Türkiye III. Kömür Kongresi Bildiriler Kitabı/I'roccedings of the /Dili Coal Congress of Turkey

RESEARCH INTO THE POSSIBILITY OF RATIONAL ELECTRICAL POWER RECOVERY IN BUCKETWHEEL EXCAVATOR

DÖNER KEPÇELİ KAZICILARDA ELEKTRİK GÜCÜN AKILCI KAZINIMI ÎLE İLGİLİ BİR ARAŞTIRMA

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ABSTRACT

The paper presents the results of research into the possibility of more rational electrical power consumption during coal and overburden excavation in open pit mines. As a research object the system bucketwheel excavator - belt conveyor - stacker is considered.

The results obtained on electrical power consumption of a bucketwheel excavator in dependence on selected slice geometrical parameters are given as an illustration of foregoing research.

OZET

Bu bildiride, açık ocaklarda kömür ve örtü tabakasının kazılmasi sırasında elektrik gücün akılcı kazanılması olanaklanyla ilgili araştırmanın sonuçları sunulmaktadır. Araştırma konusu olarak döner kepçeli kazıcı-bant rakliyepasa yayan sistem gözönüne alınmıştır.

Yukarıdaki araştırmada döner kepçeli kazıcının geometrik parametrelere bağlı olarak elektrik güç harcamasınoan elde edilen sonuçlar verilmiştir.

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1. RESEARCH MODEL INITIAL BASES

More than 40 million tons of coal and 90 million m[1] of solid overburden are excavated annually in Yugoslav openpit coal mines. Motor installed power only in basic equipment (excavator, belt, stacker) used in basic production processes including excavation, transport and disposal, totals more than 360.000 kW.

The basic research idea was based on the assumption to determine the required electrical power P_{ke} by production processes (excavation, transport and disposal) first, covering the specified amount and type of material to be excavated. Thereafter, the realized electrical power consumption in the working process by production process stages Q_{pe} is to be measured. Naturally, rational electric power consumption is secured by the condition that $Q_{pe} < P_{ke}$

Study of basic production processes from the aspect of electric power consumption yielded the following facts:

- Required (planned) amount of electric power depends on: deposit condition, given design solution and selected equipment functionality under existing operating and organizational conditions (Fig. 1);
- Realized electric power consumption depends on: degree of designed solution realization, degree of equipment adaptation to conditions under which it will operate in existing organization (Fig. 2);
- Reduction of electric power consumption may be achieved by improvement and monitoring of equipment and devices, production process, electric power consumption normatives and electric power consumption (Fig. 3).

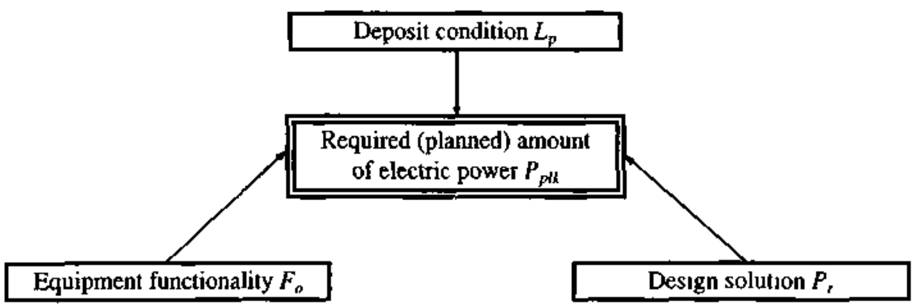

Fig. 1 - Group of elements affecting the required electric power P_{plk}

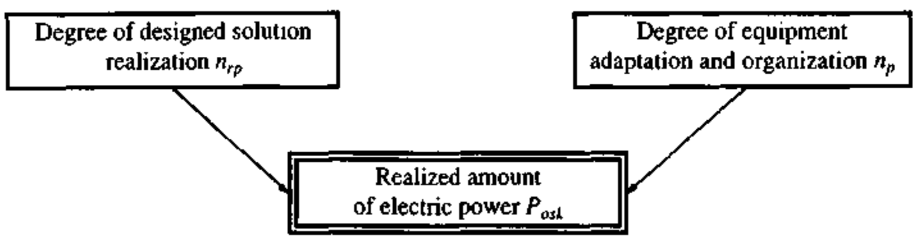

Figure 2 - Group of elements affecting electric power consumption P_{osk}

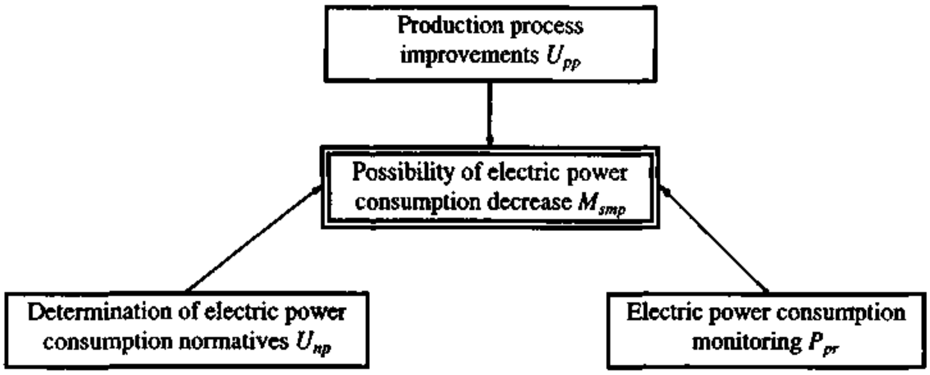

Figure 3 - Group of elements affecting consumption decrease electric power M_{smp}

As seen on Figs 1, 2 and 3 all influential elements are classified into following groups:

- Group of elements affecting the required (planned) electric power - P_{plk};
- Group of elements affecting electric power consumption - P_{osk};
- Group of elements affecting consumption decrease electric power - M_{smp}.

The basic aim of Group P_{pU} elements is to enable minimization of required electric power through detailed acquaintance with deposit conditions, design solution quality and selected equipment. The aim of Group P_{osk} elements is to achieve the planned (required) electric power consumption, i.e. a minimum difference between designed and actual consumption, by realization of a high degree of design solution and degree of equipment adaptation. The M_{smp} Group of elements should enable electric power consumption decrease by equipment and production process improvements, introduction of electric power consumption normatives for all operating process stages and consumption monitoring.

Designation of basic elements in line with symbols given on Fig. 1, 2 and 3 allows an analytical expression of functional dependencies by elements group:

$$P_{plk} = \mathrm{f}\,(L_p, P_r, F_o) \tag{1}$$

$$P_{osk} = \mathrm{f}\,(n_{rp}, n_p) \tag{2}$$

$$M_{smp} = \mathrm{f}(U_{np}, U_{pp}, P_{pr}) \tag{3}$$

2. DEFINITION OF THE PROCEDURE FOR RATIONAL UTILIZATION OF ELECTRIC POWER

In line with the foregoing it is possible to define a model for rational utilization of electric power. The required amount electric power for existing deposit conditions and production requirements should be determined first on the basis of design solution. Thereafter, the production process should be realized in such a manner that the actually consumed electric power amounts are equal to or lower than the designed required electric power amounts. In the course of production process realization measures and solutions for electric power consumption decrease should be constantly carried out. In line with this, Fig. 4 gives a schematic presentation of above model basic concept, consisting of six blocks marked by symbols A, B, C, D, E and F (Fig. 4).

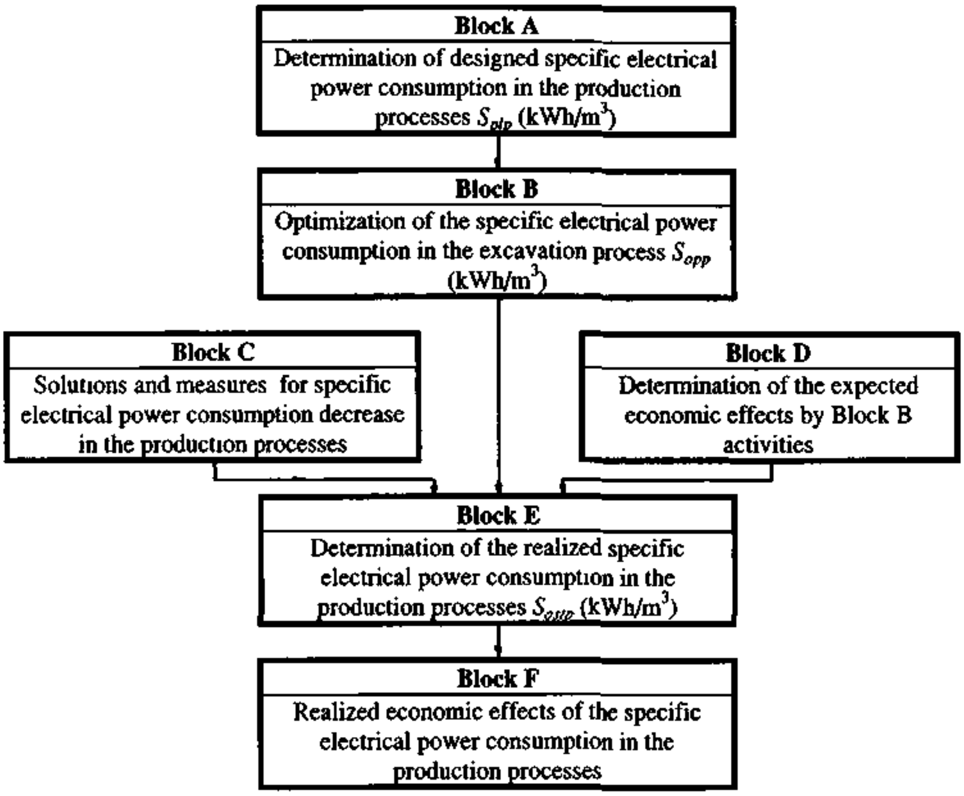

Figure 4 - Definition concept of the procedure for rational utilization of electrical power

Calculated specific electric power consumption for the selected design solution variant according to the criterion of minimum electric power consumption is defined in the input part while the output part yields the realized economic effects and differences compared with the expected ones. Block structures are different, while the connections between blocks are conditional. Also, assumptions, limitations, objective functions and criteria differ for each block. As an illustration, Fig. 5 shows only the structure of block "B" used for selection of cut geometric parameters with minimum specific electric power consumption for a specified hourly output.

On the Figure No. 5 the following signs and symbols are introduced:
H - Block height (m), S_b - block width (m), D_b - block depth (m), a_b - lateral slope angle of incline (°), a_c - face slope angle of incline (°), /„ - distance of excavator transport route axis (m), h - slice (cut) height (m), b - slice width (m), S - slice thickness (m), V„ - bucketwheel boom circular movement speed on transport route axis (m/min), K_{od} - slice

ratio, <p, - internal circular movement angle (°), <p, - external circular movement angle (°). *Qi* - theoretical output (m^3/h), L_{sr} - mean cutting length of all grasping buckets (m), *K,* - available specific cutting force (N/cm), N_{kop} - required digging power (kW), t_{re}. - cut excavation time (sec), *P.,,* - required electrical power for the one slice excavation (kWh), *Vr,,* - cut volume (m) and S_{pkop} - specific electrical power consumption for the one slice excavation (kWh/m)

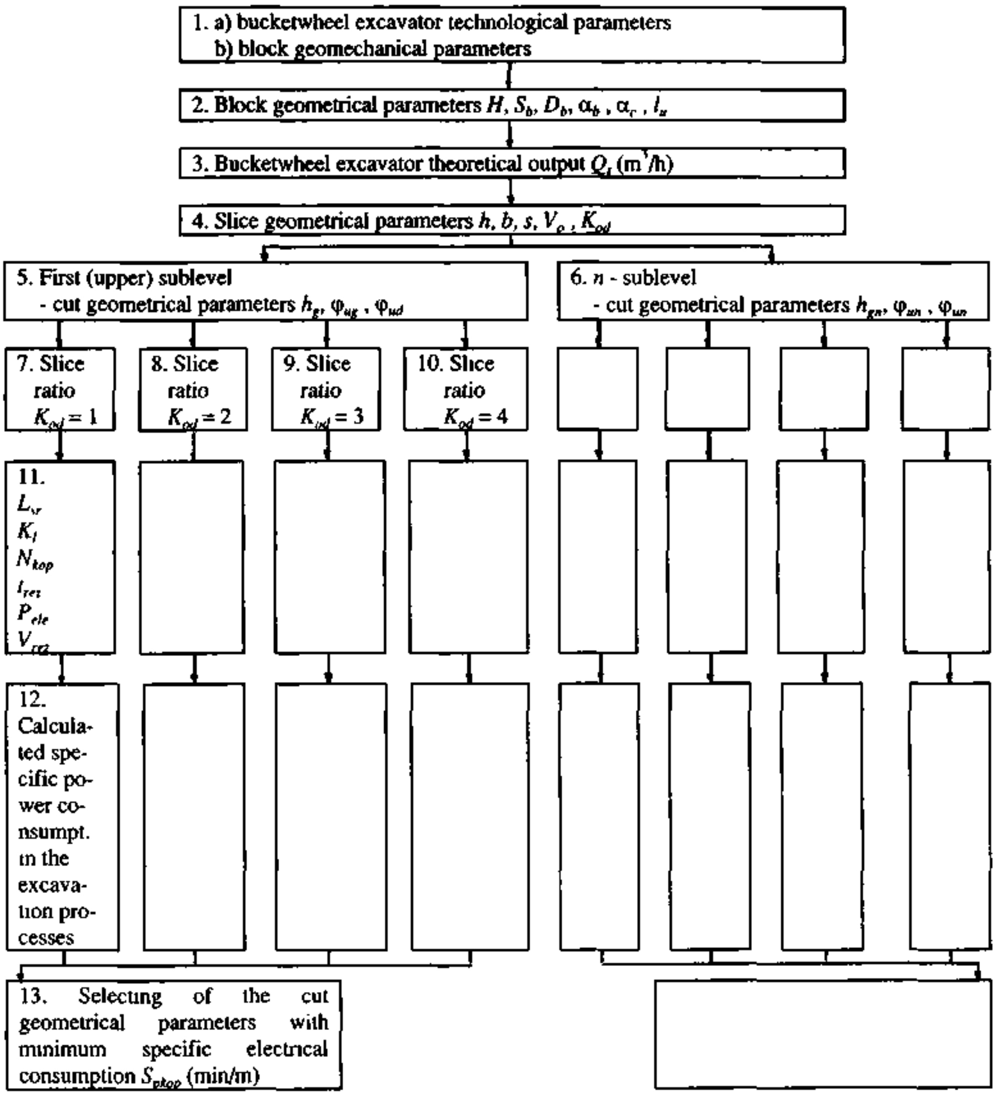

Figure 5 - Optimization of the bucketwheel excavator specific power consumption in the excavation process - Block B

In block "B" section marked by 1 initial parameters for calculation of bucketwheel wheel excavator specific electric power consumption in the excavation process are given. In block section No. 13 cut geometric parameters with minimum specific electric power consumption for the same hourly output are selected. So obtained geometric parameters are delivered to excavator operator for realization.

3. REVIEW AND ANALYSIS OF ACHIEVED RESULTS

In a coal seam block defined by block excavation technology block technological parameters, geomechanic parameters, coal tendencies and properties excavation was carried out by a bucketwheel excavator Srs 1200 22/2. The block was excavated in three sublevels.

On each sublevel after every eight cuts below parameters were recorded: cut height h (m); bucketwheel drive power N (kW); cut thickness S_0 (m); force on bucket tooth F (kN); cut width S_{rez} (m); cut excavation time t (sec) and bucketwheel boom circular movement speed in the transport route axis V_0 (m/min).

The following was defined on the basis of recorded parameters: slice width b (m); mean horizontal (transversal) slice area of all grasping bucket YA_{sr} (cm^2); mean cutting length of all grasping buckets L_{sr} (cm); mean bucketwheel drive power N_{sr} (kW); mean bucketwheel peripheral force F_{lsr} (kN); mean value of realized specific cutting force K_{lsr} (N/cm); mean value of cut hourly output Q_{lh} (m^3/h); realized specific bucketwheel electric power consumption and slice ratio K_{od}.

For excavation of the coal block second sublevel below relevant parameters were defined m advance: cut height h = 5,8 m; circular movement speed V_0 = 18,5 m/min; slice thickness S = 0,34 m; cut width S_{rez} = 23,4; slice width b = 0,25; cut excavation time t = 87,2 sec; slice ratio K_{od} = 1,32; mean cutting length of all grasping buckets L_{sr} = 2,96 m; mean excavator hourly output in a cut q_{rez} = 2188 m^3/h; mean horizontal slice area of all grasping buckets YA_{sr} = 2522 cm and mean specific digging resistance value K_{tb} = 400 N/cm.

For the mean specific material digging resistance value and calculated cutting length of all grasping buckets L_{sr} the required force on bucket cutting edges is:

$$P_t = K_{tb}\ L_{srd} \qquad \text{(N)} \tag{4}$$

The actual digging force available by bucketwheel drive:

$$P_L^K = \frac{N_r \cdot 10^3}{V_{rl}} \qquad \text{(N)} \tag{5}$$

where: N_r - required digging power (kW);

V_{rl} - bucketwheel peripheral speed (m/s)

The required digging power may also be expressed as follows:

$$N_r = Ni) - N_z \qquad \text{(kW)} \tag{6}$$

where: İV - overall power transferred to the rotor (630 kW);
$r\backslash$ - gear efficiency rate (0.85).

Power required for material lifting in the bucket up to the discharge height:

$$N_z = \frac{q_{rez}\ \gamma_n\ 9{,}81\ h_z}{3600} \quad \text{(kW)} \tag{7}$$

where: y„ - loose material volumetric density
h_z - material lifting height $h_2 = 1{,}3\ R$ where: R - bucketwheel radius (m).

Specific bucketwheel electric power consumption is as follows [3]:

$$S_{pelrt} = 0{,}00277 \frac{P_L}{A_{\Sigma SR}} \quad \text{kWh/m}^3 \tag{8}$$

In the above equations the following values are obtained: P_t = 118.400 N; P^* = 212.333 N; N_r = 509,6 kW; N_z = 25,4 kW and $S_{per„}$ = 0,130 kWh/m^3

Table No. 1 supplies measured and calculated values of relevant parameters for bucketwheel excavator digging process in the second sublevel (sublevel height is 5,1 m).

For analysis of the influence of slice shape (horizontal slice cross-section at bucketwheel axis height); i.e. slice ratio, on bucketwheel specific electric power consumption Table No. 2 was developed. In this Table the cuts are classified according to realized (measured) thicknesses and calculated cut volumes given in Table No. 1.

In the cut width column (Table No. 2) values in parentheses designate circular movement speed in m/min. Data for cut No. 7 were not entered due to inaccurate measurement of cut excavation time.

In line with Table No. 2 data a graph was drawn indicating variations in cut volume and specific bucketwheel electric power consumption in dependence on different cut excavation times (Fig. 6).

On the Figure No. 6 the bucketwheel specific electric power consumption curve is marked by I, that of slice ratio variation by II and the cut volume variation curve by III. Cut numbers are marked by 1, 2, etc.

Table 1 Measured and calculated values of relevant parameters for bucketwheel excavator digging process in the second sublevel

Cut No	*	t (m)	S (m)	v_o (m/min)	b (m)	$\sum A_w$ (cm²)	l_{sal} (cm)	N_w (kW)	F_w (kN)	K_{1p} N/cm	Q_p m³/h	W kWh/m³	K_{ed}	S_{ed} (m)
1	left	103	0,10	11 2	0.155	391,8	138	98,3	40.6	294 2	341.4	0 287	0,66	20.6
2	right	105	0.15	11,2	0.155	587 7	151	65,4	27	178 8	512,2	0,127	1,00	20,6
3	left	103	0,17	11 2	0 155	666,3	157	78,5	32,4	206,3	580.5	0,134	1,09	20 7
4	right	82	0.35	16	0 222	1965	228	133 5	55,2	242,1	1711 8	0,0771	1,57	20,3
5	left	80	0.20	16	0.222	11223	189	119 4	49.3	260 8	978.2	0.1215	0,90	21,7
6	right	84	0.27	16	0.222	1516	207	123,8	51 2	247,3	1320 5	0,0933	1.21	21,7
7	left	63	0 20	19,2	0 266	1345	205	118	48,7	235.5	1172 1	0,1004	0,75	20,5
8	right	68	0,38	19,2	0 266	2556	253	188 5	77,9	307,9	2226 9	0,084	1 42	21,2

* direction of circular movement

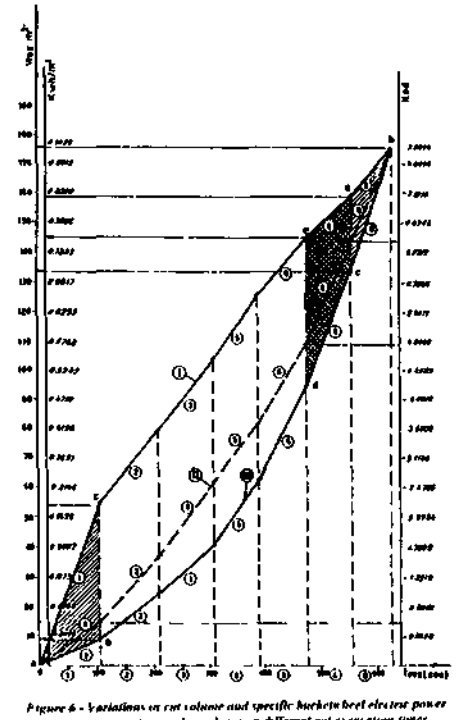

Figure 6 - Variations in cut volume and specific bucketwheel electric power consumption in dependence on different cut excavation times

Table 2 - Analysis of the influence of slice shape on bucketwheel specific electric power consumption

Cut No.	Cut thickness S„(m)	Cut width Mm)	Cut volume	Cut excavation time $t_{r„}$ (sec)	Mean value of cut hourly output q_{rri} (mVh)	Specific electncal power consumption (kWh/m^3)	Slice ratio $K_{„j}$
1	0,10	0,15(11,2)	9,79	103	341	0,287	0,66
2	0,15	0,15	14,90	105	512	0,127	1,00
3	0,17	0,15	16,70	103	581	0,134	1,09
5	0,20	0,22 (16,0)	21,90	80	979	0,121	0,90
6	0,27	0,22	31,60	84	1321	0,093	1,22
4	0,35	0,22	39,40	82	1712	0,077	1,57
8	0,38	0,26 (19,2)	42,30	68	2223	0,084	1,42

As seen from Table No. 2, the highest specific electric power consumption was realized at a minimum slice ratio in cut No. 1. At the highest slice ratio in cut No. 4 minimum specific electric power' consumption was achieved. In cut No. 1 with the lowest slice ratio the calculated mean cut hourly output is 341 m of solid mass/h, and in cut No. 4 with a maximum slice ratio is 1712 m of solid mass/h. Maximum cut excavation time was achieved in cut No. 2, and the minimum one in cut No.8. Also, in cut No. 8 the highest cut volume was achieved, as well as maximum mean cut hourly output of 2223 m of solid mass/h.

As evident from the foregoing, slice ratio, i.e. slice shape affects bucketwheel specific electric power consumption. However, when selecting slice parameters with a minimum specific electric power consumption, selection solely in line with the criterion of slice ratio maximum value is uncorrect. During slice parameters selection the volume value of the whole cut and time of cut excavation duration should be taken into consideration. This statement was confirmed by obtained cut No. 8 parameter values, where the slice ratio value is K_{od} = 1,420. For this slice ratio the calculated cut volume is 42,3 m of solid mass, excavation time is t - 68 s and mean cut hourly output is $q_{re:}$ = 2223 m of solid mass/h. Comparison of parameter value of cut No. 8 and cut No. 4 (Table No. 2) readily indicates that the techno-economic effects are in cut No. 8, disregarding the fact that bucketwheel specific electric power consumption of this cut is 9% higher compared with cut No. 4, better. In cut No. 8 the calculated cut hourly output mean value is higher by about 29,8 %.

As evident from Figure No. 6, from cut No. 5 specific electric power consumption decrease is initiated, as well as cut excavation time, while the volume of excavated cuts (5,4 and 8) rapidly grows. The objective is to excavate a high as possible cut volume and consume the lowest amount of electric power by selected slice parameters over a minimum time.

On Figure No. 6 areas to be excavated under conditions governing during measurements are marked by points a, b, c, d and e. Areas in which parameter selection is irrational are marked by A, B and C.

4. CONCLUSION

In line with the above presented procedure and realized measurement results one may infer that selection of slice shape (slice ratio) may affect the decrease of bucketwheel excavator bucketwheel specific electric power consumption. In addition, the importance of respecting cut volumes and cut excavation times when selecting geometric parameters was clearly indicated.

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