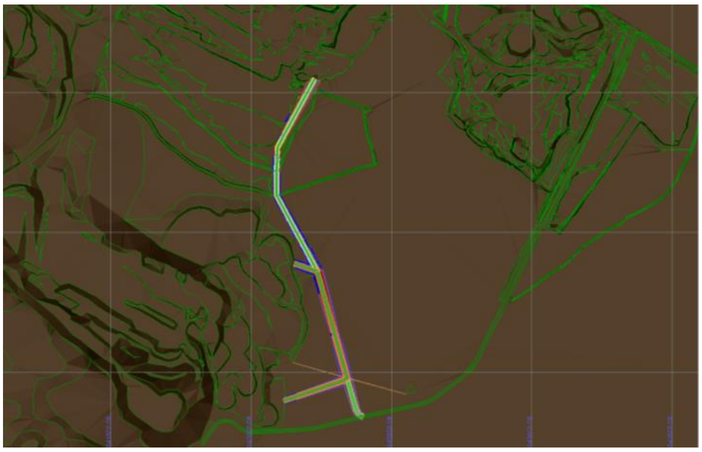

Figure 2 *Overview of the road route section for the waste transport and external landfill stabilization*

Section 1

Section 1 of the road route consists of a part located in a contour of the open pit (Field C) and a part located outside a contour of the open pit. In the contour of open pit, it is necessary to build a ramp from the level of 920 m above sea level to 938 m above sea level. After the ramp construction, the road route on the ground will be done. It is necessary to remove the quaternary sediment and replace it with a marble material. After replacement of the quaternary sediment, it is necessary to overcome the road at a height of 1.5 meters and make a connection up to a level of 750 m above sea level where a crest crown of the protective embankment of landfill will be positioned. The quantities of excavated material on the ramp development are given in Table 1. Table 2 lists the masses of quaternary sediment that need to be excavated. Table 3 lists the quantities of material that need to be filled. The length of the first road section is about 760 m, the width is 18 m. Calculation was made in the Gemcom Gems software package in the Road Construction module.

Table 1 *Quantities of materials that need to be excavated for a ramp construction*

ROCKGROUP	PLANE	Volume m^3
WASTE	N-920	10 672

Table 2 *Quantities of quaternary sediment that need to be excavated*

ROCKGROUP	PLANE	Volume m^3
WASTE	N-940	31 005

Table 3 *Quantities of material that needs to be filled up to the level 750 m above sea level*

ROCK GROUP	PLANE	Volume m^3
WASTE	N-950	113 875

Section 2

After making the Section 1, a protective embankment of the external landfill will be constructed. The embankment is formed of marble material up to the level 750 m above sea level. Table 4 lists the quantities of marls that need to be built in into the protective embankment. The length of protective embankment is about 720 m.

Table 4 *Quantities of material that need to be filled to the level 750 m above sea level*

ROCK GROUP	PLANE	Volume m^3
WASTE	N-940	98 798

Section 3

In order to establish a connection with a water collector, it is necessary to construct a part of the road from the protective embankment to the old Kulski road. The road will be built from marl. The length of the third section is about 140 m. The quantities of marl needed for road construction are given in Table 5.

Table 5 *Section 3 Kulski road– protective embankment*

ROCK GROUP	PLANE	Volume m^3
WASTE	N-940	15 355

Variant 2

Variant 2 consists of 3 sections of the road. Section 1 includes the development of road route from the mine road (the road used for transport of coal from the Roof zone) to the old Kulski road; Section 2 enables the connection from the old Kulski road to the protective embankment of the external landfill, and Section 3 represents the protective embankment (Figure 3).

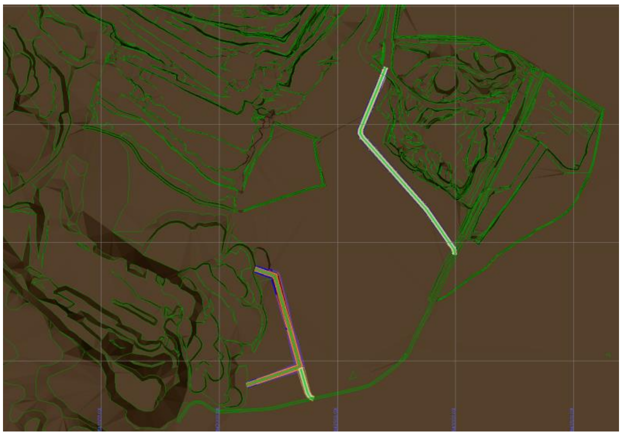

Figure 3 *Variant 1 of the road route*

Section 1

In order to construct the Section 1, it is necessary to replace the mass of quaternary sediment with marl. The length of the Section 1 is about 960 m. The quantities of quaternary sediment that need to be excavated are given in Table 6.

The quantities of marble material that need to be installed instead of the quaternary sediment are given in Table 7. The marble material needs to be filled to the level of 750 m above sea level.

Table 6 *Quaternary sediment cut*

ROCK GROUP	PLANE	Volume m^3
WASTE	N-940	77 200

Table 7 *Marble material embankment*

ROCK GROUP	PLANE	Volume m^3
WASTE	N-940	93 332

Section 2

In order to establish a connection with the protective embankment of the external landfill, it is necessary to make a route of the road. The road route is made of marl. The length of the Section 2 is about 140 m. The masses to be built during the construction of this part of road are given in Table 8.

Table 8 *Section 2 Kulski road – protective embankment*

ROCK GROUP	PLANE	Volume m^3
WASTE	N-940	15 355

Section 3

Section 2 is a protective embankment of the external landfill. The embankment is formed of marble material up to the level 750m above sea level. Table 9 list the quantities of marl that need to be built in into the protective embankment. The length of the protective embankment is about 720 m.

Table 9 *Quantities of material that need to be filled up to the level 750 m above sea level (Section 2)*

ROCKGROUP	PLANE	Volume m^3
WASTE	N-940	98 798

CALCULATION THE TRANSPORT CAPACITY PER OPERATIONS FOR THE TRANSPORT ROAD CONSTRUCTION

Belaz 75135 trucks with a capacity of 110 tons are envisaged for the material transport. The hydraulic excavators Komatsu PC 800 or Hyundai R800, bucket volume of about 5 m^3, are envisaged for excavation. Calculation is made in the Talpac software package.

The Talpac computer program was used to calculate the system of excavator - truck. On the basis of the input parameters, the time capacities of a truck for a given route are calculated.

The work organization at the open pit Gacko is 365 days a year, 7 working days a week, in 3 shifts. The total effective time during the year is 3,500 h. Based on the presented organization, the following planned working hours were used for the calculation of loading and transport:

- Total possible number of shift per year: 1,095 shift/year
- Duration of shift: 8 h
- Number of workig hours per year: 8,760 h
- Effective working hours in a shift: 5.5 h
- Effective working hours per year: 3,500 h

Tables 10 and 11 show the results of truck transport calculation per sections obtained in the Talpac software package.

Table 10 *Capacity of truck transport (hm^3/h) in the formation of transport and service roads towards the external landfill*

Transport capacity hm^3/h	Transport of humus (quaternary sediments)	Transport of marl for road formation	Transport of marl for formation the landfill embankment	Transport of marl for formation the road from landfill embankment to the asphalt road
Variant 1	115.54	149.55	139.56	116.39
Variant 2	120.31	132.16	99.27	105.87

Table 11 *Capacity of material transport (hm3/h) in the construction of envisaged facilities*

Transport capacity hm^3/h	Cut and embankment of the road	Embankment of the landfill	Road from the landfill embankment to the asphalt road
Variant 1	265.09	139.56	116.39
Variant 2	252.47	99.27	105.87

CALCULATION THE NORMS OF MATERIAL AND ENERGY ON TRANSPORT BY SECTIONS (FACILITIES)

Variant 1

Tables 12, 13, and 14 show the calculations of the consumption norms for the sections (facilities) that need to be made.

Table 12 *Material and energy consumption norms and unit costs for material transport on construction of road cut and embankment in Variant 1*

Road cut and embankment	**Quantity**	**Unit price (€/unit)**	**Unit costs (€/hm^3)**	**Unit costs(€/t)**
Fuel norm (l/hm^3)	0.395	0.70	0.277	0.146
Lubricant norm (kg/hm^3)	0.040	2.00	0.079	0.042
Oil norm (l/hm^3)	0.043	3.50	0.152	0.080
Tire norm (pcs./hm^3)	0.000005	2,000.00	0.009	0.005
Norm of spare parts (kg/hm^3)	0.004	10.00	0.035	0.018
TOTAL			**0.552**	**0.290**

Table 13 *Materialand Energy Consumption norms and Unit Costs for material Transport on Construction the landfill embankment in Variant 1*

Landfill embankment	**Quantity**	**Unit price (€/unit)**	**Unit costs (€/hm^3)**	**Unit costs(€/t)**
Fuel norm (l/hm^3)	0.750	0.70	0.525	0.276
Lubricant norm (kg/hm^3)	0.075	2.00	0.150	0.079
Oil norm (l/hm^3)	0.083	3.50	0.289	0.152
Tire norm (pcs./hm^3)	0.000009	2,000.00	0.017	0.009
Norm of spare parts (kg/hm^3)	0.004	10.00	0.035	0.018
TOTAL			**1.016**	**0.535**

Table 14 *Norms of material and energy consumption and unit costs of material transport on the road construction from the landfill embankment to the asphalt road in Variant 1*

Road from the landfill embankment to the asphalt road	**Quantity**	**Unit price (€/unit)**	**Unit costs (€/hm^3)**	**Unit costs (€/t)**
Fuel norm (l/hm^3)	0.900	0.70	0.630	0.331
Lubricant norm (kg/hm^3)	0.090	2.00	0.180	0.095
Oil norm (l/hm^3)	0.099	3.50	0.346	0.182
Tire norm (pcs./hm^3)	0.000010	2,000.00	0.021	0.011
Norm of spare parts (kg/hm^3)	0.004	10.00	0.035	0.018
TOTAL			**1.212**	**0.638**

Variant 2

Tables 15, 16 and 17 provide the calculations of the consumption norms for the sections (facilities) that need to be made.

Table 15 *Norms of material and energy consumption and unit costs for the material transport on the construction of road cut and embankment in Variant 2*

Road cut and embankment	Quantity	Unit price (€/unit)	Unit costs (€/hm^3)	Unit costs (€/t)
Fuel norm (l/hm^3)	0.415	0.70	0.290	0.153
Lubricant norm (kg/hm^3)	0.041	2.00	0.083	0.044
Oil norm (l/hm^3)	0.046	3.50	0.160	0.084
Tire norm (pcs./hm^3)	0.000005	2,000.00	0.010	0.005
Norm of spare parts (kg/hm^3)	0.004	10.00	0.035	0.018
TOTAL			**0.577**	**0.304**

Table 16 *Norms of material and energy consumption and unit costs for the material transport on the construction of landfill embankment in Variant 2*

Landfill embankment	Quantity	Unit price (€/unit)	Unit costs (€/hm^3)	Unit costs (€/t)
Fuel norm (l/hm^3)	1.055	0.70	0.738	0.389
Lubricant norm (kg/hm^3)	0.105	2.00	0.211	0.111
Oil norm (l/hm^3)	0.116	3.50	0.406	0.214
Tire norm (pcs./hm^3)	0.000012	2,000.00	0.024	0.013
Norm of spare parts (kg/hm^3)	0.004	10.00	0.035	0.018
TOTAL			**1.415**	**0.745**

Table 17 *Norms of material and energy consumption and unit costs for the material transport on the construction of road from the landfill embankment to the asphalt road in Variant 2*

Road from the landfill embankment to the asphalt road	Quantity	Unit price (€/unit)	Unit costs (€/hm^3)	Unit costs (€/t)
Fuel norm (l/hm^3)	0.989	0.70	0.692	0.364
Lubricant norm (kg/hm^3)	0.099	2.00	0.198	0.104
Oil norm (l/hm^3)	0.109	3.50	0.381	0.200
Tire norm (pcs./hm^3)	0.000011	2,000.00	0.023	0.012
Norm of spare parts (kg/hm^3)	0.004	10.00	0.035	0.018
TOTAL			**1.329**	**0.699**

Table 18 shows the unit costs of material transport for the facilities (sections).

Table 18 *Unit costs of material transport (€/hm3) in the construction of envisaged facilities*

	Road cut and embankment	Landfill embankment	Road from the landfill embankment to the asphalt road
Variant 1	0.552	1.016	1.212
Variant 2	0.577	1.415	1.329

Table 19 shows the norms of unit costs of material transport and energy in loading for construction the facilities (sections).

Table 19 *Norms of material and energy consumption for material loading*

Excavation and loading	Quantity	Unit price (€/unit)	Unit costs (€/hm^3)	Unit costs (€/t)
Fuel norm (l/hm^3)	0.238	0.70	0.166	0.088
Lubricant norm (kg/hm^3)	0.024	2.00	0.048	0.025
Oil norm (l/hm^3)	0.026	3.50	0.092	0.048
Norm of spare parts (kg/hm^3)	0.004	10.00	0.035	0.018
TOTAL			**0.340**	**0.179**

Bulldozer capacity on the road construction

The bulldozer capacity calculation was made according to a methodology proposed by Caterpillar for a mean length of 50 m, which would carry out the transport, planning and compacting of t unloaded material.

According to this methodology, the bulldozer capacity in planning is:

$$Q_{th} = 470 \cdot 0.75 \cdot 0.7 \cdot 1 \cdot 1 \cdot 0.8 \cdot 0.67 \cdot 1 = 132 \text{ rm}^3/\text{h} = 102 \text{ hm}^3/\text{h}$$

The same type bulldozer would be engaged in planning the deposited quaternary layers and its capacity in these works would be increased by 50% due to the operation conditions and material characteristics being disposed, i.e. it would be about 150 m^3/h.

Material and energy norms in marl planning in the road construction are given in Table 20, while the material and energy norms of bulldozer work in planning the deposited humus are given in Table 21.

Table 20 *Norms of material and energy in marl planning in the road construction*

Marl planning	Quantity	Unit price (€/unit)	Unit costs (€/hm^3)	Unit costs (€/t)
Fuel norm (l/hm^3)	0.453	0.70	0.317	0.167
Lubricant norm (kg/hm^3)	0.045	2.00	0.091	0.048
Oil norm (l/hm^3)	0.050	3.50	0.174	0.092
Norm of spare parts (kg/hm^3)	0.004	10.00	0.035	0.018
TOTAL			**0.617**	**0.325**

Table 21 *Norms of material and energy in planning of disposed humus*

Humus planning	Quantity	Unit price (€/unit)	Unit costs (€/hm^3)	Unit costs (€/t)
Fuel norm (l/hm^3)	0.270	0.70	0.189	0.099
Lubricant norm (kg/hm^3)	0.027	2.00	0.054	0.028
Oil norm (l/hm^3)	0.030	3.50	0.104	0.055
Norm of spare parts (kg/hm^3)	0.004	10.00	0.035	0.018
TOTAL			**0.381**	**0.201**

For the fine planning of the road wearing surface, the graders are engaged, and calculation of the standard consumption for graders is calculated on the example of a grader, power of about 200 kW, i.e. Caterpillar 16H type grader (power P = 201 kW, mass 24.7 t and plow width L = 2.98m). Capacity of this grader is calculated according to the form:

$$Q_h = v \cdot (L_e - L_o) \cdot k_t$$

where:

- Q_h – hourly capacity of a grader
- v – operation speed of grader movement (v=4.5 km/h – medium speed of movement in planning)
- L_e – effective plough width of a grader

$L_e = L \cdot \cos\alpha = 2.98m \cdot \cos 30^o = 2.58$ m

where:

- L – plow width (and plow width l=2.98 m)
- α – plow inclination angle relative to the angle (frequently 30^o)
- L_o – width of passage overlapping for grader (L_o = 0.3 m)
- k_t – coefficient of time utiliyation in a shift (k_t = 0.8) and capacity is:

$Q_h = v \cdot (L_e - L_o) \cdot 1000 \cdot k_t =$

$= 4.5 \cdot (2.58\text{-}0.3) \cdot 1000 \cdot 0.8 =$

$= 8208\ m^2/h$

Norms of energy and material consumption for a grade type CAT 16H, power 201 kW and capacity of 8208 m^2/h are given in Table 22.

Table 22 *Norms of grader consumption in fine road planning*

Fine planning	Quantity	Unit price (€/unit)	Unit costs (€/m^2)
Fuel norm (l/m^2)	0.004	0.70	0.003
Lubricant norm (kg/m^2)	0.000	2.00	0.001
Oil norm (l/m^2)	0.000	3.50	0.002
Tire norm (pcs/m^2)	0.0000001	1,350.00	0.00013
Spare parts norm (kg/m^2)	0.004	10.00	0.035
TOTAL			**0.041**

Table 23 gives the unit costs for individual technological procedures for the construction of transport road and landfill embankment.

Table 23 *Unit costs of material transport according to certain technological procedures for transport road construction and landfill embankment*

Technological procedure	Unit	Variant 1	Variant 2
Transport of materials during the construction of the road and road	(€/hm^3)	0.552	0.577
Transport of materials in the construction of landfill sites	(€/hm^3)	1.016	1.415
Transport of materials during the road construction from embankment landfill to the asphalt road	(€/hm^3)	1.212	1.329
Loading material	(€/hm^3)	0.34	0.34
Construction of road embankment and rough material planning by bulldozer	(€/hm^3)	0.617	0.617
Planning a disposed humus by bulldozer	(€/hm^3)	0.381	0.381
Construction of the wearing surface of road and fine material planning by graders	(€/hm^3)	0.041	0.041

Table 24 gives the unit costs, material quantities and total costs for variant solutions.

Table 24 *Unit costs, quantities of materialand total costs for variant solutions*

		Unit costs		Material quantities (m^3)		Total costs (€)	
Technological procedure	Unit	Var. 1	Var. 2	Var. 1	Var. 2	Var. 1	Var. 2
Transport of materials in the road construction and road	(€/hm^3)	0.552	0.577	144,880	170,532	79,974	98,397
Transport of materials in the construction of landfill sites	(€/hm^3)	1.016	1.415	98,798	98,798	100,379	139,799
Transport of materials in road construction from the landfill embankment to the asphalt road	(€/hm^3)	1.212	1.329	15,355	15,355	18,610	20,407
Loading material	(€/hm^3)	0.34	0.34	269,705	284,685	91,700	96,793
Construction of road embankment and rough material planning by bulldozer	(€/hm^3)	0.617	0.617	191,240	185,887	117,995	114,692
Planning a disposed humus by bulldozer	(€/hm^3)	0.381	0.381	62,010	77,200	23,626	29,413
Construction of the road wearing surface and fine planning of matrix by a grader	(€/hm^3)	0.041	0.041	29,408	32,882	1,206	1,348
					SUM	**433,489**	**500,849**

CONCLUSION

In comparison the analyzed variants, the advantage 1 is given to the Variant 1 due to lower cost of production. In addition to this factor, it should be kept in mind that the eastern outer landfill can also be used for placement of layered and inter-layered waste from the central exploitation zone to the extent that the combined system cannot accept the all excavated material. It is also advantageous that the material excavated by a combine and transported by trucks is disposed to the subject location. The road construction in Variant 1 does not interfere the development of works in the upcoming period, and the eventual advance of works in that zone would be possible only by construction a new ramp. In this case, the transport of waste from the return zone would go directly through the old Kulski route. The Variant 1 provides more favorable conditions for waste transport from the central exploitation zone, and the average length of material transport from the center of work in the central zone and in Variants 1 and 2 is about 1800 m and 3600 m, respectively.

The analysis was carried out for equipment with which the open pit already possesses but the other mechanization cold be also applied that meets the characteristics of the working environment. The formation of the road embankment would also have the function of protecting space from water. The disposal of quaternary sediments is envisaged on the final surface of the inner landfill of the central field and this mass would be used in the subsequent stages for remediation of a wider area, and these areas could be immediately rehabilitated by the formation of grasslands.

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