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Ivana Jovanović, Sanja Petrović*, Dejan Bugarin*, Srđana Magdalinović**

LABORATORY TESTING THE GRINDABILITY OF CARBONATE MINERAL RAW MATERIAL OF THE SITE SPASINA BRDJANI – CHALK SAMPLES**

Abstract

This work presents the results of the Bond work index in a ball mill on samples of carbonate mineral raw material (chalk) of the site Spasina - Brdjani. Determination of the Bond Work Index was carried out on total of six samples of chalk from different exploration drill holes, as well as two samples of chalk from the exploration trenches. Comparing the results, it was found that in most cases the value of the Bond Work Index is between 2 and 3 Deviations, which means slightly higher values of Bond work index, were achieved in samples where the presence of alevrolyte interlayers was observed as well as a large concentration of calcified fossils. Very low value of the Bond Work Index 1,520 kWh/t was determined in chalk samples with high content of soft silty clayey component.

Keywords: *Bond work index, chalk*

INTRODUCTION

Considering the overall energy consumption in the exploitation and preparation of mineral resources, it was established that the major part (even 65 - 80%) is spent in the grinding process. Therefore, the assessment of energy consumption in the grinding process is of great importance, not only during the design of future plants, but also for monitoring the changes in grindability of mineral raw material whose processing is in progress. The Bond Work Index is used as an indication of this energy consumption [1,2]. In the case of carbonate mineral raw material from the site Spasina – Brdjani, the Bond Work Index is determined in the ball mill.

The explored area Spasina - Brdjani (narrower locality the Prokos hill) is situated at the extreme northeast hills of the mountain Majevica, at a distance of about 20 km southwest of Bijeljina. It was found that this area is characterized by limestone and associated sediments belonging to the Marine Middle Miocene of Central Paratetis - Baden and Sarmatian, and Quaternary formation – deluvial and proluvial sediments.

In the engineering - geological terms, this site is characterized by a complex of carbonate of different physical and mechanical properties. Higher areas are hypsometrically covered by compact rock

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masses of sand, loose to limestone cores, which in depth lean on a package of compact and loose chalk. In general, these carbonate sediments in terms of stability provide a solid rock mass and belong to the group of stable to conditionally stable terrains. In places of unstable slopes, where the sediments are subject to erosion and slipping, these environments are converted from stable into conditionally stable terrains in notches [3].

Detailed geological explorations of carbonate on the site Spasina - Brdjani included a series of exploration works which among other things included the exploration drilling and mining works (exploration trenches).

For the needs of determining the Bond Work Index, eight composite samples of chalk were selected, wherein the 6 samples were tested from the exploratory drill holes (in designation KR-2 to KR-14) and 2 samples from exploratory trenches (in designation R-13 and R-14). Table 1 shows the coordinates of corresponding drill holes or trenches.

Table 1 *Coordinates of realized exploration drill holes/trenches*

Designation of drill hole/trench	Coordinates			Interval of drill hole
	X	Y	Z	
KR-2	4 948 845.900	6 578 222.810	327.08	40.50-61.00
KR-3	4 948 990.670	6 578 212.520	331.88	36.00-76.00
KR-6	4 948 959.360	6 578 388.030	329.22	30.00-68.00
KR-9	4 948 981.690	6 578 503.420	330.01	30.30-60.60
KR-13	4 949 024.580	6 578 742.280	325.67	34.00-76.00
KR-14	4 948 970.650	6 578 870.220	320.67	30.00-70.50
R-13	4 948 856.670	6 578 861.800	270.67	/
R-14	4 948 975.520	6 578 962.490	283.57	/

EXPERIMENTAL PROCEDURE

Characterization and Preparation of Samples

Chemical analysis of samples from drill holes and trenches at subsequently intervals determined their chemical composition shown in Table 2.

Table 2 *Chemical composition of chalk samples*

Element, %	KR-2	KR-3	KR-6	KR-9	KR-13	KR-14	R-13	R-14
SiO_2	11.44–19.9	0.83–17.26	0.40–15.76	0.90–11.44	3.24–10.70	0.10–15.52	1.36	0.22
CaO	38.6–44.60	40.76–53.99	42.83–52.74	45.87–54.00	45.18–51.89	40.56–55.44	52.40	54.50
Al_2O_3	0.81–0.91	0.21–1.00	0.34–0.68	0.28–0.62	0.32–0.72	0.26–1.62	0.57	0.43
Fe_2O_3	0.47–0.76	0.17–0.54	0.21–0.39	0.19–0.40	0.24–0.39	0.15–0.89	0.34	0.28
FeO	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MgO	0.64–3.52	0.43–0.80	0.20–0.27	0.35–0.51	0.34–0.52	0.40–1.70	0.60	1.00
SO_3	0.06–0.53	0.030–0.095	0.033–0.055	0.03–0.43	0.03–0.07	0.04–0.05	0.068	0.08
Na_2O	0.09–0.11	0.054–0.181	0.065–0.16	0.11–0.26	0.062–0.066	0.034–0.16	0.051	0.051
K_2O	0.14–0.15	0.039–0.19	0.095–0.016	0.088–0.15	0.060–0.15	0.058–0.35	0.10	0.077
MnO	0.014–0.015	0.012–0.014	0.004–0.008	0.006–0.022	0.013–0.017	0.006–0.025	0.013	0.009
P_2O_5	0.035–0.057	0.050–0.071	0.044–0.055	0.044–0.055	0.050–0.057	0.044–0.082	0.066	0.046
TiO_2	0.028–0.035	0.012–0.042	0.012–0.027	0.011–0.025	0.015–0.033	0.015–0.082	0.027	0.015
S	0.024–0.21	0.012–0.038	0.013–0.022	0.012–0.017	0.013–0.028	0.014–0.019	0.027	0.032
LOI	32.36–35.56	34.96–40.59	36.26–40.80	37.14–41.89	37.34–41.14	34.98–42.40	41.76	42.04

The starting samples of chalk (Figure 1) were dried at room temperature, and then on each of the samples the grain size distribution was determined according to the standard ISO 2591-1:1992. Preparation of samples for testing included crushing in a closed cycle, and sieving on a sieve, mesh size of 3.35 mm.

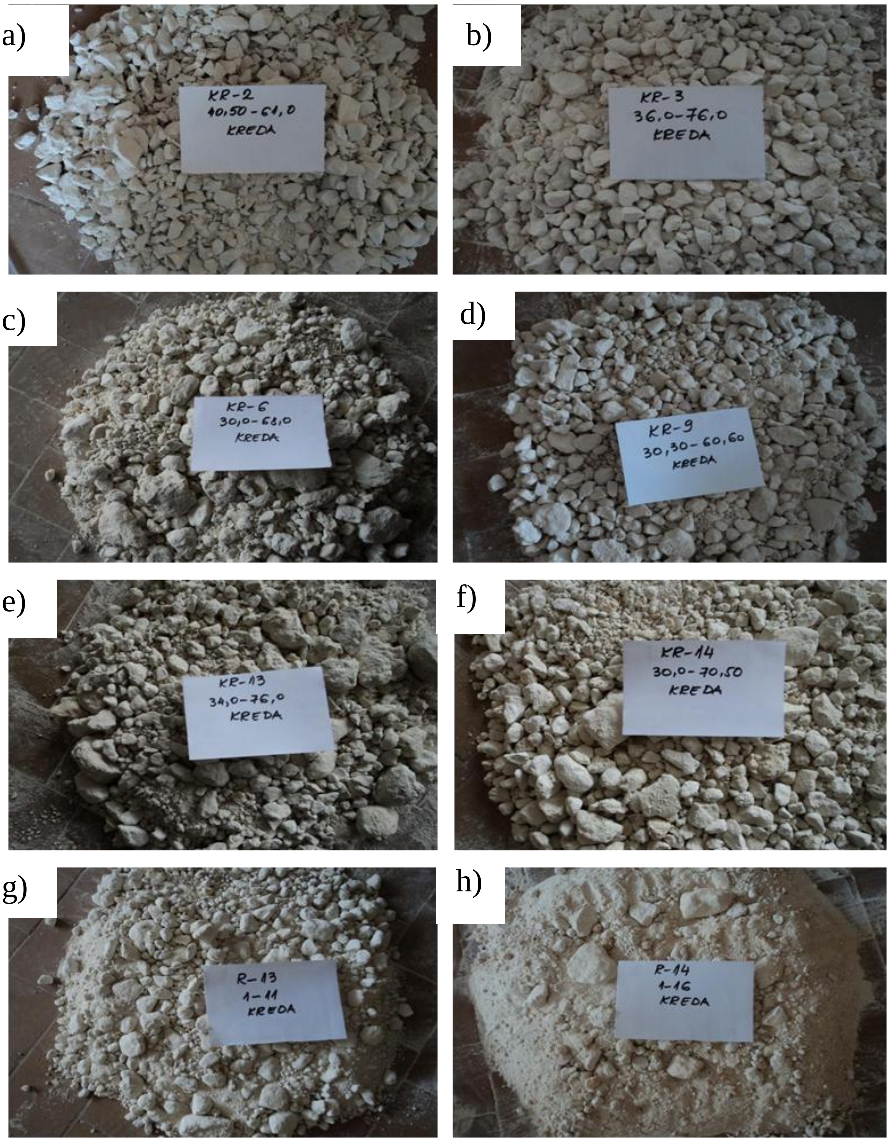

Figure 1 *Starting samples of chalk: a) – f) samples from drill holes; g), h) samples from trenches*

Testing the Bond Work Index

Testing the Bond Work Index was performed in the laboratory Bond ball mill, according to the established procedure, whereby the sieve is selected as a comparative sieve, mesh size 212 µm.

Figures 2 - 9 show the grain size distribution of crushed chalk samples (prepared for testing) as well as the grain size distribution of undersize of the comparative sieve.

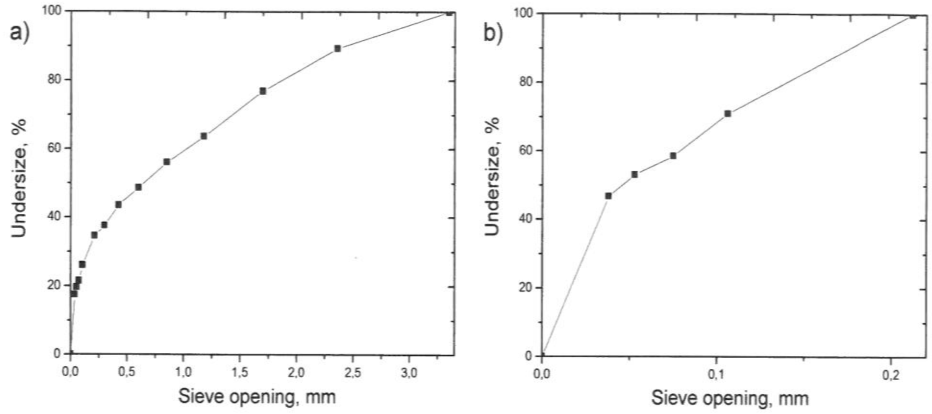

Figure 2 *Grain size distribution of sample KR-2: a) crushed starting sample, b) undersize of comparative sieve*

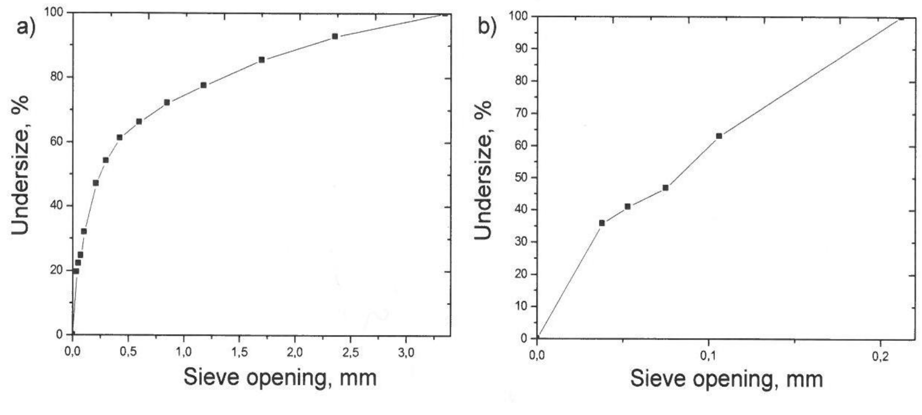

Figure 3 *Grain size distribution of sample KR-3: a) crushed starting sample, b) undersize of comparative sieve*

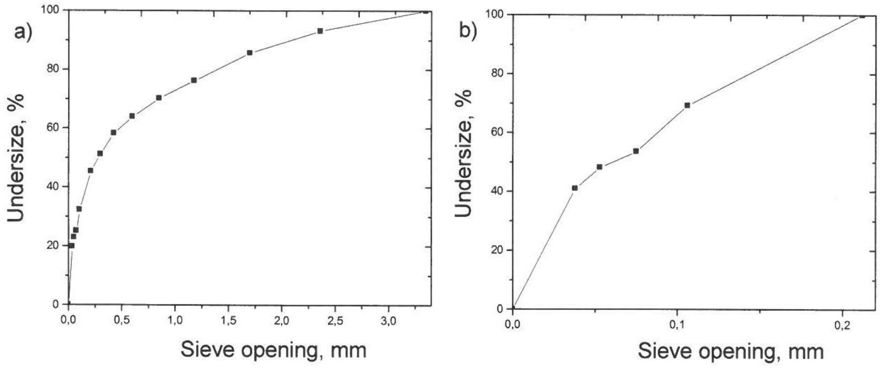

Figure 4 *Grain size distribution of sample KR-6: a) crushed starting sample, b) undersize of comparative sieve*

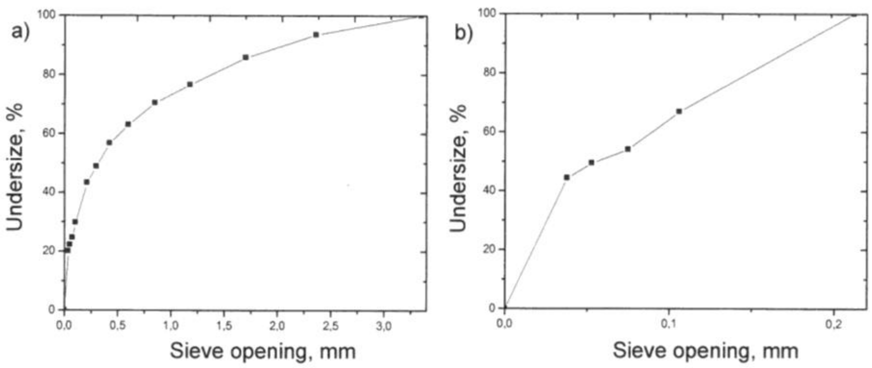

Figure 5 *Grain size distribution of sample KR-9: a) crushed starting sample, b) undersize of comparative sieve*

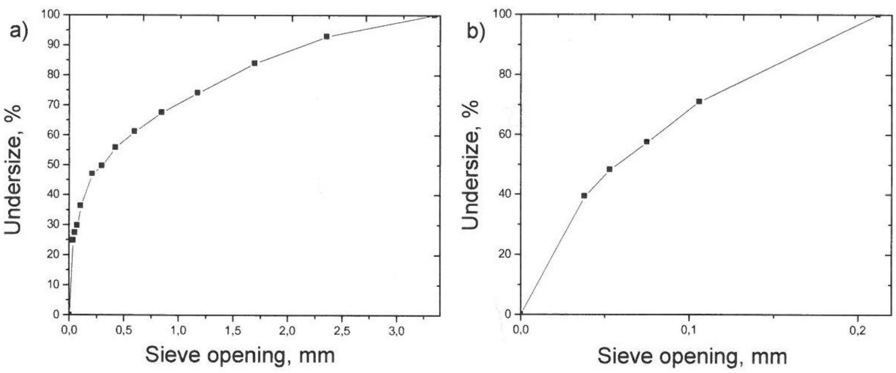

Figure 6 *Grain size distribution of sample KR-13: a) crushed starting sample, b) undersize of comparative sieve*

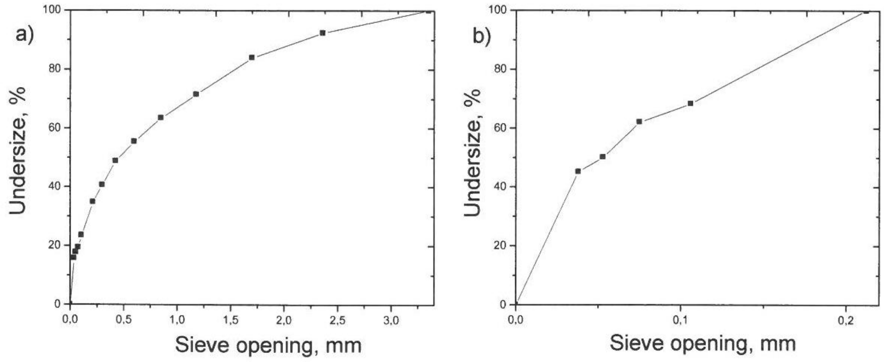

Figure 7 *Grain size distribution of sample KR-14: a) crushed starting sample, b) undersize of comparative sieve*

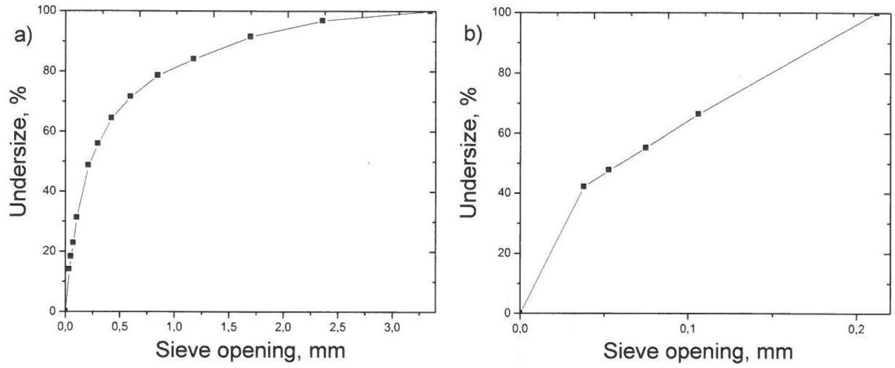

Figure 8 *Grain size distribution of sample R-13: a) crushed starting sample, b) undersize of comparative sieve*

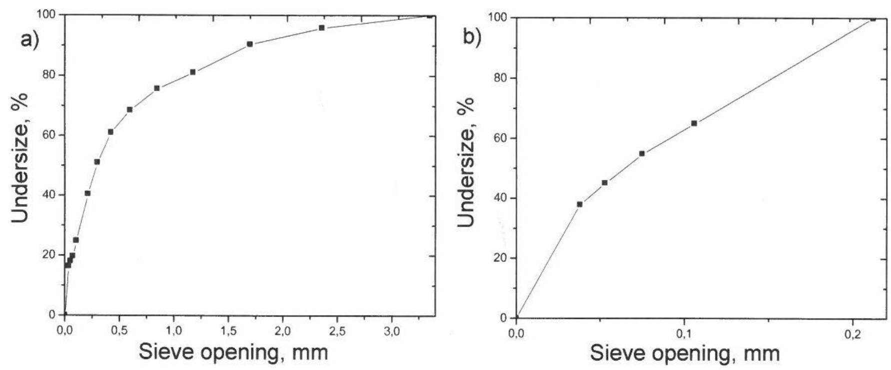

Figure 9 *Grain size distribution of sample R-14: a) crushed starting sample, b) undersize of comparative sieve*

RESULTS AND DISCUSSION

The Bond Work Index was calculated according to the formula:

Where:

P_k – mesh size of comparative sieve, µm

G - new-created undersize per one revolution of mill, g/rev.

P - mesh size through which 80% of undersize of comparative sieve passes, from the last experiment, µm

F - mesh size through which 80% of starting sample passes whose the Bond Work Index is determined, µm

Table 3 shows the values of characteristic parameters, and values of the Bond Work Index for all 8 tested chalk samples.

Table 3 *Characteristic parameters and the Bond Work Index for chalk samples*

Samples	KR-2	KR-3	KR-6	KR-9	KR-13	KR-14	R-13	R-14
Pk, µm	212	212	212	212	212	212	212	212
G, g/rev.	7.985	20.484	19.973	13.272	18.288	10.684	36.279	7.648
P, µm	138	153	142	148	138	147	148	152
F, µm	1840	1320	1390	1381	1487	1510	930	1120
Wi, kWh/t	4.244	2.251	2.146	3.099	2.226	3.608	1.520	5.256

Based on the test results shown in Table 3, it is evident that in most cases the value of the Bond Index ranges between 2 and 3. Deviations, which mean slightly higher values of the Bond Index were realized in samples with designations KR-2, KR-14 and R-14. These deviations are explained by a greater presence of interlayers of alevrolyte in the samples KR-2 and KT-14, or high concentration of calcified fossils in the sample R-14.

Sample R-13 has the lowest value of the Bond Work Index, which amounts to 1.520 kWh/t. Such low power consumption in milling in a ball mill was expected, since it was observed that the sample R-13 had the increased participation of soft silty component. The correlation between the Bond Work Index and spatial position of explora tory drill holes in the deposit was established in this case.

CONCLUSION

The site Spasine - Brdjani is characterized by a complex of carbonate of different physical and mechanical properties. Higher areas are hypsometrically covered by compact rock masses of sand, loose to limestone cores, which in depth lean on a package of compact and loose chalk. In general, these carbonate sediments in terms of stability provide a solid rock mass and belong to the group of stable to conditionally stable terrains.

The values of the Bond Index mainly ranges between 2 and 3 with certain deviations. Therefore, the samples KR-2, KR-14 and R-14 are characterized by the Bond Index higher than 3 due to the presence of interlayers of alevrolyte, or high concentration of calcified fossils. On the other side, large presence of dusty component in the sample R-13 resulted in a very low value of its Bond Work Index. The explicit relationship between the spatial position of drill holes and the Bond Work Index was not established.

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ANALYSIS OF BLASTING IMPACTS AT THE OPEN PIT MANASTIRISTE NEAR TOPOLA ON THE MONASTERY COMPLEX

Abstract

This paper discusses the problems associated with the negative effects that accompany blasting operations, and the certain conclusions were derived. One of the negative effects of blasting operations is the phenomenon of seismic action and its effects on the buildings and the environment. Shock waves, induced by blasting, could cause damages to the building facilities and the environment. Those shocks seem to be very unfavorable to both humans and the environment. Therefore, certain standards were developed that define permissible values of impacts on buildings and people in buildings. In Serbia, there are no standards for assessing the impact of such shock waves. The international regulations and standards, mostly Russian and German, will be used to solve this problem.

This case study provides an overview the measurement of shock waves during blasting at the open pit Manastiriste near Topola in a function of the quantity of used explosives, their impact on the surrounding buildings with special reference to the Monastery of the Holy Archangel Michael, as well as the assessment of measurement results according to the appropriate scales in the world.

Keywords: *blasting, shock waves, measurement, impact, seismics*

1 INTRODUCTION

With the aim to reduce costs and increase production of blasted rock mass, as well as methods of exploitation the mineral resources, the large - hole blasting has been increasingly applied. Due to the need for increasing amounts of the rock mass, there is a need to increase the amounts of explosives, which means increasing the negative effects of blasting (seismic effects of blasting, effect of air waves, sound effect, blast induced fly rock, etc.) [1, 2].

During trial blasting, it is necessary to determine, among other things, the pattern of propagation of seismic waves in all directions, in which there is a risk of damage to buildings. This is achieved by monitoring the rate of oscillation of all three components, as well as the frequency and duration of the phenomenon. Measurements will be made using instruments which, as output data, provide the specified sizes. This particularly is applied to the buildings of the Monastery of the Holy Archangel Michael, located in the southeast direction at a distance of 250-300 m from the minefield.

In addition to properly selected explosives, determination, i.e. harmonization of appropriate geometry of blasting parameters is of great importance. The objective of determining the appropriate parameters is to increase utilization of the explosion energy to maximum, and to reduce the negative effects of blasting, primarily seismic effect [3].

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2 GEOLOGICAL AND ENGINEERING CHARACTERISTICS OF DEPOSITS

The marble deposit Manastiriste is located on the southern and southeastern slopes of the Mountain Vencac, on the eastern periphery of the village Brezovac. The basic rock mass is consisted of deposits of carbonate rocks: calcitic marbles of different varieties (white, gray, gray-white, pink in gray to purple shades and stripes). Roof and floor are consisted of the mica, dolomite, metamorphosed limestone, then quartzite, sericitic schist and delluvial cover. From the floor towards the roof alternate phyllite, quartzite and sericitic schists, then alternation of dolomite, limestone, marble and quartzite, dolomite, marble of different varieties (useful raw materials).

The quality of calcite marbles has the following indicators:

- mean content: CaO 53.75 %
- mean content: $CaCO_3$ 96.05 %
- mean content: MgO 1.17 %
- mean content: $MgCO_3$ 2.45 %
- total carbonate: 98.5 %
- mean degree of whiteness: 90.266 %
- mean content of harmful components is low:

SiO_2 – 0.89 %;	Al_2O_3 – 0.54 %;
Fe_2O_3 – 0.098 %;	SO_3 – 0.42 %;
Na_2O – 0,06 %;	K_2O – 0,01 %;
M_nO_2 – 0.01 %;	Pb < 0.2 ppm;
Ni < 0.09 ppm;	Cd – 0.24 ppm;
Cu 7.88 ppm;	Cr – 6.88;
Hg < 0.008 ppm and	As < 0.05 ppm.

- raw material complies with the relevant Serbian standards regarding the use as calcium carbonate,
- can be used in metallurgy for all classes of quality; industrial paints and varnishes; sugar industry for quality class II; the mineral fertilizer industry; glass industry - for the IV and V quality classes; in fodder industry; in cement industry.

Laboratory geomechanical investigations - the tests of physical and mechanical properties were carried out on representative samples, whose results are given Table 2.1.

Table 2.1 *Results of geomechanical investigations*

- Bulk density, γ (t/m^3)	2.71
- Angle of internal friction, (α°)	34°12'
- Cohesion, (daN/cm^2)	71.42
- Uniaxial compressive strength, (daN/cm^2)	651.73
- Tensile strength, (daN/cm^2)	83.47
- Velocity of longitudinal waves, (m/s)	4,452
- Velocity of transverse waves,(m/s)	2,107
- Dynamic modulus of elasticity, (GN/m^2)	32.15
- Dynamic Poisson's ratio	0.357

3 CRITERIA FOR EVALUATION THE SEISMIC EFFECTS OF BLASTING

The elastic deformations caused by the dynamic effect of explosive charges represent the oscillatory process, i.e. seismic effect of blasting. The resulting elastic deformation spread out in the form of elastic waves radially from the blast site. According to the form of transmission of elastic deformation, seismic waves can be divided into two basic groups: **bulk** and **surface** elastic waves. Among bulk elastic waves, the most famous are longitudinal and transverse waves, while among surface the elastic waves; the most famous are the Raylleigh and Love elastic waves. The action of explosion in the working environment creates all kinds of elastic waves at the same time, whereby the change of distance, changes their intensity [4].

The intensity of seismic waves can be determined by measuring one of the basic dynamic parameters of the actuated environment as follows: oscillation velocity (v), acceleration (a) or displacement of soil (x). Realization the connection between these parameters is possible by determination of one parameter instrumentally, which allows the other parameters to be be determined by calculation. One of the most common parameters used for evaluation the seismic intensity is the oscillation velocity of actuated soil (v).

Maximum resulting soil oscillation velocity (V_{max}) is obtained as the intensity of the vector components in directions of X, Y and Z-axis, using the formula:

$$v_{\max} = \sqrt{V_v^2 + V_l^2 + V_t^2}\ , \text{(mm/s)} \qquad (1)$$

Where:

v_v - vertical component of soil oscillation velocity (mm/s),

v_l - longitudinal component of soil oscillation velocity (mm/s),

v_t - transverse component of soil oscillation velocity (mm/s).

3.1 Scales for Assessment the Seismic Effects of Blasting

In larger number of countries there are regulations governing the level of shocks caused by explosions with which buildings can be loaded, depending on their nature, status and dynamic resistance. These regulations have not been adopted in our country, therefore the international regulations and standards, mostly Russian, German and American, are used in solving of this issue. Some criteria are given in the following table.

- Seismic scale of the Institute of Physics of the Earth, Russian Academy of Sciences - used for assessment the blast induced shocks is shown in Table 3.1.

Table 3.1 *Seismic scale of the Russian Academy of Sciences*

Oscillation Velocity v [mm/s]	Level of seismic intensity	DESCRIPTION OF ACTIONS
To 2.0	I	Action is revealed only by instruments
2.0 – 4.0	II	Action is felt only in some cases when there is a complete silence
4.0 – 8.0	III	Action is felt by very few people or only those who are expecting it
8.0 – 15.0	IV	Action is felt by many people, the clink of the window-pane is heard
15.0 – 30.0	V	Plaster fall, damage on buildings in poor condition
15.0 – 30.0	V	Plaster fall, damage on buildings in poor condition
30.0 – 60.0	VI	Air cracks in plaster, damage, damage to buildings that already have developed deformations
60.0 – 120.0	VII	Damage to buildings in good condition, cracks in plaster, parts of the plaster fall down, air cracks in walls, cracks in tile stoves, chimney wrecking
120.0 – 40.0	VIII	Considerable deformations on buildings, cracks in bearing structure and walls, bigger cracks in partition walls, wrecking of factory chimneys, fall of the ceiling
240.0 –480.0	IX	Wrecking of buildings, bigger cracks in walls, exfoliation of walls, collapse of some parts of the walls
Bigger than 480.0	X - XII	Bigger destruction, collapse of complete structures, etc.

Permissible oscillation velocities in building structures (residential, industrial, etc.) dependon the type of structure, character and purpose. For these reasons, all buildings are divided into four classes.

Class I - especially important facilities of federal and republic importance, architectural and historical monuments. Blasting in the vicinity of these objects is possible only in the exceptional cases.

Class II - industrial buildings of great importance: pipelines, large factory halls, export towers in mines, water towers and similar facilities whose lifetime is longer than 20 - 30 years; residential buildings with greater number of inhabitants, cultural centers, cinemas and other.

Class III - industrial buildings and administrative buildings of relatively small size, whose height does not exceed three stories: mechanical workshops, compressor stations and similar facilities; residential buildings inhabited by fewer people, warehouses and similar.

Class IV – buildings and industrial facilities where expensive machinery and equipment are placed and whose damage does not endanger human life and health; warehouses, automobile bases, cold storage buildings, compressor stations and similar.

- Criteria in the FR of Germany - This standard contains information on determination and evaluation the vibrations on building structures. Standard states the approximate values whose compliance cannot cause damages in terms of reducing the use value of building structure.

Assessment of total vibrations on structures is carried out from a numerous measurements of oscillation velocity on the foundation and ceiling structures. For this assessment the maximum value is taken for three individual components of oscillation velocity (see Table 3.2).

Table 3.2 *Approximate values for oscillation (v) and oscillation frequency*

Row	Type of the structure	Approximate values of vibration velocity (v) mm/s			
		Foundation			Top floor ceilings
		Frequency, HZ			All frequencies
		< 10	10-50	50-100	
1	Structures used for craftsmanship, industrial and similar structural structures	20	20 – 40	40 – 50	40
2	Dwelling buildings and structures similar in construction or function.	5	5 – 15	15 – 20	15
3	Structures that because of their particular sensitivity to vibrations do not fall into groups 1 and 2 and are essential for conservation (for inst. as cultural-historical monuments)	3	3 – 8	8 – 10	8

4 MEASUREMENT AND BLASTING PARAMETERS

Measurement of seismic effects, i.e. soil particles oscillation velocity (v) actuated by blasting was carried out using the measuring instrument type Vibraloc, a product of the Swedish company ABEM. The basic characteristics of seismographs Vibraloc are as follows:

* Measurement possibilities	Velocity, acceleration, displacement and air impacts
* Frequency range	2 - 250 Hz
* Location possibilities	Flat floors, slabs, foundations, soil and other
* Trigger levels	0.1 – 200 mm/s
* Sampling	1000, 2000 or 4000 Hz
* Recording length	1 – 100 s or automatic length
* Data transfer	Vibraloc PC software
* Data analysis	UVSZ software; UVSZA software

Measuring points were located in the following places:

- Measuring point MP-1	- auxiliary facility for water
- Measuring point MP-2	- at 20 m from MP-1
- Measuring point MP-3	- at 2 m from the bell, to the right
- Measuring point MP-4	- in the middle of dormitory, 1 m from the slope

Blasting parameters and funds spent for trial blasting operations at the open pit Manastiriste are shown in Table 4.1.

Table 4.1 *Blasting parameters and funds spent*

Funds spent per blasting	**Number of trial blasting**										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Total number of boreholes, N_b	1	2	4	4	3	5	4	5	8	4	5
Total length of boreholes L_{uk}, m		20.5	43.8	42.1	29.0	32.5	39.0	50.0	80.0	35.5	38.5
Total quantity of explosive Q_{uk}, kg	53.3	117.6	256.7	254.7	157.9	133.0	140.0	193.5	229.5	152.0	91.0
Max. quantity per interval Q_i, kg	53.3	60.8	66.3	70.3	64.3	35.3	38.0	41.5	48.0	44.0	21.5
Nonel detonator, 25/500 N_d, pcs.	1	2	4	4	3	5	4	5	8	5	5
Delay time between boreholes ms	-	50	50	-	-	-	-	-	-	-	-
Stemming length $L_č$,m	3.5	3.5	3.5-4.0	3.5-4.0	3.5	2.0-5.0	3.5	3.5	3.0-3.5	3.0-3.5	3.0-3.5
El. detonator N_{ed} , pc.	1	1	1	1	1	1	1	1	1	1	1

Centre of explosion of minefields (MP) and locations of measuring points are shown in Figures 1 and 2.

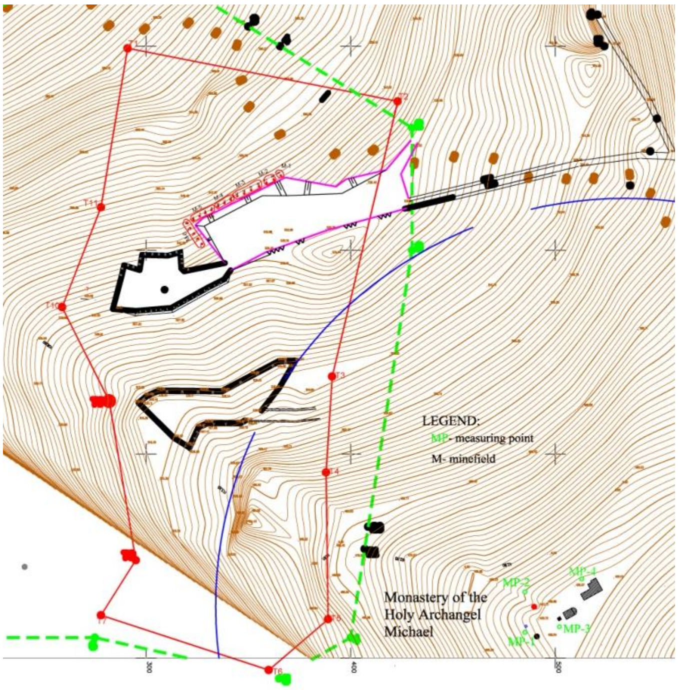

Figure 1 *Locations of minefields M-1 to M-6 in relation to the measuring points*

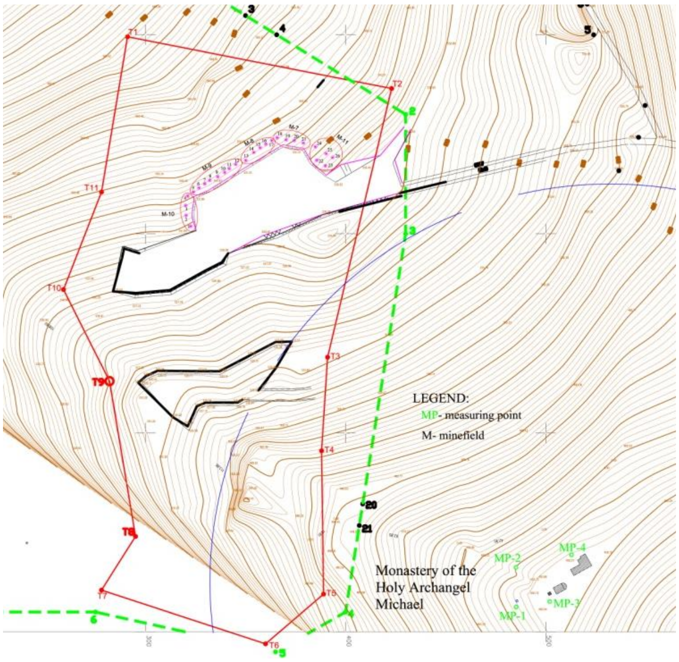

Figure 2 *Locations of minefields M-7 to M-11 in relation to the measuring points*

Schematic view of boreholes arrangement, structure of charge and connection diagram including the order of initiation of boreholes is shown in Figure 3

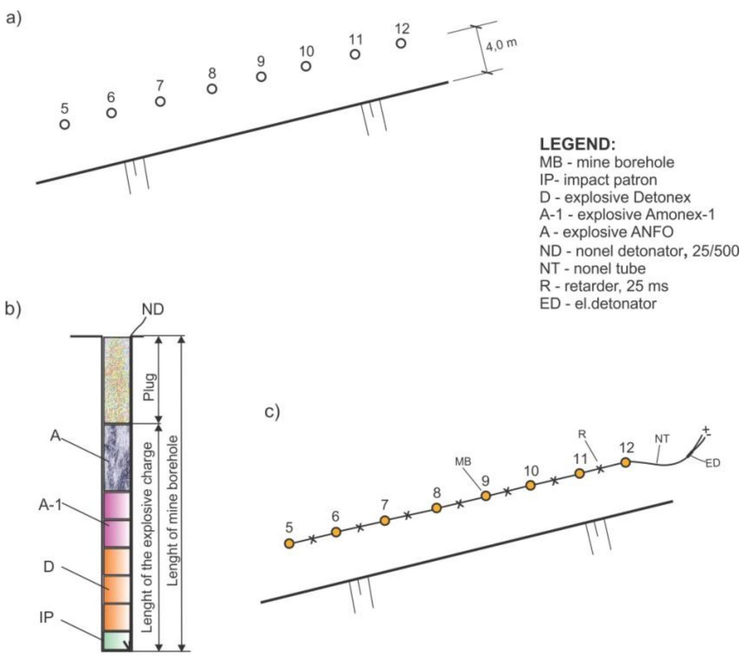

Figure 3 *Borehole arrangement, structure of charge and connection diagram with performed blasting No. IX*

5 REVIEW THE MEASUREMENT RESULTS

In order to evaluate the shocks in Table 5.1, the following is given: registered velocity values per components, resulting maximum oscillation velocity, frequency per components, whose value shall be compared with the values given in Tables 3.1 and 3.2.

For fulfilling the Table 5.1, the following marks are used for the assessment of performed blastings as follows:

- Criterion according to the scale of the Institute of Physics of the Earth, Russian Academy of Sciences (I Class facilities are taken):

- A – satisfies, within the limits of permitted oscillation velocity,

- B - does not satisfy, above the values of permitted oscillation velocity.

- Criterion according to DIN 4150 (III Class facilities are taken in accordance with Table 3.2):

- C – satisfies, within the limits of permitted oscillation velocity,

- D – does not satisfy, above the values of permitted oscillation velocity.

Figure 4 shows a graphic representation of velocigram of the blast No. X, at the measuring point MP-1 performed at the open pit Manastiriste – near Topola.

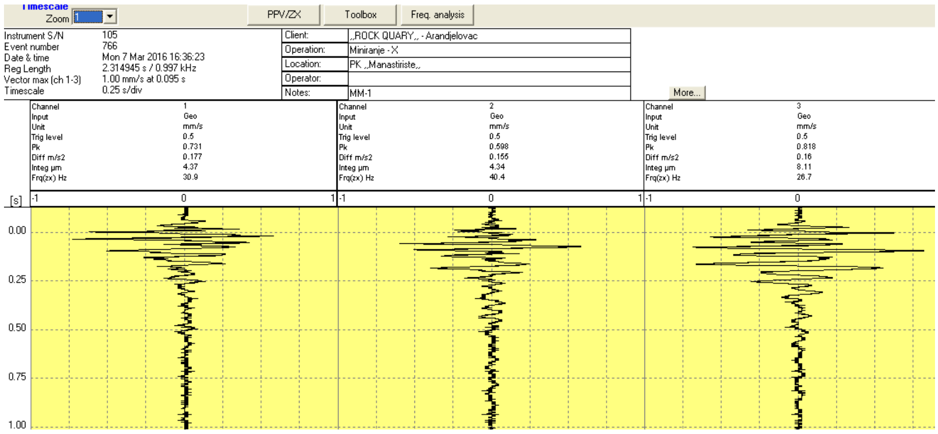

Figure 4 *Snapshot of soil oscillation velocity for blast No. X at the measuring point MP-1*

Table 5.1 *Measurement results of trial blasts performed at the open pit Manastiriste near Topola*

Blasting No.	Measuring point M.P.	Dist. from blasting field to measuring point, *m*	Max. quantity per one inter. kg.	Overall quantity of exp. in *kg*	Maximum oscillation velocity per comp. mm/s			Res. max. oscillation velocity *mm/s*	Frequency per components, *Hz*			Evaluation of measurement results	
					V_V	V_T	V_L		*V*	*T*	*L*	By IFZA	By DIN
I	MP-1	253.95	53.0	53.0	-	-	-	-	-	-	-	A	C
	MP-2	236.55	53.0	53.0	0.358	0.420	0.594	***0.811***	40.7	35.6	35.6	A	C
	MP-3	259.78	53.0	53.0	-	-	-	-	-	-	-	A	C
	MP-4	246.39	53.0	53.0	-	-	-	-	-	-	-	A	C
II	MP-1	254.35	117.0	60.5	0.364	0.754	0.562	***1.008***	24.9	22.63	33.2	A	C
	MP-2	237.03	117.0	60.5	0.626	0.774	0.924	***1.358***	38.9	29.3	20.9	A	C
	MP-3	260.45	117.0	60.5	0.475	0.508	0.516	***0.860***	30.5	19.9	27.7	A	C
	MP-4	247.52	117.0	60.5	0.465	0.450	0.597	***0.880***	17.7	17.2	25.6	A	C
III	MP-1	255.34	255.5	66.0	0.545	0.931	0.652	***1.260***	23.7	24.3	22.1	A	C
	MP-2	238.77	255.5	66.0	0.649	0.796	1.541	***1.852***	26.2	33.8	24.2	A	C
	MP-3	262.74	255.5	66.0	0.656	0.596	0.605	***1.073***	24.8	17.2	26.2	A	C
	MP-4	250.55	255.5	66.0	0.598	0.517	0.597	***0.991***	21.1	33.2	23.2	A	C
IV	MP-1	256.62	253.5	70.3	0.866	0.776	0.495	***1.277***	19.8	21.1	26.8	A	C
	MP-2	240.74	253.5	70.3	0.626	0.796	1.168	***1.546***	23.4	17.8	22.4	A	C
	MP-3	264.72	253.5	70.3	0.678	0.331	0.538	***0.926***	24.4	34.4	24.9	A	C
	MP-4	253.59	253.5	70.3	0.465	0.450	0.685	***0.942***	20.2	26.2	36.5	A	C
V	MP-1	258.49	157.0	64.0	0.636	0.599	0.585	***1.051***	19.7	11.9	19.5	A	C
	MP-2	243.28	157.0	64.0	0.492	1.040	0.748	***1.372***	32.2	18.0	39.1	A	C
	MP-3	266.93	157.0	64.0	0.520	0.486	0.807	***1.122***	26.6	21.1	18.9	A	C
	MP-4	257.26	157.0	64.0	0.433	0.405	0.552	***0.815***	19.9	20.5	20.8	A	C
VI	MP-1	253.85	132.0	35.0	1.159	0.931	0.787	***1.682***	22.9	15.6	22.9	A	C
	MP-2	238.78	132.0	35.0	0.984	1.261	1.409	***2.087***	23.7	21.6	34.4	A	C
	MP-3	262.97	132.0	35.0	0.814	0.817	0.807	***1.407***	21.2	27.4	18.7	A	C
	MP-4	253.89	132.0	35.0	0.797	0.697	0.795	***1.324***	18.2	17.4	19.2	A	C
VII	MP-1	260.31	140.0	38.0	0.421	0.775	0.730	***1.145***	22.7	17.4	16.3	A	C
	MP-2	242.44	140.0	38.0	-	-	-	-	-	-	-	A	C
	MP-3	265.94	140.0	38.0	-	-	-	-	-	-	-	A	C
	MP-4	251.11	140.0	38.0	-	-	-	-	-	-	-	A	C
VIII	MP-1	262.89	193.5	41.5	0.354	0.620	0796	***1.069***	23.7	23.0	22.7	A	C
	MP-2	245.44	193.5	41.5	-	-	-	-	-	-	-	A	C
	MP-3	268.96	193.5	41.5	-	-	-	-	-	-	-	A	C
	MP-4	255.94	193.5	41.5	-	-	-	-	-	-	-	A	C
IX	MP-1	262.91	229.5	47.5	0.709	1.085	0.951	***1.607***	26.8	19.2	15.2	A	C
	MP-2	247.15	229.5	47.5	0.643	0.771	0.675	***0.924***	30.5	16.3	23.5	A	C
	MP-3	270.84	229.5	47.5	-	-	-	-	-	-	-	A	C
	MP-4	259.87	229.5	47.5	-	-	-	-	-	-	-	A	C
X	MP-1	258.19	152.0	44.0	0.731	0.598	0.818	***1.249***	30.9	40.4	26.7	A	C
	MP-2	242.72	152.0	44.0	0.444	0.683	0.436	***0.924***	30.7	23.7	24.0	A	C
	MP-3	266.76	152.0	44.0	-	-	-	-	-	-	-	A	C
	MP-4	257.96	152.0	44.0	-	-	-	-	-	-	-	A	C
XI	MP-1	246.67	91.0	21.5	0.487	0.421	0.597	***0.878***	23.7	18.8	18.5	A	C
	MP-2	228.42	91.0	21.5	-	-	-	-	-	-	-	A	C
	MP-3	251.56	91.0	21.5	-	-	-	-	-	-	-	A	C
	MP-4	236.28	91.0	21.5	-	-	-	-	-	-	-	A	C

CONCLUSION

This case study shows the results of measurements the seismic impacts caused by trial blasting at the open pit Manastiriste near Topola.

The assessment of shocks on surrounding facilities during blasting operations was carried out based on criteria according to the scale of the Institute of Physics of the Earth, Russian Academy of Sciences and DIN.

Measuring points in the vicinity of the open pit Manastiriste were located in the vicinity of the Monastery of the Holy Archangel Michael, as shown in Figures 1 and 2.

Blasting operations at the open pit Manastiriste location near Topola were carried out under the following conditions:

- 11 trial blastings were performed,
- trial blastings were carried out for the purpose of creating the conditions for marble exploitation applying blasting operations,
- explosives Detonex 60/1500 and 70/2000; Amonex-1 60/1000, 70/1500 and ANFO-J in sacks 25.0 kg were used for blasting operations,
- quantity of explosives used during blastings varied from 53.0 – 255.5 kg,
- maximum quantity of explosive per one interval was 70.3 kg,
- initiation of explosives was performed with NONEL detonator 25/500.

On the basis of the results obtained for blasting operations and measurements, carried out at the open pit Manastiriste, the following conslusions can be derived:

1. The total of 11 trial blasting operations was performed and 24 results of oscillation velocity were instrumentally recorded at 4 measuring points.

2. The recorded values of oscillation velocity in the complex of the Monastery of the Holy Archangel Michael (measuring points MP-1; MP-2; MP-3; MP-4), are in the domain of permissible values in view of their impact on building structures, *therefore it can be concluded that they do not have an impact on building structures.*

3. During blasting operations and measurements at the open pit Manastiriste, there were no fly rocks induced by blasting, cancellation of blasting and similar, therefore the blasting went well.

4. With the aim of a more detailed consideration of blasting impacts, as well as the importance of the monastery itself, it is necessary to conduct the visit and view of all monastery buildings before each blasting in order to ascertain the status of buildings before blasting operations.

5. If there is a change in blasting technology, it is necessary to make a new recording of seismic impacts.

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DESIGNING AND PLANNING OF AREAS AFFECTED BY SURFACE DISLOCATIONS AT THE OPEN PITS

Abstract

The designing and spatial planning of areas affected by instability at the open pits represents an analysis of all conditional factors that create a potential representation of a wider area. The specificities that characterize the conditions on the field, created after the instabilities had occurred, require research which along with the calculation results presents a starting point for further design. The terrain leveling, shaping of the slopes and depressions of the open pit, are interpreted based on geological structure, engineering - technical conditions of the work environment, disposition of the existing objects, junctions of the mining area, environmental conditions and factors which add to the stability of the future area. The inclines and slope geometry are defined by the law as well as by the intended purposes of the areas that are to be planned.

The entire area survey for the purpose of its planning should be regarded as a whole which requires the project solutions from multiple technical areas for the purpose of functional area planning. The technological solutions of terrain modeling, taking into consideration the analysis of foundation the acquired results, including the experiences of applied procedures from the subject area, undoubtedly demands synchronization with the technical, technological and capacitive capabilities in a particular case. The definition of technological solutions must be based on the principles of environment preservation.

Keywords: *ground instability, rehabilitation, design solution*

GENERAL OBSERVATION ABOUT THE OPEN PITS OF THE KOSTOLAC COAL BASIN

Mineral ore exploitation in the Republic of Serbia was conducted in an ambiance of the economic crisis in the past years, which has negatively impacted the mining activities mostly on the economic level. The production processes were reduced to the minimal investments not only in the basic means and maintenance, but in research activities, which along with an inadequate number of workers in production, makes the system barely sustainable. Therefore, because of the insufficient data, which is necessary for the quality technological procedure, and with strict demands for fulfillment the designed coal production, with insufficient investments and bad weather conditions, the production processes are characterized by often work environment instability occurrences.

During previous years, in the area of the Kostolac pits, two cases with the aforementioned hallmarks had appeared.

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First, in the area of the open pit "Ćirikovac" at the end of coal exploitation, a landslide occurred that encompassed a surface of about 30 ha.

Cessation of coal exploitation and repurposing of the area with the designed operation dynamics was made significantly more difficult due to a lack of equipment, work force, changes during activities in the area in question which were conditioned by priority principles. An insufficient number of parameters for reliable planning of the all influential factor for realization the all operations designed for the area of the open pit "Ćirikovac" were made complete by appearance of the aforementioned landslide.

Figure 1 *The open pit "Ćirikovac" after surface dislocation*

The consequences of bad weather, which have been more frequent in the last couple of years, followed by massive rainfalls in short intervals, during 2014 have conditioned an instability of occurrence on the internal depot of the open pit "Drmno".

Due to this, not only did the short term halts in exploitation occur, but so did the changes that required alterations to the technological procedures and activity dynamics of designed operations.

Figure 2 *Landscape of the open pit "Drmno" after flooding*

Figure 3 *The open pit "Drmno" after the instabilities in the slopes*

The specificity of the information basis, exploitation parameter analysis, as well as the production process itself at the open pits were faintly considered, and the main problems over the past years are as follows:

- ✓ Relatively low exploration degree of certain basins;
- ✓ Lack of complete indicators of work environment;
- ✓ Conditioned production capacities;
- ✓ The necessity for ore homogenization for the purpose of greater quality for the required standards;
- ✓ Inadequate basic equipment maintenance;
- ✓ Insufficient workforce;
- ✓ Dynamic imbalance of the conditions in the field with project solutions;
- ✓ Imbalance in the utilization of the ore base of deposited materials and materials treated as byproducts in our country;
- ✓ Insufficient application of work safety measures;
- ✓ Obsolete legal regulation in the area of mineral ore exploration and in the areas of mining and geology.

INPUT ANALYSIS FOR THE PURPOSE OF QUALITATIVE PLANNING AND DESIGNING SOLUTIONS

For the purpose of a safer, more efficient, and unimpeded technological exploitation procedure, during the designing of the spatial plans of the area, long-term plans and all other documents, which relate to the landscaping, i.e. the environment in which we live, it is necessary to analyze as large as possible number of elementary and potential factors.

Primarily, it is necessary to harmonize all papers with the project solutions and eventually correct them within the confines of the law. All changes in the technological procedure, activity dynamics, imbalance of conducted and realized technological procedures during exploitation have to be logged, monitored, analyzed and to apply solutions which should provide a safe and continuous operation while taking a great care to protect people and the environment. In this sense, participation and creation the quality applicable solutions with a high degree of responsibility is very important.

Parameter analysis during planning and activity designing at the open pits should encompass several complex areas: geological, hydro-geological, geo-mechanical characteristics of the area, internationally applied experiences from the domain of research and innovative methodologies, the predicted equipment and technological procedure, dynamics and investment-potential specificities as a whole and a basis for the project surface with techno-economic justification. Studying of all these inputs should contribute to the removal of all negative occurrences, which represent potential factors that can contribute to the instability occurrences. Spatial improvement that stopped after the exploitation has stopped should be synchronized with the spatial plan.

Through synthesis of the all elements that characterize the subject area and database creation, variant overview of solutions is enabled and a possibility of choice is created, not applications of conditioned procedures because of circumstances. In this manner, an ambiance of controlled and reliable workforce is created in the confines of legislated safety factors.

Analyzing as great number as possible of functionally connected inputs, knowledge is expanded during activities, with which based on the available resources and with creative design, quality applicable solutions are made.

For quality planning with the purpose of landscaping of the terrain affected by surface dislocation, coordination in synchronization of these fields is necessary during the process of database analysis, during designing. In this sense, it is necessary to analyze an area affected by the dislocation during surface exploitation, as well as the surrounding area with all of its elementary specificities - environment characteristics, with obligatory consulting with all laws and codes and regulations on the subject matter.

Technological exploitation procedure should be based on continuous monitoring and analysis of all relevant parameters, in order to prevent an eventual instability occurrence in the work environment. However, in case the aforementioned occurrences do happen, during the designing of dislocated surfaces, it is necessary to analyze the input parameters:

- Description of the area and its surroundings;
- Surfaces with previous exploration results;
- Analysis of designed and achieved activities;
- Geological description;
- Geo-mechanical stability conditions analysis;
- Definition of exploration procedures;
- Data processing;
- Choice of terrain stabilization method;
- Technological activity description;
- Field monitoring methodology after terrain stabilization.

Along with all of this, the obsolete equipment and incapability of application the new technological procedures in function production process efficiency should not be left out.

Because of frequent bad weather conditions, daily hydro-meteorological reports must be kept in everyday information bases of operative units, which beside other basic inputs should represent the basic database to be presented to the top management. In this sense, it is necessary to constantly upgrade the information system with as plentiful data as possible with functional purposes.

CONCLUSION

Analyzing the instability occurrences at open pit areas, it is primarily necessary to form information systems, which should prevent eventual work space occurrences at the open pit, which are not unavoidable, but always have a reason for occurring.

According to everything described, a continuous exploration and analysis of obtained data, made complete by the weather parameters, should present a foundation of everyday information database of an organizational whole of management the mining complexes.

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THE EFFECT OF DIFFERENT COLLECTORS ON THE QUALITY OF BASIC COPPER CONCENTRATE OF THE ORE BODY TENKA***

Abstract

This paper presents the results of a part of technological tests, whose aim was to determine the optimum techno-economic conditions for the flotation concentration of ore from the deposit Tenka-3 - North Mining District, Copper Mine Majdanpek. The given view refers to testing the effects of collectors NaIPX, 3418 A and 5500 AP, as well as the pulp pH value on the quality of concentrate from the primary flotation process. It was found that the majority of copper, gold and silver in the primary concentrate is obtained using the collector AP 5500. In addition, a better quality of primary concentrate was obtained at higher pH values of pulp in the tested pH range (10.0 – 11.5).

Keywords: *flotation, quality of concentrate, copper, gold, silver*

1 INTRODUCTION

The polymetallic-goldbearing deposit "Tenka" is located in the far northern part of the North Mining District of the porphyry copper deposit "Majdanpek". The deposit has an irregular trapezoid shape and direction of north-south. Length of deposit is 650 m, while the width ranges from 150 to 250 m. Polymetallic sulphide mineralization is spatially restricted to the western part of mineralization zone [1,2].

The Tenka deposit consists of several ore bodies of complex morphology, among which the mining wires, pillars, lenses and pockety ore bodies dominate. Its position is determined by tectonic zones at the contact of volcanic rocks of the Upper Cretaceous and Jurassic age structure. In zones with more prominent tectonics (breccias), along which the movement of mineralized fluids was easier, there are smaller ore bodies of irregular shape, stock work-impregnation type of mineralization. Polymetallic as well as the copper-pyritic mineralization were deposited in scarns, tectonic breccias and partly in andesites. The area around the massive-sulphide mineralization is filled with the stockwork-impregnation and wire type of mineralization with occurrences of limestone inclusions.

The massive sulphide type of mineralization is regularly present in limestones with a sharp border to the surrounding rock mass and in tectonic breccias in the form of combination with smaller ore veins and interveins. The interveins are most often frequent in andesites, while the ore veins

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are less frequent. Mineralization is deposited in breccia limestones in the existing cavities and cracks where cementation of limestone fragments is developed [1].

From an economic point of view, three ore bodies are of particular importance - Tenka-1 (located to the north); Tenka-2 (located in the south); and Tenka-3 (the ore body located in the eastern part of productive zone). These ore bodies vary according to the morphological characteristics, and partly to the mineralogical composition and content of useful components [1].

The ore body Tenka-3 is formed in fault zones at the contact of limestone of Starica and volcanic rocks of the Upper Cretaceous, and partly in limestone, or hydrothermally altered andesites. In terms of mineralogical composition, the ore body Tenka-3 is an agglomerate composed of massive pyrite body (pyrite content is 60 - 90%), magnetite the ore bodies of magnetite in scarns as well as vein-impregnation copper mineralization in andesites [1,2].

The issue of this scientific-research work essentially represents testing the possibilities for valorization the useful compo nents (copper and precious metals) from a complex polymetallic raw materials of the ore body Tenka-3. In this aspect, defining the optimal conditions of its processing and obtaining a commercial product with satisfactory technological effects, presents a difficult task and requires a serious research approach to the technological testing. An important factor for the concept of laboratory testing is the use of the existing technological solutions and parameters from current production in the flotation plant of RBM [2,3].

2 CHARACTERIZATION OF STARTING SAMPLES

Ore sampling for laboratory tests was performed at 3 locations of a boundary part of the deposit Tenka-3. After crushing and homogenization of each sample from the above mentioned locations, a composite sample is formed (in mass ratio 1:1:1). Thus prepared sample was used as a raw material for the flotation concentration experiments. Chemical composition of individual samples, as well as a composite sample is shown in Table 1.

Table 1 *Chemical composition of samples from the ore body Tenka-3*

Component	***Location 1***	***Location 2***	***Location 3***	***Composite***
Pb, %	0.06	0.10	0.06	0.073
Zn, %	0.0075	0.0160	0.0240	0.016
Cu, %	0.63	0.30	0.49	0.473
Cu_{sulf}, %	0.608	0.288	0.462	0.453
Cu_{ox}, %	0.0175	0.0120	0.0320	0.021
S,%	17.86	41.59	6.11	21.853
Au, g/t	<0.03	1.50	<0.03	0.520
Ag, g/t	1.65	4.65	10.4	5.567

Qualitative mineralogical analysis was carried out under the polarizing microscope for reflected light in the air, with identification of ore and non-ore minerals. In samples taken from all three locations, the presence of mineral pyrite, chalcopyrite, limonite, quartz, silicates and carbonates was found out. A sample from the location 1 contains tetrahedrite, while samples from the location 3, besides specified minerals, also contain bornite, galena and sphalerite (Figure 1).

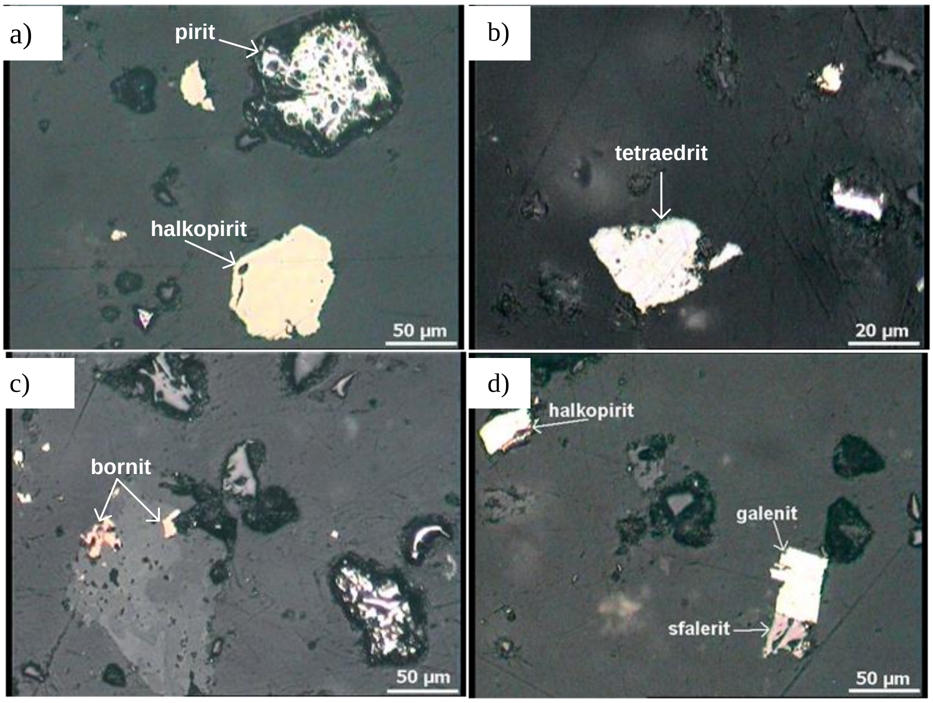

Figure 1 *Results of microscopic tests of samples: a) mineral grains of chalcopyrite and pyrite - location 1; b) grain of tetrahedrite - location 1; c) aggregate of carbonate with bornite inclusions – location 3; d) polymetallic ore – location 3*

Moisture content in a composite sample was 6.6%, and the natural pH value of pulp with mass participation of solid phase of 32% was 7.43.

Composite sample, with the upper size limit of 2 mm, was further reduced by grounding to a fineness of 60% -0.074 mm, thus achieving the optimum size class of mineral grains (according to the mineralogical analysis) for the needs of flotation concentration experiment. Testing the particle size distribution of ground mineral resources was carried out by the method of screening on sieves, and the result is shown in Table 2.

Table 2 *Grain size distribution of ground ore (composite)*

Size class, mm	***M, %***	***ΣM↓, %***	***ΣM↑, %***
+0.589	0.36	100.00	0.36
–0.589+0.295	8.18	99.64	8.54
–0.295+0.104	25.29	91.46	33.83
–0.104+0.074	7.56	66.17	41.39
–0.074+0.052	13.77	58.61	55.16
–0.052+0.037	5.12	44.84	60.28
–0.037+0.000	39.72	39.72	100

3 TECHNOLOGICAL CONDITIONS OF TESTING

Laboratory technological tests the conditions of flotation concentration have comprised a change of relevant technological parameters in the scope of existing values, applicable in the Flotation Plant Majdanpek, as follows:

- Tests were carried out through six test series of the primary flotation experiment.
- Each series consisted of four experiments, wherein the pulp pH value by the experiments was 10.0, 10.5, 11.0 and 11.5.
- Pulp density in grinding in all experiments was 70% of solid phase.
- Pulp density in flotation in all experiments was 32% of solid phase.
- Grinding fineness in all experiments was 60% -0.074 mm (size class in which the optimum release of useful minerals is achieved).
- AEROFROTH 76A was used as a frother in all experiments with the recommended consumption by the manufacturer.
- The following reagents were used as collectors as well as their combinations:
  - ➢ NaIPX (sodium isopropyl xanthate) as a good collector of sulphide minerals,
  - ➢ 3418 A (ditiophosphinate), characterrized by good results in terms of gold and silver recovery, and
  - ➢ AP 5500 (ethoxycarbonyl thiou-rea), reagent that is in theory and practice well known as a good collector of sulphide copper minerals and highly selective relative to iron sulphides and at lower pH values of pulp.
- Consumption of collectors, either individually or in combination, was 40 g/t of ore in all experiments of the primary flotation. This dose of collector was determined on the basis on content of sulphide minerals, because it should be borne in mind that, apart from copper mineral, the content of pyrite in the ore is very high (about 30%). Consumption of individual collector by the series of experiments is shown in Table 3.
- In the all experiments, the conditioning time was 7 minutes, and the primary flotation time was 18 minutes. The collectors were added in three equal doses, that is one dose in the conditioning and in two in the primary flotation.

Table 3 *Consumption of collectors in the flotation experiments by series of experiments*

Consumption of collectors, g/t dry ore	***Series of experiments***					
	I	***II***	***III***	***IV***	***V***	***VI***
NaIPX	/	/	40	24	/	24
3418 A	40	/	/	16	20	/
AP 5500	/	40	/	/	20	16

4 RESULTS AND DISCUSSION

Copper content in the basic concentrate by series of experiments is shown in Figure 2.

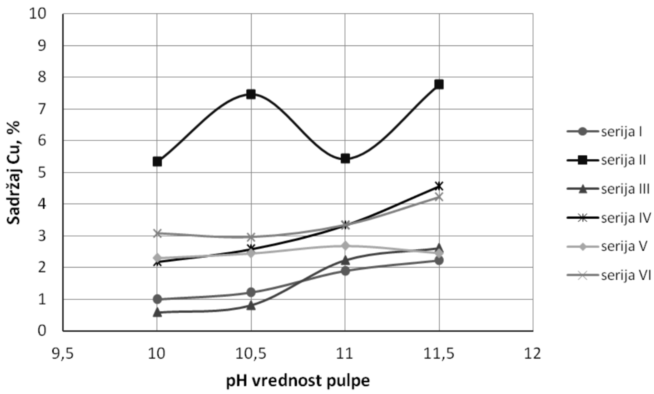

Figure 2 *Copper content by series of experiments*

It is seen from Figure 2 that the highest copper content is in the basic concentrate, obtained in the second series of experiments, or using the collector AP 5500 in the primary flotation. In addition, the combinations of collectors (series IV, V and VI) have given better results in terms of quality of copper concentrate than it is the case when collectors 3418 A and NaIPX are used individually (the I and III series of experiments, respectively). Low values of copper content in the basic concentrate, obtained in the first and third series of experiments, can be explained by large mass participation of the basic concentrate [2]. As expected, with increasing pH value of t pulp increases and the quality of basic concentrate.

Gold content in the basic concentrate by series of experiments is shown in Figure 3.

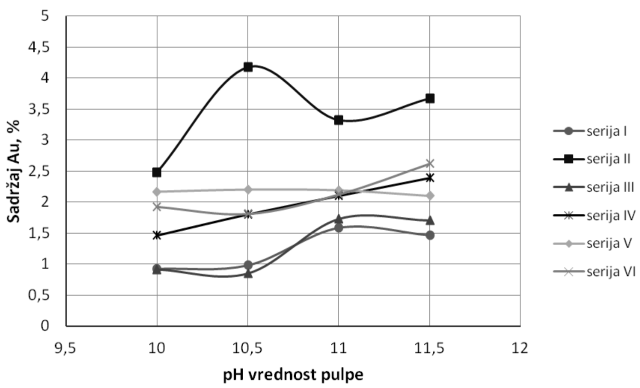

Figure 3 *Gold content by series of experiments*

Similarly as in the previous case, the highest content of gold in the basic concentrate was obtained in the second series of experiments (using the collector AP 5500), while the lowest contents of gold were achieved in the first and third series of experiments (using the collectors 3418 A and NaIPX, respectively). Combinations of all three types of collectors (series IV - VI) have given mutually the similar results. Generally, and in this case, the increase in pH value of pulp affects the increase of gold content in the basic concentrate.

Silver content by series of experiments is shown in Figure 4.

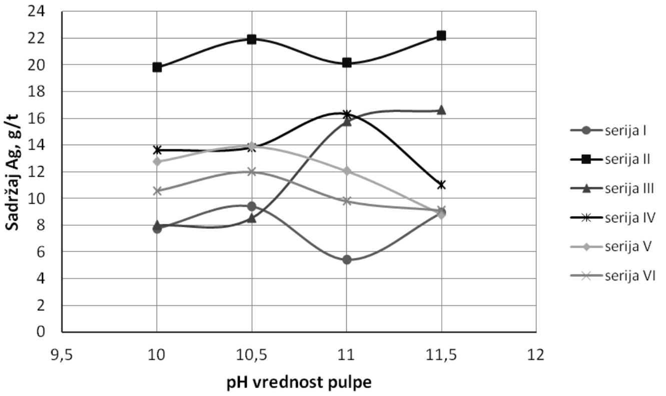

Figure 4 *Silver content by series of experiments*

Analogue to the content of Cu and Au, the individual use of collector AP 5500 (II series of experiments) has also given, in the case of the silver content in the basic concentrate, the best results, and the individual use of the collector 3418 A (I series of experiments) has given the worst results. Mutually similar results were again achieved combining the collectors. Dependence of silver content on the pH value of pulp in the primary flotation is not explicitly visible.

4 CONCLUSION

By individual use of the collector 3418 (series of experiment I) were obtained the low contents of copper, gold and silver in the basic concentrate. Slightly better results were achieved combining this collector with NaIPX and AP5500.

The use of collector AP 5500 (series of experiment II) gave conceivably the best results regarding the quality of concentrate, however, it should be noted that the recovery of copper and precious metals in this case is low [2].

Similar to the collector 3418 A, sodium isopropyl xanthate has not given a satisfactory quality of the concentrate, but in a combination with two other collectors resulted into improvement the primary flotation results, and the increase of Cu, Ag and Au content in concentrate.

In accordance with the established regime of flotation concentration of copper minerals in the plant RBM, the effect of increasing the pH value of pulp was manifested by improvement the quality of basic concentrate.

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INVESTIGATION THE CALCITE HYDROPHOBISATION OF DIFFERENT GRAIN SIZES**

Abstract

This paper presents the investigations of possibility of calcite hydrophobisation. Two samples of calcite of different size classes from the site "Dobar kamen", Arandjelovac, Serbia, were used in the experimental work. Modifying the surface of calcite was carried out by stearic acid with "dry" method. Concentrations of stearic acid in the modifying method were as follows: 0.3, 0.5, 0.8, 0.9, 1, 2, 2.5, 3 and 4%. The results showed that a complete hydrophobicity (Io=99.9%) of calcite sample with the medium diameter (d_{50}) 10.87 μm was achieved at concentration of stearic acid of 0.8%, while for the sample with the mean grain diameter (d_{50}) of 29.14 μm, it was achieved at concentration of stearic acid of 3%. These results were confirmed by the microscopic analysis.

Keywords: *calcite, stearic acid, degree of coating, grain-size distribution*

INTRODUCTION

Limestone is a sedimentary carbonate rock that is built of calcite as a dominant mineral, with a slight presence of aragonite, as well as the other minerals that represent impurities [1]. Calcite and aragonite are two polymorphic forms of $CaCO_3$. By chemical composition, calcite is $CaCO_3$, hardness per Mohs 3 and very brittle. Density of pure mi-neralis 2.72 kgm^{-3}, and if it contains impu-rities, density varies from 2.7 to 2.85 kgm^{-3}, [2]. Limiting factor in the application of limestone in certain industries (eg. as filler in the polymer industry) is its hydro-philic surface. Using the methods of surface calcite modifying by organic modifiers, type of surfactants, it is possible to convert its hydrophilic surface into hydrophobic [3,4]. As a measure of the achieved surface hydrophobicity of calcite, the degree of coating was taken that was presented by the group of authors in their works [5, 6, 7].

EXPERIMENTAL PART

Materials and Methods

Investigations, presented within this pa-per, were carried out on a sample of lime-stone from the deposit "Dobar kamen", Arandjelovac, Serbia. Two fractions were used with the following mean grain diameter (d_{50}): 10.87 μm and 29.14 μm. The results

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for a fraction of 25.19 μm, which was an integral part of these tests, the authors published before [8]. Modifying the surface of calcite was carried out by stearic acid $CH_3(CH_2)_{16}COOH$ - content of stearic acid: 0.3; 0.5; 0.8; 0.9; 1; 2; 2.5; 3 and 4%.

Modifying of calcite. It was done using so called "dry" method (without presence of water). Nine samples of 200 g were sampled where the certain concentration of stearic acid was added. A vibro mill was used with ring operating elements, model "MN 954/3", manufacturer "KHD Humboldt WEDAG"-Germany. Device operates discontinuously in the air environment. Modifying time is 7 minutes at temperature of 70°C.

Chemical composition. CaO content was determined by the volumetric method, while the content of SiO_2 and loss by calcination (900°C) was determined by the gravimetric method (JUS B.B8. 070). Atomic absorption spectrophotometer, type "Perkin Elmer Analyst 703 300", was used for determining Al_2O_3, Fe_2O_3, MgO, Na_2O and K_2O.

Mineralogical composition. Qualitative mineralogical analysis was carried out under a polarizing microscope for rejected and transmitted light, brand "JENAPOL", company Carl Zeiss Jena, using the immersion method (immersion xylene) with qualitative identification of present minerals. Magnifition of lens is from 3.2 to 50X. Binocular magnifies is of the Leitz Wetzlar company. System for microphotography "STUDIO PCTV" (Pinnacle Systems).

X-ray diffraction analysis. The XRD samples were obtained on a Philips PW-1710 automated diffractometer. JCPDS (Joint Committee on Powder Diffraction Standards) base was used to identify minerals.

Infrared spectroscopy (IC). Infrared spectra were recorded on apparatus "Perkin Elmer 983 G", the range of 4000-250 cm^{-1}.

Grain-size distribution. Grain-size distribution of limestone was determined by "Cyclosizer", manufacturer "Warmen". The mass of sample for determining the grain-size distribution is 30 g.

Determining of coating degree. A method, presented in the works of a group of authors, was used to determine a coating degree [5, 6, 7]. The method consists in the following: 10 g of modified calcite is submerged in 100 ml of distilled water with periodical stirring with a glass rod. After 10 min of standing, the floating fraction and sinking fraction are clearly observed. The floating fraction and sinking fraction were dried at 60°C, and measured. The form 1 can be applied for calcuting the coating degree Io:

$$I_o = \frac{m_p}{m_p + m_t} \cdot 100\% \qquad (1)$$

where:

I_o - coating degree, %;
m_p - mass of floating fraction, g;
m_t - mass of sinking fraction, g.

RESULTS AND DISCUSSION

Characterization the Starting Sample of Limestone from the Deposit "Dobar kamen"

A detailed chemical and mineralogical composition and X-ray diffraction analysis was given by the authors in an earlier published report [4] (dominated by calcite and the CaO content is 55.43 %).

Infrared spectroscopy. Infrared spectroscopic analysis was carried out on the starting sample of limestone, and the resulting infrared spectrum is shown in Figure 1.

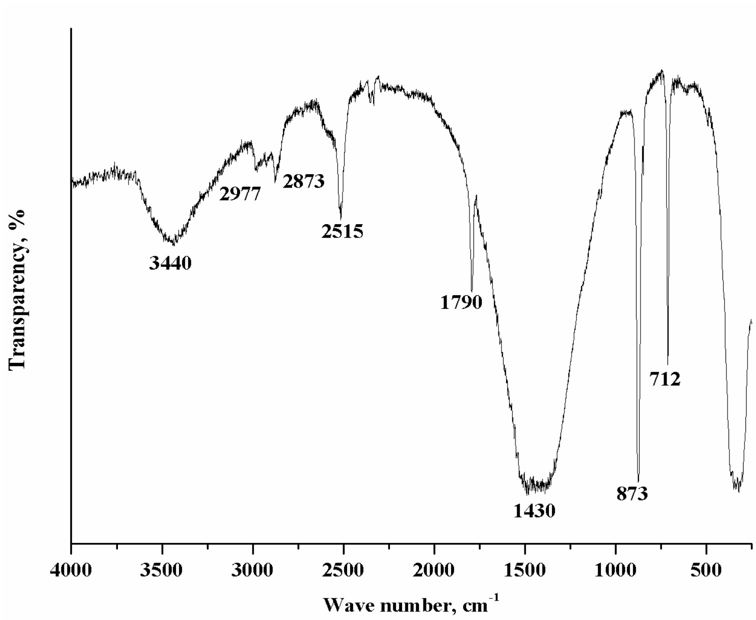


Figure 1 *Infrared spectrum starting sample of calcite "Dobar kamen"*

Characteristic strips for calcite are observed in the infrared spectrum of starting limestone sample, thus confirming the results obtained by the X-ray diffraction that calcite is the primary mineral in sample. The strips of various intensity appear in the area of wave numbers of 3000 cm^{-1} to 700 cm^{-1}. The carbonate functional group in calcite is planar (space group D_{3h}), and as a non-linear with the number of atoms N=4 has 3N-6=6 fundamental vibrations, out of which N-1=3 as valence. Symmetrical valence vibration $_1$ is infrared inactive. A broad and strong strip at about 1430 cm^{-1} is attributed to the asymmetrical valence vibration of $_3$, which is a double degenerated ($_{3a}$ and $_{3b}$). A sharp strip at 873 cm^{-1} belongs to the deformation vibration $_2$ of the planar carbonate group. Also, $_4$ is a deformation one by type, double degenerated vibration ($_{4a}$ and $_{4b}$), for which the strip at 709 cm^{-1} is characteristic in spectrum in Figure 3. Generally, 3 strips occur instead of 6 in calcite spectrum, which belong to the basic vibrations $_2$, $_3$ and $_4$, since $_1$ IC is inactive, and $_3$ and $_4$ are double degenerated. In addition to the strips of fundamental vibrations, the strips of the sum and high harmonics, i.e. the strips of upper tones (overtones) also appear in the spectrum [9]. Thus, two strips of low intensity at 2977 and 2873 cm^{-1}, strips of upper tone (2 $_3$) of fundamental valence $_3$ vibration of carbonate functional group are observed in the spectrum of starting samples, and which occur in the range from 2980 to 2830 cm^{-1} [10]. According to Osman and Suter [11], the strip at 2515 cm^{-1} belongs to bicarbonate ion, CO_3H^-, on calcite surface. However, according to Gilbert and associates [9], that strip is the strip of the sum ($_1$ (1083 cm^{-1}) + $_3$) of fundamental vibrations of carbonate group. The strip at 1790 cm^{-1} is also the strip of the sum, that is ($_1$ + $_2$) of the fundamental vibrations of ion [12]. The broad strip at about 3440 cm^{-1} originates from the valence vibrations of water molecules that are present in the sample, connected to each other by the hydrogen bonds.

Grain-size distribution: Figures 2 and 3 show curves of particle size distribution of the limestone starting samples with mean grain diameter (d_{50}): 10.87 μm and 29.14 μm as follows: direct curve (1), cumulative curve of oversize (2) and cumulative curve of undersize (3). Also, the upper limit coarseness (ulc) was read for samples using the cumulative curve of oversize.

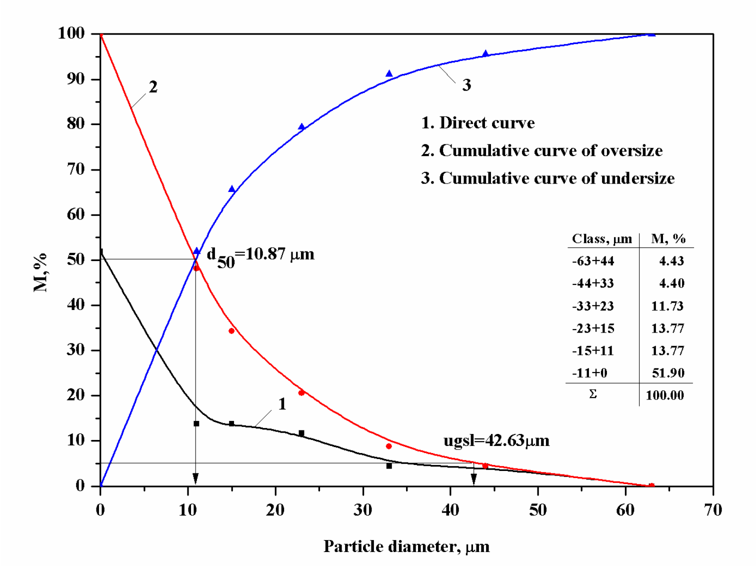


Figure 2 *Curves of particle size distribution of limestone d_{50}=10.87 μm*

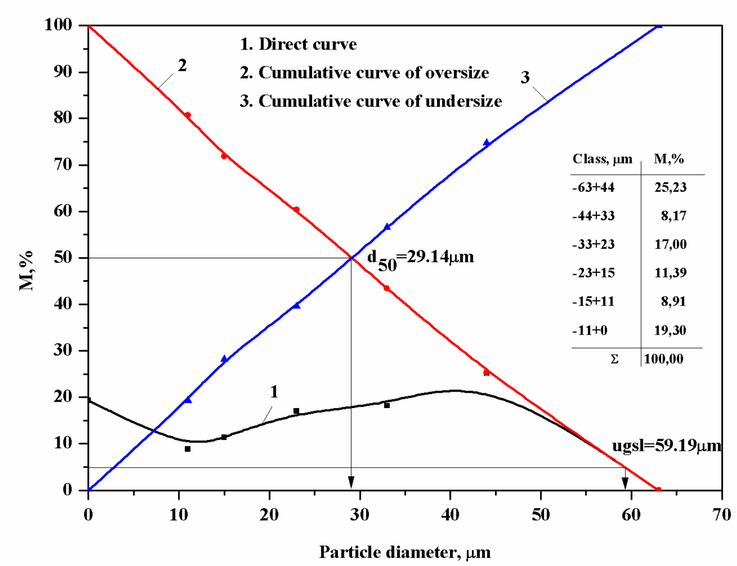


Figure 3 *Curves of particle size distribution of limestone d_{50}=29.14 μm*

Coating Degree of Modified Calcite

Limestone modifying actually means calcite modifying as the main mineral. In order to monitor the results of calcite modifying using stearic acid with "dry" method, and achievement the satisfactory surface hydrophobicity, a coating degree was determined on all modified samples according to the form 1. Values of coating degree for all three size classes of calcite at various concentrations of stearic acid are shown in Table 1; the comparative graphs in Figure 4.

Table 1 *Coating degree of modified calcite*

Concentration of stearic acid, %	d_{50}=10.87µm	d_{50}=29.14µm
	Io, %	**Io, %**
0.3	92.6	25.72
0.5	96.6	42.78
0.8	**99.9**	69.08
0.9	99.9	68.89
1.0	99.9	71.2
2.0	99.9	73.4
2.5	99.9	80.2
3.0	99.9	**99.9**
4.0	99.9	99.9

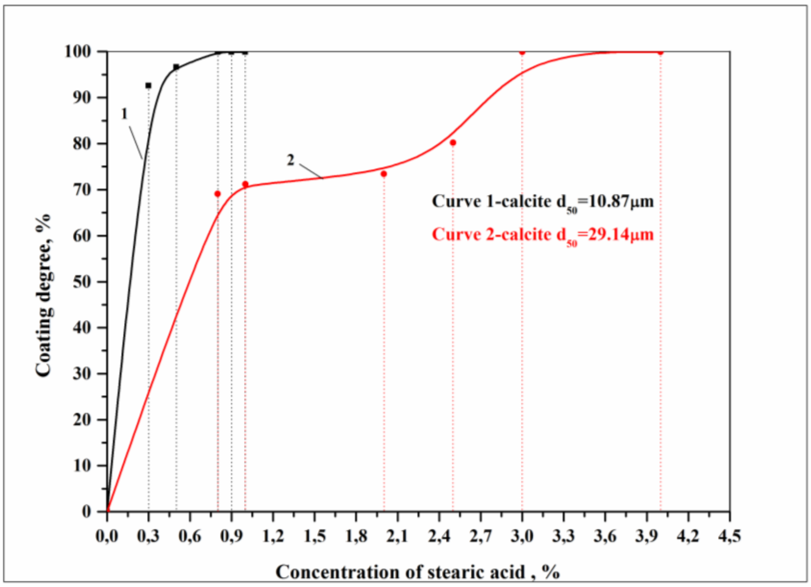


Figure 4 *Comparative graphs of coating degree of modified calcite samples*

Coating degree of 99.9 %, in calcite d_{50r} = 10.87 μm, was achieved at concentration of stearic acid of 0.8%, while in calcite d_{50} = 29.14 μm it was achieved at concentration of 3%. By further increasing the concentration of stearic acid in the modifying procedure, the coating degree remains unchanged. This indicates that the orientation of hydrocarbon chains was not changed in the adsorbed layer with an increase of stearic acid concentration available for adsorption. Adsorption was always such that the molecule of surfactant, in this case stearic acid, was kept an orientation of its hydrophobic portion (hydrocarbon chain) in the opposite from calcite surface. As coating degree can be taken as a measure of hydrophobicity of the obtained products [13], the results indicate that total hydrophobicity of calcite surface with "dry" method was achieved at stearic acid concentration of 0.8 % for sample d_{50} = 10.87 μm, and at concentration of 3% for sample d_{50} = 29.14 μm.

X-Ray Diffraction Analysis of Modified Calcite

In order to monitor the structural changes of calcite occurring during modifying, the X-ray diffraction analysis was carried out on fully modified, or completely hydrophobic samples. Comparative X-ray diffractograms of calcite powder are shown in Figure 5.

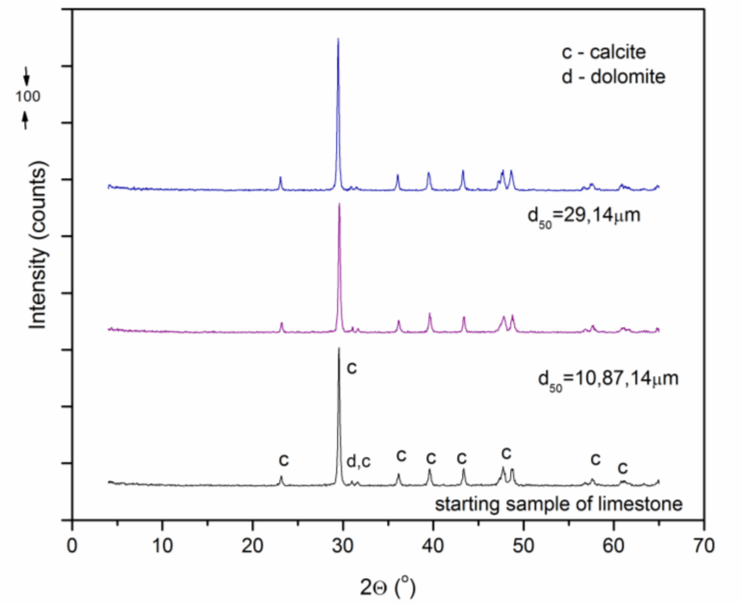


Figure 5 *X-ray diffractograms of powders of coated calcites d_{50}=10.87 μm and d_{50}=29.14 μm*

Calcite upon modifying with stearic acid and achieving a complete hydrophobicity retains the basic structure irrespective of size class, which is modified. These results indicate that the adsorption process occurs on the phase boundaries. It can be seen by analysis of the fundamental diffraction peaks of calcite that there are no changes in their diffraction angles (θ) and intensities, and that there was no systematic displacement of reflections and amorphization after adsorption of stearic acid.

Infrared Spectroscopy of the Starting Sample and Modified Sample

The infrared spectra of the starting sample and modified calcite sample of the largest size classes d_{50} = 29.14 μm are shown in Figure 6. Compared to the typical strips of starting calcite (spectrum 1), it is observed that there was no change in the position and intensity of most strps in modified calcite d_{sr} = 29.14 μm (spectrum 2). In modified sample d_{sr} = 29,14 μm (spectrum 2), in the range from 3000 to 2800 cm^{-1}, the strips are observed at 2950, 2918, 2873 and 2852 cm^{-1}, originating from valence vibrations of C-H bonds in $-CH_3$ and $-CH_2$ groups of hydrocarbon chains of the adsorbed organic component [11-13].

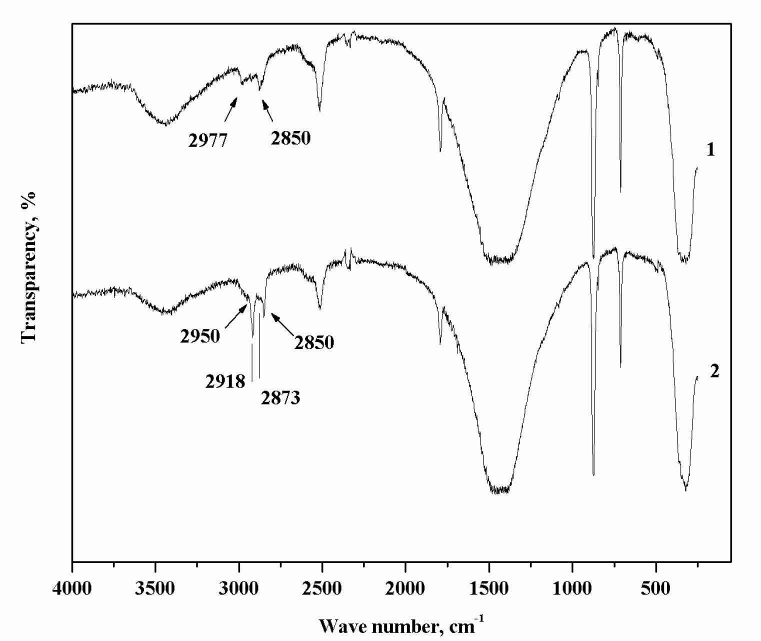
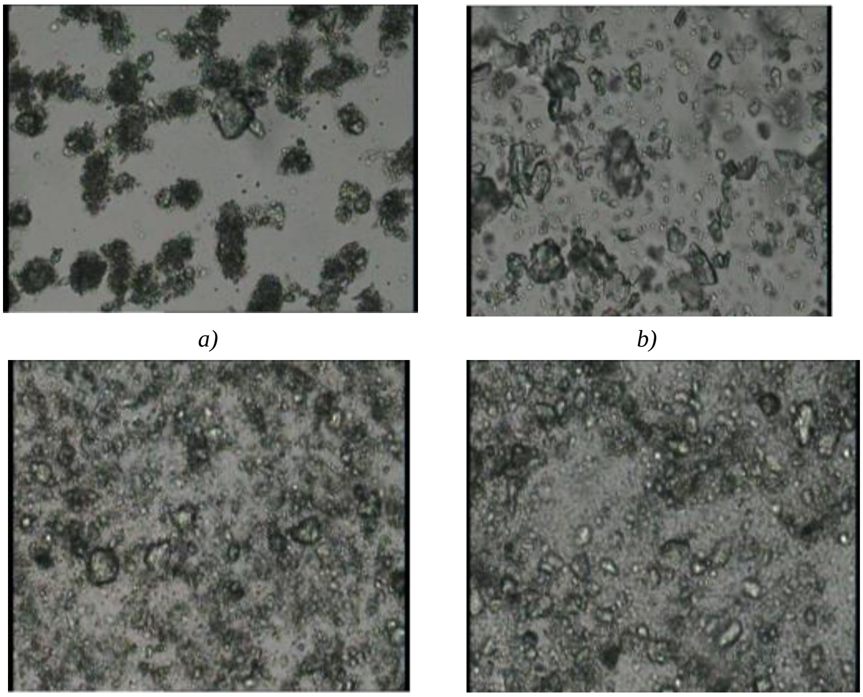


Figure 6 *Comparative infrared spectra: 1) starting sample of calcite; 2) sample d_{50}=29.14 μm*

When the wave numbers of IC strips of C-H vibrations in the spectrum of 2 are compared to the strips that Osman and Suter [11] observed in the spectrum of crystalline stearic acid (2954, 2916, 2872 and 2849 cm^{-1}), it is seen that the strips in calcite, treated with stearic acid, are slightly displaced towards higher values, except the strip corresponding to the asymmetrical C-H vibration of $-CH_3$ group (2950 cm^{-1}). This displacements towards smaller wave numbers as well as poorly expressed strips of valence C-H vibrations in $-CH_3$ group, indicate a greater representation of the Gauch conformation and sloping orientation of the hydrocarbon chain regarding to the calcite surface, i.e. lower density of "pac-king" the hydrocarbon chains in the adsor-bed layer of modified calcite d_{sr}=29.14 μm.

Microscopic Analysis of Modified Calcite

Microphotographs are shown in Figure 7.



a) b) c) d)

Figure 7 *Microphotographs of the starting calcite sample a) d_{50}=10.87 μm; b) d_{50}=29.14 μm and modified calcite sample c) d_{50}=10.87 μm; d) d_{50}=29.14 μm (magnification 20X)*

In microphotographs 7a i 7b, free grains of calcite are clearly observed, which have the characteristic interference colors of high-order, what is the feature of uncoated calcite mineral. However, in Figures 7c i 7d showing the microphotographs of sample with the coating degree Io = 99.9%, only the aggregates are observed indicating a complete coating of calcite.

CONCLUSION

Coating degree increases with increasing the concentration of stearic acid used to modify. However, it can be noted that for the same concentration of stearic acid, different coating degree was achieved in different class sizes. Maximum value of coating degree of 99.9%, in calcite of size class d_{50} = 10.87 μm, was achieved at stearic acid concentration of 0.8%, while in calcite of size classes of d_{50} = 29.14 μm it was achieved at concentration of 3%. Adsorption was always such that the molecule of surfactant, in this case, stearic acid, has kept orientation of its hydrophobic portion opposite to the surface of calcite. The results of microscopic analysis are also consistent with the obtained coating degree of analyzed samples. Namely, the grains having characteristic interface colors of high order were observed in the starting samples which is a characteristic of uncovered calcite mineral, while figures show the micro-photos of sample with the coating degree Io = 99.9%, where aggregates are only observed indicating a complete covering of calcite. The results of X-ray diffraction analysis confirmed that there was no distortion of the crystal calcite structure by modifying method. Infrared spectroscopic analysis has shown that modifying does not change the positions and intensities of the fundamental IC strips, characteristic for calcite, but stronger strips appear in the range from 3000 cm^{-1} to 2800 cm^{-1} as well as a number of strips than in the starting sample due to the symmetric and asymmetric valence vibrations of C-H bonds of hydrocarbon chain of adsorbed organic component. Poorly expressed IC strips of valence C-H vibrations in $-CH_3$ group appear in the modified calcite sample of size class d_{sr} = 29.14 μm as well as displacement of IC strip corresponding to the asymmetric C-H vibration of $-CH_3$ group towards smaller wave numbers as compared to the strip of stearic acid. It has pointed to the increased representation of the Gauch conformation and sloping orientation of the hydrocarbon chain regarding to the surface of calcite, and lower density of "packing" of hydrocarbon chains in the adsorbed layer.

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LABORATORY TESTING THE GRINDABILITY OF CARBONATE MINERAL RAW MATERIAL OF THE SITE SPASINA BRDJANI – LIMESTONE SAMPLES**

Abstract

This work presents the results of the Bond work index in a ball mill on samples of carbonate mineral raw material (limestone) of the site Spasina - Brdjani. Value of the Bond Work Index was carried out in a ball mill on six samples of limestone from exploration drill holes. The obtained results indicate that in 4 samples of limestone the value of the Bond Work Index is in the range of 5.9 to 6.4 kWh/t. Higher values of the Bond Work Index are achieved in 2 samples and the same amounts 7.059 and 9.526 kWh/ t. The increased value of the Bond Work Index in these samples of limestone is explained by the presence of white-yellow limestone cores and increased magnesium content.
Keywords: *Bond Work Index, limestone*

1 INTRODUCTION

Limestone is among the most widespread carbonate rocks, or the most widespread sedimentary rocks. The explored area Spasina - Brdjani (narrower locality the Prokos hill) is situated at the extreme northeast hills of the mountain Majevica, at a distance of about 20 km southwest of Bijeljina. The explored belt is covered with carbonate deposits with prominent hills and frequent very steep rock sections (especially in the northern part). The exploration area is limited on the west and north by the rivers Mezgrajica and Janja, on the east rests on a contour of the North landfill, while on the south side is the active open pit Bogutovo Selo.

The site Spasine - Brdjani is characterized by limestone and associated sediments belonging to the Middle Miocene of Central Paratetis - Baden and Sarmatian, then Quaternary formations – deluvial and proluvial sediments.

In the engineering - geological terms, this site is characterized by a complex of carbonate of different physical and mechanical properties. Higher areas are hypsometrically covered by compact rock masses of sand, loose to limestone cores, which in depth lean on a package of compact and loose chalk. In general, these carbonate sediments in terms of stability provide a solid rock mass and belong to the group of stable

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to conditionally stable terrains. In places of unstable slopes, where the sediments are subject to erosion and slipping, these environments are converted from stable into conditionally stable terrains in notches [1].

Detailed geological explorations of carbonate on the site Spasina - Brdjani included a series of exploration works which among other things included the exploration drilling and mining works (exploration trenches).

For the needs of determining the Bond Work Index, six composite samples of limestone were selected (in designation KR-2 to KR-14). Table 1 shows the coordinates of corresponding drill holes.

Table 1 *Coordinates of realized exploration drill holes*

Designation of drill hole	Coordinates			Interval of drill hole
	X	Y	Z	
KR-2	4 948 845.900	6 578 222.810	327.08	10.00-40.50
KR-3	4 948 990.670	6 578 212.520	331.88	6.00-36.00
KR-6	4 948 959.360	6 578 388.030	329.22	6.00-30.00
KR-9	4 948 981.690	6 578 503.420	330.01	3.00-30.30
KR-13	4 949 024.580	6 578 742.280	325.67	3.00-34.00
KR-14	4 948 970.650	6 578 870.220	320.67	5.60-30.00

2 EXPERIMENTAL PART

2.1 Characterization of Samples

Chemical analysis of samples from drill holes at subsequently intervals determined their chemical composition (Table 2).

Table 2 *Chemical composition of limestone samples*

Element, %	KR-2	KR-3	KR-6	KR-9	KR-13	KR-14
SiO_2	0.92-1.72	0.50-1.22	0.50-0.80	1.00-1.50	1.97-3.85	0.10-0.89
CaO	53.85-54.48	53.04-54.38	52.30-53.56	52.98-53.67	52.26-53.84	54.35-55.31
Al_2O_3	0.28-0.53	0.21-0.36	0.43-0.62	0.38-0.59	0.32-0.57	0.46-0.66
Fe_2O_3	0.30-0.44	0.24-0.30	0.26-0.40	0.24-0.57	0.30-0.47	0.27-0.38
FeO	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
MgO	0.52-0.59	0.45-0.54	0.26-0.29	0.42-0.55	0.41-0.46	0.43-0.53
SO_3	0.04-0.28	0.028-0.048	0.07-0.143	0.025-0.038	0.06-0.14	0.03-0.04
Na_2O	0.035-0.065	0.048-0.054	0.049-0.061	0.063-0.18	0.048-0.074	0.028-0.054
K_2O	0.048-0.072	0.040-0.047	0.068-0.12	0.049-0.12	0.062-0.087	0.062-0.098
MnO	0.015-0.018	0.019-0.030	0.015-0.019	0.012-0.039	0.024-0.030	0.018-0.034
P_2O_5	0.044-0.048	0.037-0.046	0.041-0.046	0.048-0.060	0.046-0.053	0.034-0.046
TiO_2	0.012-0.018	0.012-0.017	0.014-0.022	0.011-0.022	0.016-0.022	0.017-0.026
S	0.017-0.11	0.011-0.019	0.028-0.057	0.010-0.015	0.024-0.057	0.013-0.017
LOI	38.54-40.71	39.89-40.95	41.14-41.19	41.20-41.44	41.45-41.81	41.70-42.40

The starting samples of limestone – 6 samples (Figure 1) were dried at room temperature, and then on each of the samples the grain size distribution was determined according to the standard ISO 2591-1:1992. Preparation of limestone samples for testing included crushing in a closed cycle, and sieving on a sieve, mesh size of 3.35 mm.

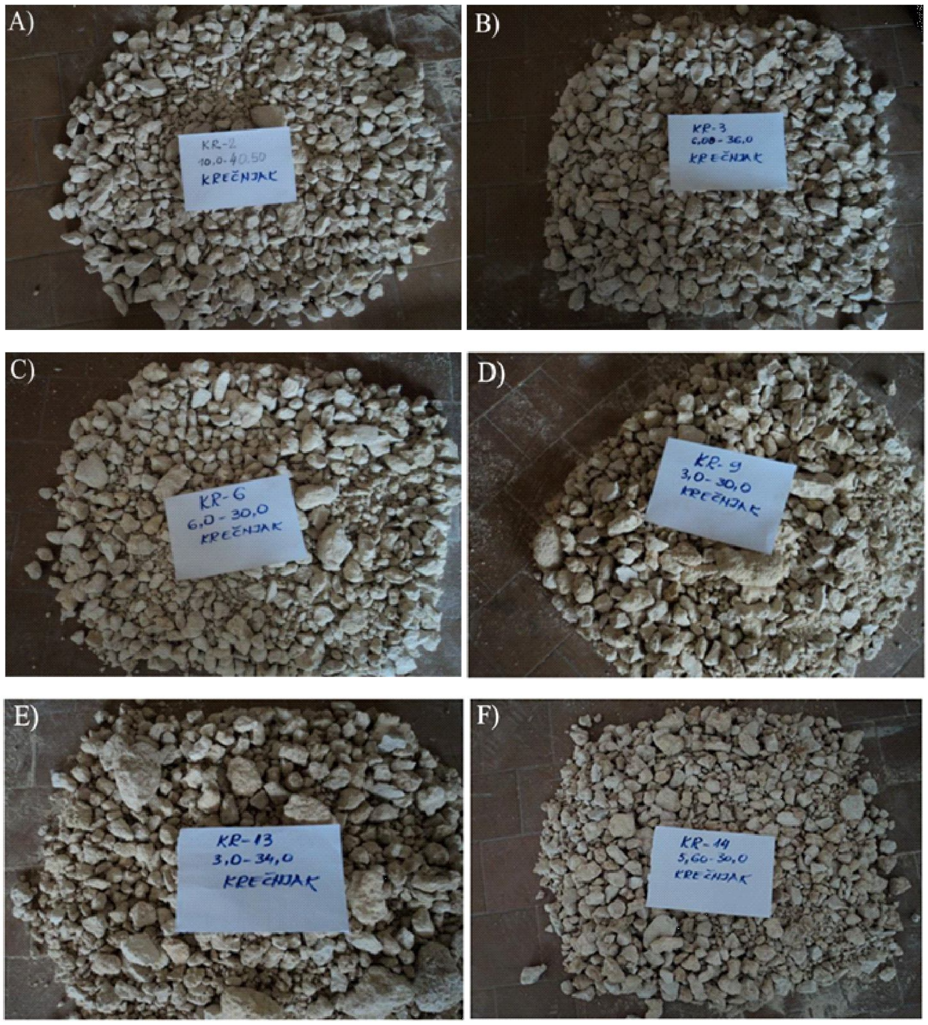

Figure 1 *Starting samples of limestone from different drill holes*

2.2 Testing the Bond Work Index

Testing the Bond Work Index on limestone samples was performed in the laboratory Bond ball mill, according to the established procedure [2]. Sieve is selected as a comparative sieve, mesh size 212 µm. Figures 2 - 7 show the grain size distribution of crushed limestone samples (prepared for testing the Bond Work Index) as well as the grain size distribution of undersize of the comparative sieve.

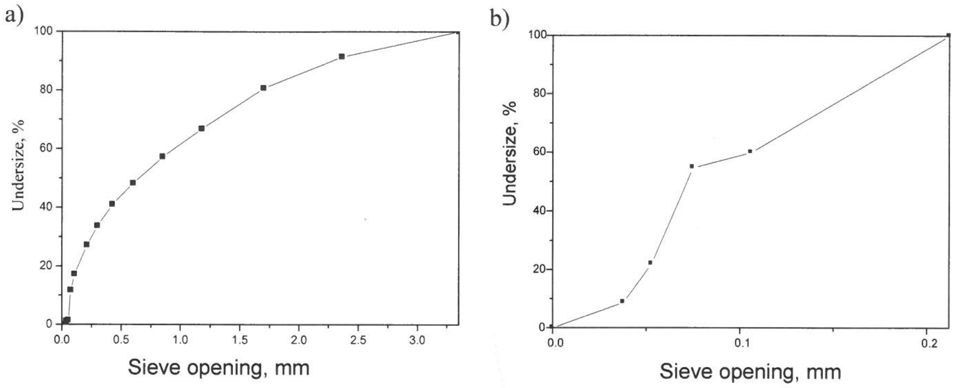

Figure 2 *Grain size distribution of sample KR-2: a) crushed starting sample, b) undersize of comparative sieve*

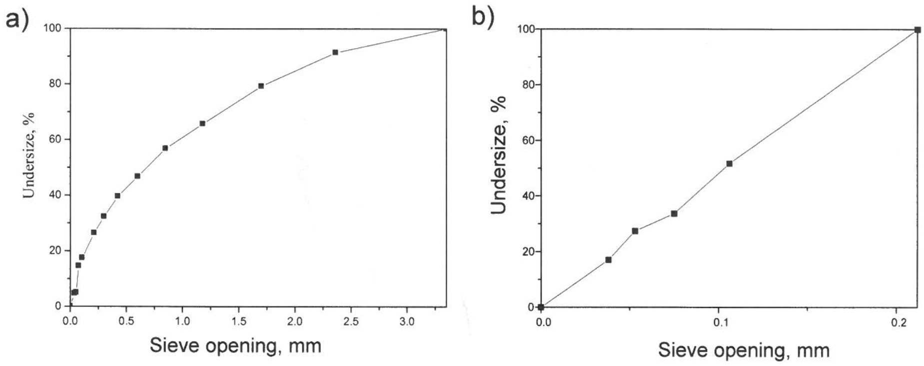

Figure 3 *Grain size distribution of sample KR-3: a) crushed starting sample, b) undersize of comparative sieve*

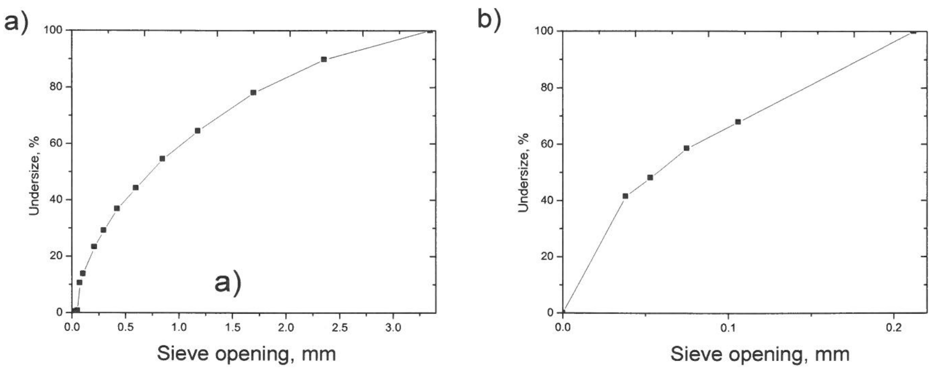

Figure 4 *Grain size distribution of sample KR-6: a) crushed starting sample, b) undersize of comparative sieve*

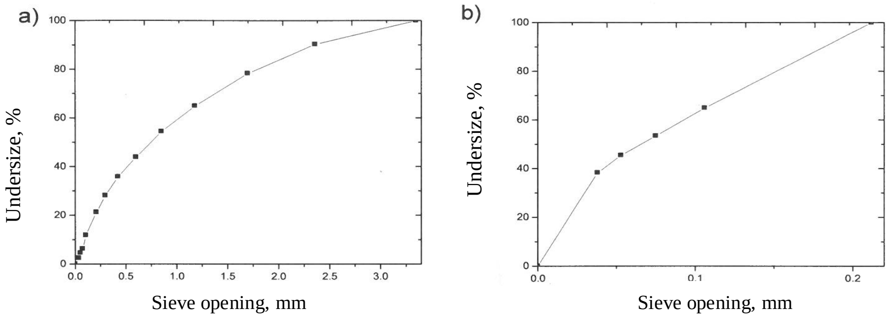

Figure 5 *Grain size distribution of sample KR-9: a) crushed starting sample, b) undersize of comparative sieve*

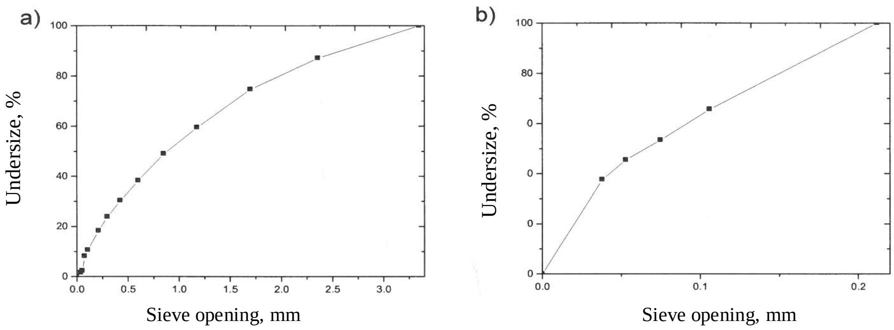

Figure 6 *Grain size distribution of sample KR-13: a) crushed starting sample, b) undersize of comparative sieve*

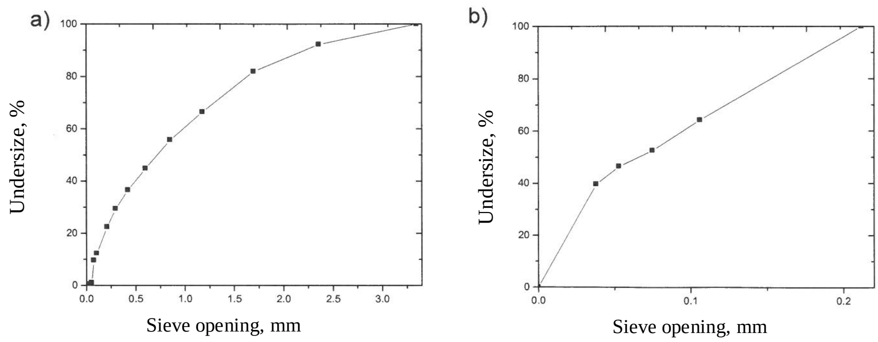

Figure 7 *Grain size distribution of sample KR-14: a) crushed starting sample, b) undersize of comparative sieve*

3 RESULTS AND DISCUSSION

The Bond Work Index was calculated according to the formula:

$$W_i = 1.1 \cdot \frac{44.5}{{P_k}^{0.23} \cdot G^{0.82} \cdot \left(\frac{10}{\sqrt{P}} - \frac{10}{\sqrt{F}}\right)} \; kWh/t$$

Where:

Pk – mesh size of comparative sieve, µm

G – new-created undersize per one revolution of mill, g/rev.

P – mesh size through which 80% of undersize of comparative sieve passes, from the last experiment, µm

F – mesh size through which 80% of starting sample passes whose the Bond Work Index is determined, µm.

Table 3 shows the obtained values of the Bond Work Index for 6 tested limestone samples.

Table 3 *Characteristic parameters and the Bond Work Index for limestone samples*

Samples	**KR-2**	**KR-3**	**KR-6**	**KR-9**	**KR-13**	**KR-14**
Pk, µm	212	212	212	212	212	212
G, g/rev.	5.553	3.523	5.601	4.645	5.358	5.438
P, µm	159	167	147	152	150	153
F, µm	1681	1735	1800	1780	1960	1620
Wi, kWh/t	6.375	9.526	5.901	7.059	6.104	6.360

The present test results (Table 3) indicate that the value of the Bond Index ranges between 5.9 and 6.4 kWh/t. It can be seen that the deviations, which means slightly higher values of the Bond Work Index were realized in samples with designations K-R 3 and KR-9, 9.526 and 7.059 kWh/t, respectively. The increased value of the Bond Work Index in these samples is explained by the presence of white-yellow limestone cores and increased content of magnesium. The correlation between the Bond Work Index and spatial position of exploratory drill holes and the deposit was established in this case.

4 CONCLUSION

The site Spasine - Brdjani is characterized by limestone and associated sediments belonging to the Middle Miocene of Central Paratetis - Baden and Sarmatian, then Quaternary formations – deluvial and proluvial sediments. In the engineering - geological terms, this site is characterized by a complex of carbonate of different physical and mechanical properties.

The values of the Bond Index mainly ranges between 2 and 3 with certain deviations. Therefore, the samples KR-2, KR-14 and R-14 are characterized by the Bond Index higher than 3 due to the presence of interlayers of alevrolyte, or high concentration of calcified fossils. On the other side, large presence of dusty component in the sample R-13 resulted in a very low value of its Bond Work Index. The explicit relationship between the spatial position of drill holes and the Bond Work Index was not established.

Determined values of laboratory testing the Bond Index range between 5.9 and 6.4 in limestone samples. Slightly higher values of the Bond Work Index were realized in samples with designations KR-3 (interval 6.00-36.00) and KR-9 (interval 3.00-30.30) and the same amount to 9.526 and 7.059 kWh/t, respectively. The increased value of the Bond Work Index is explained by the presence of white-yellow limestone cores in these samples (especially in sample KR- 3 (interval 6.00-36.00) as well as in a sample with designation KR-9 (interval 3.00-30.30) with increased content of magnesium.

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CHECKING THE FORMULATION MODELING PROCESS OF INDUSTRIAL MILL FOR DIFFERENT TYPES OF GRINDING BODIES**

Abstract

This paper presents checking the formulation modeling process of industrial mill for different types of grinding bodies. It is known that changing the type of drilling bodies realizes various efficiency of grinding the mineral raw materials and/or different grinding fineness. This paper gives a hypothesis on bulk mass (density) of a mill batch as an influential factor to the size of specific grinding capacity of the specific mineral resources. The experiment was carried out in the industrial conditions of grinding when the Damkohler's criteria $D_{a_{q-d}} = \frac{q_{-d}}{n \cdot \rho_{\check{S}}}$ *was calculated [1]. Verification of this formulation was done in the industrial conditions, and testing results are present in this paper.*
Keywords: *specific capacity, bulk density, Damkohler's criteria*

INTRODUCTION

Production of water glass requires to have a high quality raw material (Fe_2O_3 <0.03%) and specific granularity. Particle size distribution of raw materials affects the energy consumption in the production of water glass, and is the optimal requirements sized quartz sand class -0,40 mm + 0.05 mm. Quartz sand from the deposit Bijela stena is mined and prepared for production of water glass in the site Lukic Polje near Milici up to 2014, when the company took over the entire site Kesogradnja and moved it to the location Kozluk, near Zvornik, in order to execute the adaptation of technology. The new facility has built a high gradient electromagnet for satisfactory chemical quality and the type of grinding body was changed to achieve finer grinding process.

THEORY

Buckingham's π Theorem

According to the Buckingham π theorem, every equations containing n_i does not relate to physical quantities (υ, where υ = nd, ρ, D, r .., etc.), among which m_i values have independent dimensions of size (M, L, t), can be transferred into equation which has n_i to m_i of dimensionless criteria and simplex, composed of these parameters

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[2,3]. This theorem is of great importance in the experimental and theoretical work. Dimensionless numbers are met practically for solving any problems in chemical engineering. Formation of dimensionless numbers for a particular problem is most easily achieved using dimensional matrixes [3]. Generally speaking, in the area of application, the chemical reactions with transfer of a power impulse and heat are used by Damkohler I (D_{aI}). The modified Damkohler [1] represents the equation of modeling the specific capacity of the mill q_{-d} .

$$D_{a_{q-d}} = \frac{q_{-d}}{n \cdot \rho_s} \qquad (1)$$

Where:

q_{-d} - specific capacity of the mill to the newlyformed $-d$ calculated size class $ML^{-3}t^{-1}$,

d - side of square mesh openings in µm

n - number of revolutions of the mill per unit of time t^{-1},

$\rho_{\check{S}}$ - batch density ML^{-3},

Bulk Density of Batch of the Mill

Bulk density of batch is a size that mostly depends from the bulk density of grinding bodies and less than the pulp density. Bulk density of batch in the mill is calculated according to the formula [2] 3 and denoted by $\rho_{\check{S}}$:

$$\rho_{\check{S}} = \rho_{vk} + 1{,}15 \cdot (1 - \frac{\rho_{vk}}{\rho_{sk}}) \cdot \rho_p, \frac{kg}{m^3} \qquad (2)$$

Wherein:

ρ_{vk} - bulk weight or density of balls in bulk density, in kg/m^3

ρ_{sk} - density of ball material from which was ball created or volume mass of balls, in kg/m^3

ρ_p - pulp density, kg/m^3

Bulk density of batch of the mill is the sum of the bulk density of balls bulk density, bulk density of material and density of water, which is located in the gap between the balls. Number of 1.15 in Equation 2 means that the empty space between the balls, which is filled with material which needs to be increased by 15% to make the balls, could perform the work of raw material and not to self-touch in the process of rotation of batch. The term in parentheses, Equation 2, is the empty space between the balls and it changes so that the different types of balls have different values: steel (0.46), pressed Al_2O_3 (0.44), and silicate (0.27). A large difference can be seen for empty space between the steel and silicate balls, as well as the pressed and silicate balls as expected because the steel and pressed balls are of spherical shape and a gap between the balls is larger; while the silicate balls are created in nature and have, in the least number of cases, a spherical shape, and a gap between them is smaller. The formula for the apparent density batch or bulk weight of the total charge of the mill, the first summand has over 80% influence on the bulk weight of the batch $\rho_{\check{S}}$.

Change the type of drilling body has therefore a major influence on batch density. A change of type the drilling bodies is rarely applied in the industrial mills because this kind of change is very expensive. In one mill, if it is permitted by motor power, with a change in type of drilling body, a specific grinding capacity is also changed. Water in the wet grinding process has a transport character due to its high viscosity. Water provides a particular lower pulp viscosity ranging from the input to output sleeve until balls rotate in the shell of the mill and do not move together with the pulp. Pulp density should be as much due to the efficiency of the grinding material in the mill. Pulp density in changing the bulk density of balls in the mill as a result of changes in species milling body does not remain the same already has a new value in order to ensure adequate grinding efficiency. For smaller bulk density of balls ρ_{vk} pulp density ρ_p is lower, and the higher the bulk density is higher. In a particular bulk mass of balls ρ_{vk} in the mill and pulp density ρ_p may remain constant when changing the capacity of the mill. These statements relate to more open regime of grinding and discharging of mill through the sleeve. The technological tests milling can be held constant density of a batch $\rho_{\check{S}}$ to change the time of milling capacity.

Specific Capacity of the Mill

Specific capacity of the mill for the open grinding regime according to Magdalinović [4] is:

$$q_{-d} = \frac{M}{V \cdot t} \cdot (\beta_{-d} - \alpha_{-d}) \left[\frac{kg}{m^3 \cdot s} \right] \quad (3)$$

Wherein:

q_{-d} - specific capacity of the mill to the newly calculated size class

$-d$ at $kgm^{-3}s^{-1}$ (*d* representing square mesh sieve)

M -material weight in the mill *kg*,

V - volume of the mill m^3,

t - grinding time s ,

α_{-d} i β_{-d} - content of calculated size class $-d$ in the entry and grinding product in the unit parts

From the formulas for specific capacity, it can be seen that it depends on technological and design parameters. Constructive parameter is the mill volume (V), and the mass of material in the mill (M). The mass of material in the mill is a type of constant because the size means filling the empty space between the balls and very little changes with the capacity of mill. Technological parameter is the content of calculated size class $_{-d}$ in input and product of milling and is located to the formulation of specific capacity. To change the technological parameters of the mill is necessary to carry out the experiments changing hour capacity and output testing sized milling products. Then, the share of size class -*d* has to be determined in the product of grinding and feed grade. The specific capacity of the mill has a different value if there are different modes, open or closed regime. In open mode, the mill has a lower specific power while in the closed mode, he becomes hig-her for the same output plumpness milling products. The specific capacity of milling in the open mode, the mill can be easily changed by increasing or reducing the residence time of material in the mill. Changing specific grinding capacity in the closed mode, the mill is much more demanding, almost impossible, because then changes the amount of material that is returned to the mill, it is necessary to change the classification of devices. It should be noted that the process of grinding in a closed regime is more effective, however, the specific milling capacity increases relative to the open operation of the mill [5,6,7].

MATERIALS AND METHODS

In the open mode, the process of wet grinding sand from the deposit "Bijela stena", in operation Lukic Polje near Milici during the running section of the grinding silex balls varied the time of milling capacity to perform modeling of formulating the operation of industrial mill. In the procedure of the technological tests the pulp density was kept constant, and thus the density of the batch $\rho_{\check{S}}$. The paper [1] presents the results of modeling when dimensionless number of the "modified Damkohler" $D_{a\,q-d}$ was established.

Table 1 *Values of criteria* D_a *for different specific capacities* q_{-d}

Measured hourly capacity $Q\left[\frac{t}{h}\right]$,	**Specific grinding capacity** $q_{-d}\ \frac{kg}{m^3 \cdot s}$	**Charge density mill** $\rho_s\left[\frac{kg}{m^3}\right]$	**r.p.m of mill** $n\left[s^{-1}\right]$,	**Value of Damkohler criterion** $D_a = \frac{q_{-d}}{n \cdot \rho_{up}}$
4	0.084	2198	0.3	$D_a = \frac{q_{-200}}{n \cdot \rho_{up}} \cong 0{,}000127$
10	0.194	2198	0.3	$D_a = \frac{q_{-600}}{n \cdot \rho_{up}} \cong 0{,}000295$
15	0.272	2198	0.3	$D_a = \frac{q_{-830}}{n \cdot \rho_{up}} \cong 0{,}000413$

Dimensionless number $D_{a\,q-d}$, is a formulation that is a linear model function of the specific capacity of the mill, Figure 1, for different output because the fineness: density batch and a constant number of revolutions, Table 1 in column 3 and 4. If the apparent density of the batch mill is increased, then a new linear relationship

$$D_{a\,q-d_i} = \mathrm{f}\,(q_{-d_i})$$

is obtained, Figure 2 a straight line 2 and 3. The new linear relationship can be obtained by computation if known $D_{a\,q-d}$, Table 1 column 5. Calculation of determining the specific capacity of the new grinding q_{-d} for a new batch density $\rho_{\check{S}}$ is obtained by simply rearranging the equation 1. All is needed to do is to calculate the new specific milling capacity for the new density batch mill. During this operation it is necessary to know that at a higher bulk density of the balls can be used higher density pulp, which is defined by empirical equations for the design of mills. Linear dependence

$$D_{a\,q-d_i} = \mathrm{f}(q_{-d_i})$$

can be used for reading interpolation specific capacity of a size class for which is not experimentally determined specific capacities and is located between the minimum and maximum specific capacity, which is the work done. The same mill that is used Lukic Polje grinding by silex balls in Kozluk has more capacity for the same specific milling capacity q_{-d} because it uses steel balls. Also mill with steel balls can have the same time as the mill capacity to sileks balls or for two different sizes of output two different values q_{-d}.

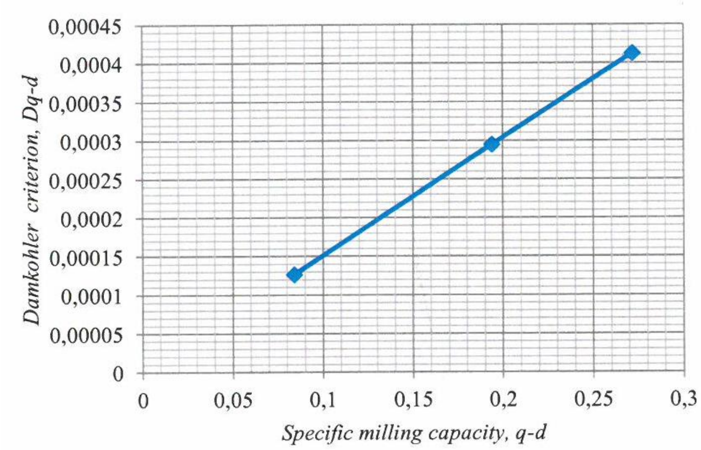

Figure 1 *Dimensionless criterion "Damkohler" in operation with specific capacity of the mill* $\rho_s = 2198\left[\frac{kg}{m^3}\right]$

RESULTS AND DISCUSSION OF RESULTS

Checking formulation modeling industrial mill will be carried out by the industrial conditions of the mill capacity to record time and determine the specific capacity for a new milling bulk weight of the batch mill with steel balls (law 3) in Figure 1. Figure 2 shows the three straight lines depicting three different the bulk density of the batch mill, and in line with different specific milling capacity when Damkohler criterion remains the function of the specific grinding capacity $q_{-d\,i}$. Analyzing the equation 1, it can be seen that for one and the same mill, the rule is that if it is required to increase the specific capacity of a certain size class, it is needed to increase the density of the batch mill. This idea in practice is rarely applied because the devices are designed for a specific technological scheme, so the adaptation is very unpopular. In the paper, "Modeling of the Mill to the Mill Batch Density and Specific Capacity" [1], an adaptation of a used mill with rods in the mill with silex balls was done in considering the engine power and the fact that in operation in an open-cycle the capacities can be changed. Then, experimentally are defined dimensionless criteria Damkohler for various specific milling capacity and density for the same batch. This dimensionless criterion is also appllied to the amended density batch mill, now a steel milling body when giving the new values of 0 specific grinding capacity, and thus predictable capacity mill in new technological circumstances. After downloading and installing the same equipment at the site Kozluk made the running plants with altered operating parameters section mills. This is based on the running and actual operating parameters led to the following results. The plant for grinding quartz raw materials in Kozluk is designed to work with the following operating characteristics [8]: the capacity of the mill is q = 10 th^{-1}, while size is 90% - 400 μm. Power output of the mill is N = 280, and the volume of the mill is V = V = 13 m^3. The mass of steel milling bodies in the mill is 18,000 kg. Speed mill is 17.8 o/min. The mill is discharged through the sleeve, and the density of the pulp at the outlet is 1,879 kg/l which means it has 76% of a firm in the pulp, (S:L then 1: 0.7). The mass of material in the mill is 2.34 t. During the milling is 10 minutes, the value of the Bond work index of quartz sand is 14.0 kWh/t. The apparent density batch mill in the industrial process of the mill in operation separation Kozluk was calculated according to the equation 2. Bulk density batch therefore has value $\rho_{\check{S}}$ = 5125 kgm^{-3}, Table 3. In order to find the specific capacity designed mill, the content of calculated size class was determined in the process input material, Figure 2, curve 1. At the optimum pulp density, it has been experimentally determined that the time capacity was 14 th^{-1}, Table 2. Then, it was obtained about 90% of class -400 μm in the final product, Figure 2, curve 2.

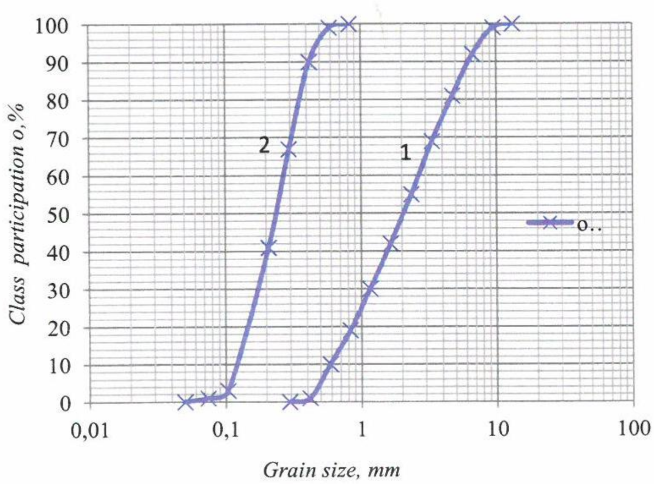

Figure 2 *Particle size distribution of the starting sample 1 and grinding product 2 at hourly grinding capacity of Q = 14 t / h*

The model was checked based on experimentally obtained values for the specific milling capacity in the site Kozluk and found that the point which defines the specific capacity of curve 3, applied to the density of the batch q_{-d} = 5125, Figure 3.

The same grinding mill in the same mode or with higher density batch gave higher capacity milling in comparison with the experiment, which was carried out with silex balls in the site Lukic Polje.

Table 2 *Experiment of kinetics in the industrial grinding mill with steel balls of the newly calculated size class –d*

Hourly capacity $Q\left[\frac{t}{h}\right]$,	Grinding time t $t=\frac{M}{Q}\cdot 3600[s]$	Material mass in mill *m/kg*	Mill volume V/m^3	The content of calculated size class in grinding product in inlet		$q_{-d}=\frac{M}{V\cdot t}\cdot(\beta_{-d}-\alpha_{-d})\left[\frac{kg}{m^3\cdot s}\right]$
				β_{-d}	α_{-d}	
14	600	5125	13	0.90	1	q-400 = 0.27

Table 3 *Value of criteria* D_a *for the experimentally obtained capacity* q_{-d}

Calculated capacity $Q\left[\frac{t}{h}\right]$,	q_{-d} $\frac{kg}{m^3 \cdot s}$ **according to Magdalinović with metal balls**	**Total charge density** $\rho_{up}\left[\frac{kg}{m^3}\right]$	**r.p.m of mill** $n\left[s^{-1}\right]$,	$D_{aIM} = \frac{q_{-d}}{n \cdot \rho_{up}}$
14	0.27	5125	0.3	$D_{aIM} = \frac{q_{-400}}{n \cdot \rho_{up}} \cong 0{,}000175$

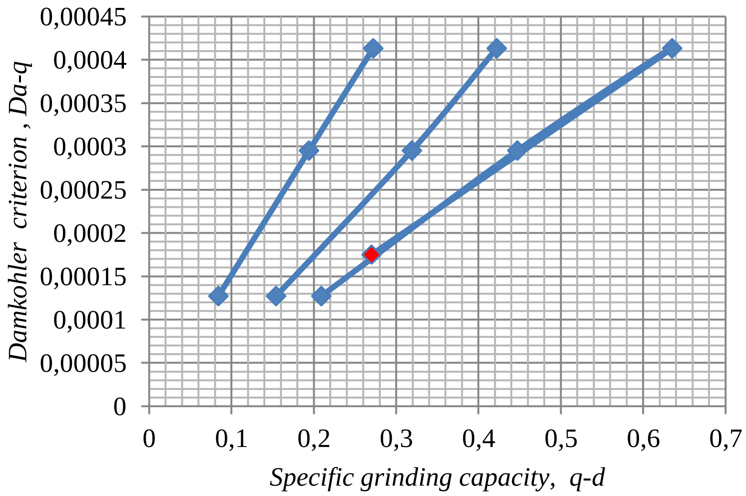

Figure 3 *Experimentally obtained points on the curve of dimensionless criteria "Damkohler" in function of the specific mill capacity. 1. silex balls; 2. alloy balls; 3. steel balls*

CONCLUSION

The aim of formulation modeling is predicting a new capacity of mill in terms of density variation drilling bodies in the mill batch. To be modified D_{aq-d} for a particular class of size remains the same as provided by dimensionless number, and if it is necessary to increase the bulk weight of the batch mill also increase the specific capacity of milling. Checking the modeling in industrial conditions was made after taking over the drive by the new investor, when it changed a type ofof balls, and instead silex balls are now used the steel balls. Bulk density batch, which depending on the type of milling bodies and grinding efficiency, increases with the use of balls with higher density. In this study confirmed the hypothesis about the influence of density milling bodies in a specific batch mill grinding capacity. This change allows the adaptation of the mill plant to increase capacity of the mill time, or to increase the fineness of grinding capacity at the same hour. The variation of the specific capacity of the mill is carried out on the basis of the Damkohler criteria. A good fact on specific mill that is built into the drive separation of quartz sand in Kozluk, near Zvornik, and which have been tested, is that the mill motor can support higher density batch milling body, so that the realized tests can be implemented in practice.

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HYDRAULIC ANALYSIS THE STATIONARY PHENOMENA UPON GRAVITATIONAL PIPELINE TRANSPORT OF BRINE

Abstract

This paper will demonstrate the methodology and results of analysis the stationary phenomena upon gravitational pipeline transport of brine from the Salt Mine Tuzla to the ultimate consumer. Moreover, it will provide the analysis of reciprocal effects of flow, change in diameter, speed of hydraulic ascent, loss of pressure and density of brine.

Keywords: *brine, pipeline, stationary phenomena, hydraulic analysis, flow*

1 INTRODUCTION

1.1 Salt Mine Tuzla - Salt Deposit Tetima

Exploitation of salt in Bosnia and Herzegovina is closely linked to the area of Tuzla, namely to the salt deposit in Tuzla, where the industrial exploitation of salt is conducted over a period of more than 100 years. In the last 10 years, the exploitation in the new salt stones deposit Tetima has been more intensified and represents an alternative capacity for the deposit Tuzla.

In research the salt stone deposit Tetima, a multidisciplinary principle was enforced, but the exploration drilling has the main role in deposit exploration, and a geometrization of the salt object is conducted based on it. The level of understanding the certain important deposit characteristic and parameters (geological, hydrogeological, and chemic technological) that were contemporary then, and which have a crucial impact in choosing the manner and method of exploitation of one salt deposit, intruded as an optimal solution in choosing a concept by which the exploitation of this deposit is conducted by controlled leaching the individual boreholes on the field surface.

The Basic Mining Project, made in the end of the eighties, appropriates a phase development ranging from 1 600 000 m^3 over 2 500 000 m^3 to the final 4 500 000 m^3 of salt water per year. All of the mining objects, facilities and devices were sized according to the final capacity and were constructed in the early nineties [5].

In March 1992, the Mine started working in trial period on five exploration boreholes, but after only two months due to the war the trial period ended.

After the revitalization of the mine objects, facilities and devices, which lasted from 1996 to 2000, production was again launched in 2001.

In the last eighties, due to the increased number of salt water consumers, the production of salt water was intensified. Due to this, all of the mining works following the production of salt water were intensified as well. In the period from 2005 to

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2014, fourteen new exploitation boreholes were drilled as the capita; objects. With these fourteen boreholes and five boreholes drilled before the war, nineteen of the designed one hundred are operational. Hence, it can be concluded that in this way the demands of consumers were met.

1.2 Transport System from the Mine to the Consumers

From the reservoir of salt water Tetima, brine is transported to the consumer by gravitational force. Due to a high available energy in the pipelines, and in order to unburden the pressure on sections of the line routing, supporting chambers are provided.

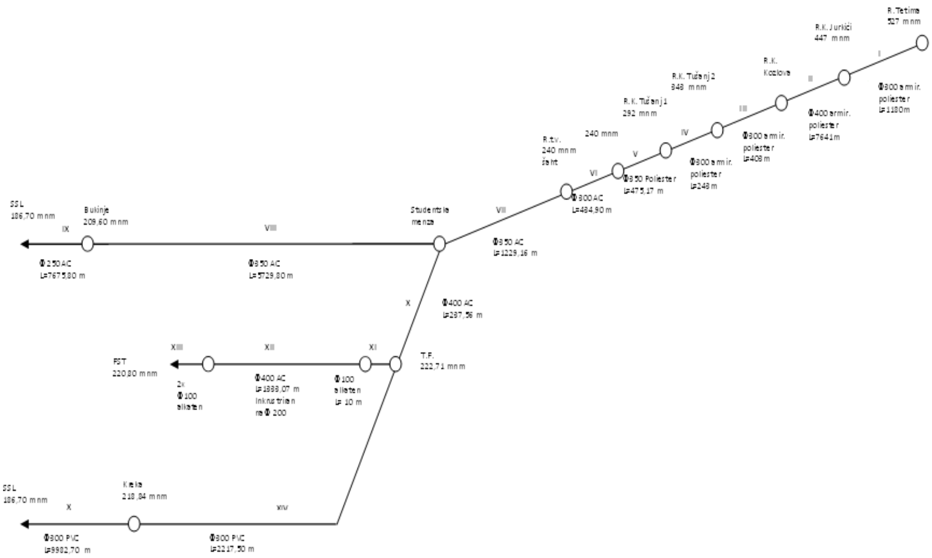

Figure 1 *Schematic view of pipeline from the mine to the consumers*

2 METHODOLOGY OF HYDRAULIC ANALYSIS THE STATIONARY PHENOMENA UPON GRAVITATIONAL PIPELINE TRANSPORT OF BRINE

The line routing for transport of brine is divided into i=15 routes.

The calculation is done for:

- Maximum projected flow Q1= 516,6 m^3/h;
- 2014: minimum flow Q_4= 309 m^3/h; maximum flow Q_3= 331 m^3/h
- 2015: minimum flow Q_4= 309 m^3/h; maximum flow Q_2= 361 m^3/h

For every route, the following data were collected:

- Pipeline type
- Length of pipeline L_i (m)
- Diameter of pipeline D_i (m)

- Flow Q_i (m^3/s)
- Abrasion coefficient k (m)
- Elevation of reservoir bottom H_{i1} (m nm)
- Elevation of supporting chamber overflow H_{i2} (m nm)
- Brine density (kg/m^3)
- Kinematic viscosity ϑ (m^2/s) for temperature up to 30ºC
- i= up to 15

The methodology of analysis the hydraulic parameters for each route:

Available upper – air difference $H_{0i}=H_{i1}-H_{i2}$; (m)

Speed through pipelines:

$$v_i = \frac{4Q_i}{D_i^2 \cdot \pi};\ \left(\frac{m}{s}\right)$$

Reynolds' number: $R_{ei} = \frac{v_i \cdot D_i}{\vartheta}$

For calculation of abrasion coefficient, the Swamee-Jain Friction Factor is used (for $10^{-6} \leq \frac{k}{D} \leq 10^{-2}\ i\ 5000 \leq R_e \leq 10^8$)

$$\lambda_i = \frac{1{,}325}{\left[l_n\left(\frac{k}{3{,}7 \cdot D_i} + \frac{5{,}74}{R_{ei}^{0{,}9}}\right)\right]^2}$$

Hydraulic slope: $i_i = \frac{\lambda_i \cdot v_i^2}{D_i \cdot 2g}$

Exertion loss: $\Delta h_{ti} = i_i \cdot L_i\ ; (m)$

In accordance with calculation, the local losses of exertion are frequently not defined, but it is perceived that they range from 5 to 10 % of exertion loss in straight – lined routes of pipelines.

Local loss of exertion (loss of pressure) 10%: $\Delta h_{Li} = \frac{10}{100} \cdot \Delta h_{ti}\ ; (m)$

Total loss of exertion (loss of pressure) on "i" route are: $\Delta h_i = \Delta h_{ti} + \Delta h_{Li}\ ; (m)$

Elevation of piesometric line $H_i=H_{i1}-\Delta h_{ti}$; (m)

Loss in pressure:

$\Delta p_i = \Delta h_i \cdot \rho \cdot g\ ; (Pa)$

Brine volume in pipe on "i" route: $V_i = \frac{D_i^2 \cdot \pi}{4} \cdot L_i;\ (m^3)$

Brine mass in pipe on "i" route:

- for ρ_1=1200 kg/m^3 → $m_{1i} = V_i \cdot \rho_1; (kg)$
- for ρ_2=1201 kg/m^3→ $m_{2i} = V_i \cdot \rho_2\ ; (kg)$
- for ρ_3=1202 kg/m^3→ $m_{3i} = V_i \cdot \rho_3; (kg)$

Each route is calculated.

Table 1 *Calculation results for individual hydraulic parameters on route I*

Route I	**Elevation of bottom m of altitude**	**L_1 (m)**	**Q (m^3/year)**	**Q (l/s)**	**D_1 (m)**	**v_1 (m/s)**	**k_1**	**Re_1**
R Tetima RK Jurkići	527	1180	4525416	143.50	0.3	2.03	0.4	319027
			3162360	100.28		1.42		222936
			2899560	91.94		1.30		204410
			2706840	85.83		1.21		190823
		Λ_1	**I_1**	**Δh_{t1} (m)**	**Δh_{l1} (m) 10%**	**Δh (m)**	**Elevation pij.lin. (m)**	**Δp (Pa)**
		0.02197	0.015402	18.17417	1.817417	19.99159	507.01	235340.97
		0.02229	0.00763	9.003639	0.900364	9.904003	517.10	116589.93
		0.02239	0.006441	7.600579	0.760058	8.360637	518.64	98421.42
		0.02246	0.005633	6.646726	0.664673	7.311398	519.69	86069.78

The following diagrams will demonstrate the interdependency between some calculated parameters specified in Table 1.

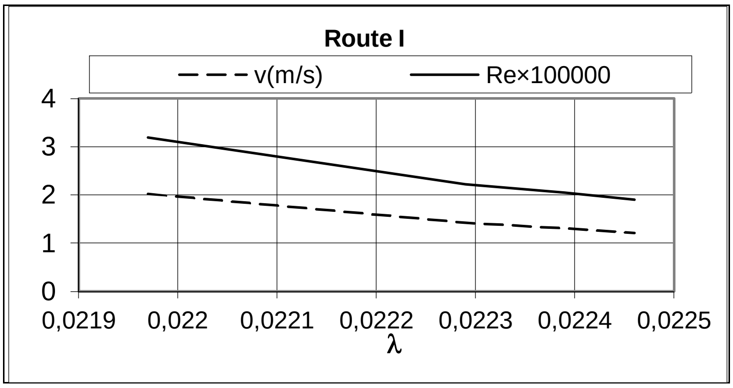

Figure 2 *Abrasion coefficient in the function from speed "i" to the Re number on the route I*

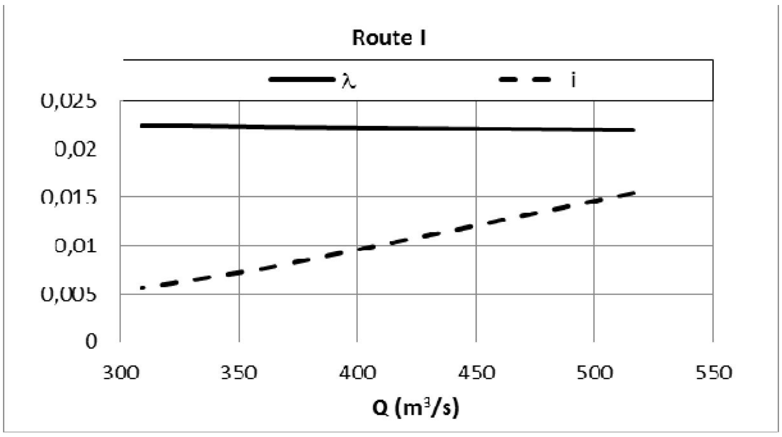

Figure 3 *Hydraulic elevation on the route I of pipeline in the function form of abrasion coefficient*

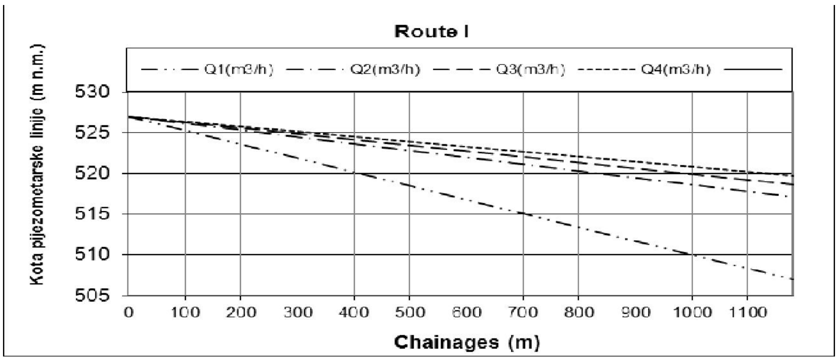

Figure 4 *Piesometric line on the route I in dependency to the size of brine flow through pipeline*

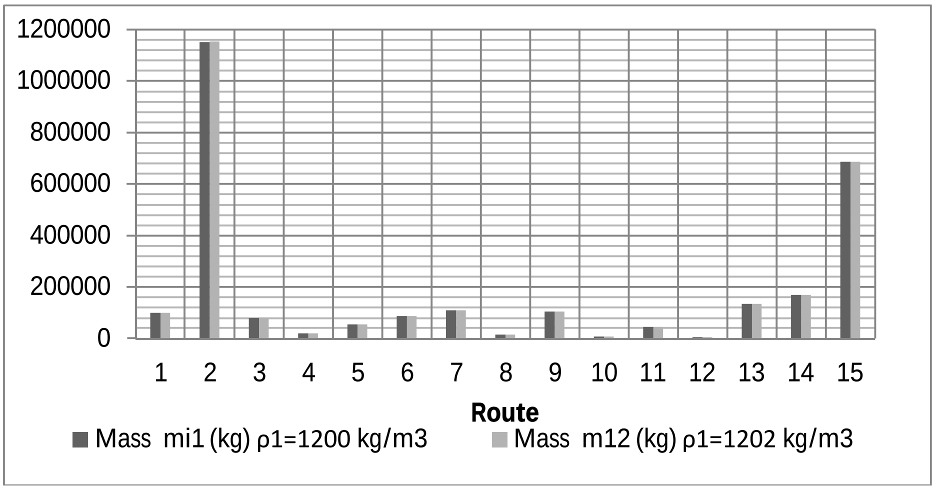

Figure 5 *Diagram of mass dependency from brine density in pipeline on all routes*

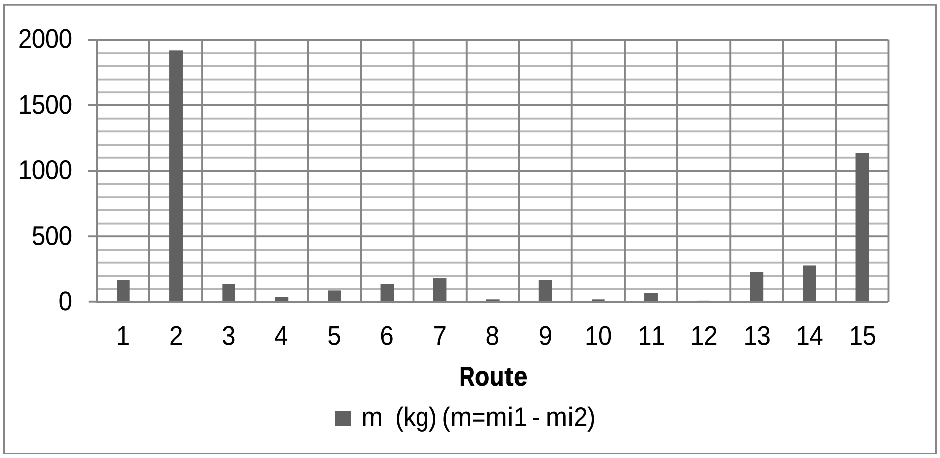

Figure 6 *Diagram of difference in brine masses upon density increase on some routes*

Increasing the brine density from 1,200 to 1,202 kg/m^3 on the first route, the brine mass in pipeline is increased from 100.04 t to 100.21 t (for 170 kg). On some routes, the value of difference in brine masses is not only influenced by increase in density, but by the length and diameter of pipeline as well.

Diagrams in Figures 7, 8 and 9 show the change in diameters along the line routing.

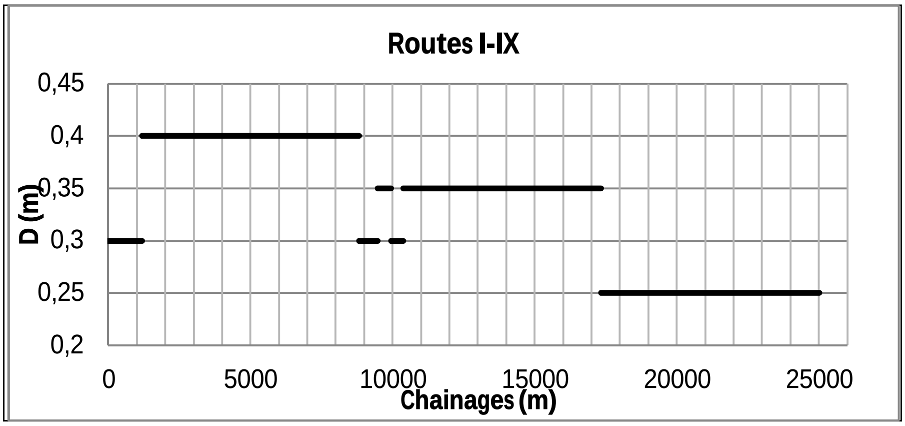

Figure 7 *Change in pipeline diameter on the routes I to IX*

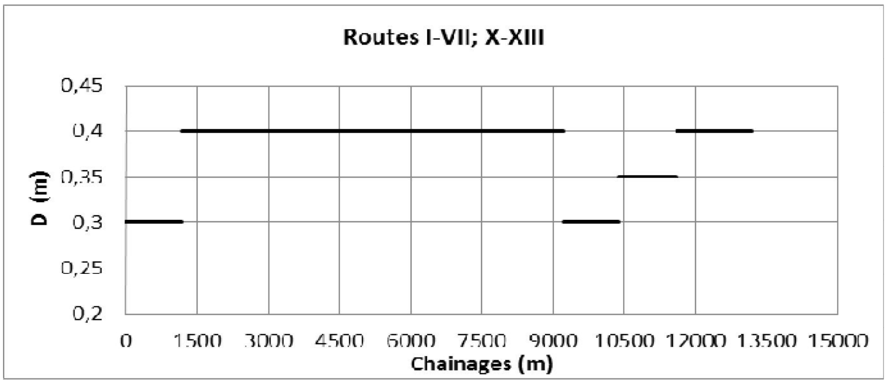

Figure 8 *Change in pipeline diameters on the routes I –VII, X-XIII*

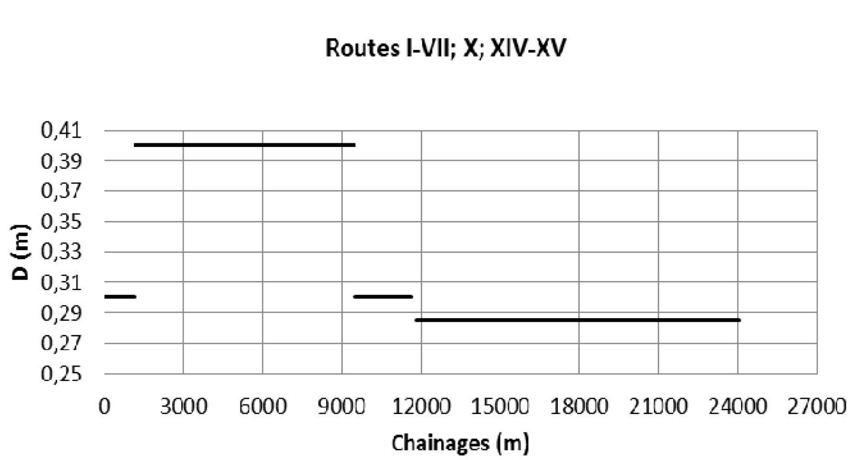

Figure 9 *Change in pipeline diameters on the routes I –VII, X, XIV-XV*

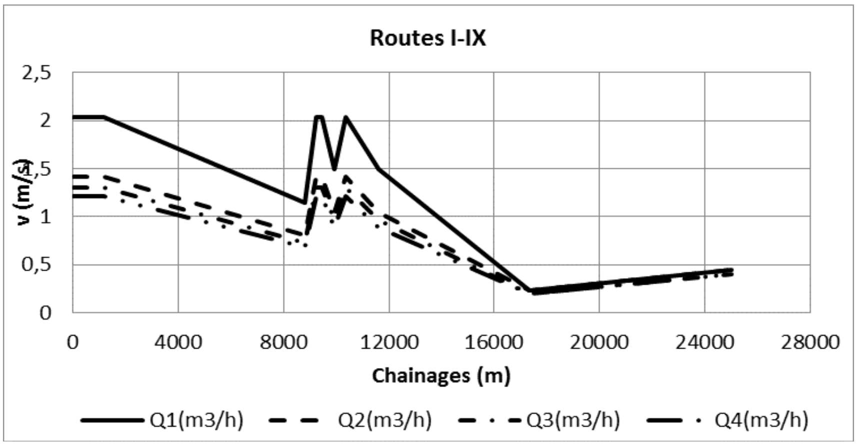

Figure 10 *Change in flow speed in pipeline on the routes I to IX depending to the flow size*

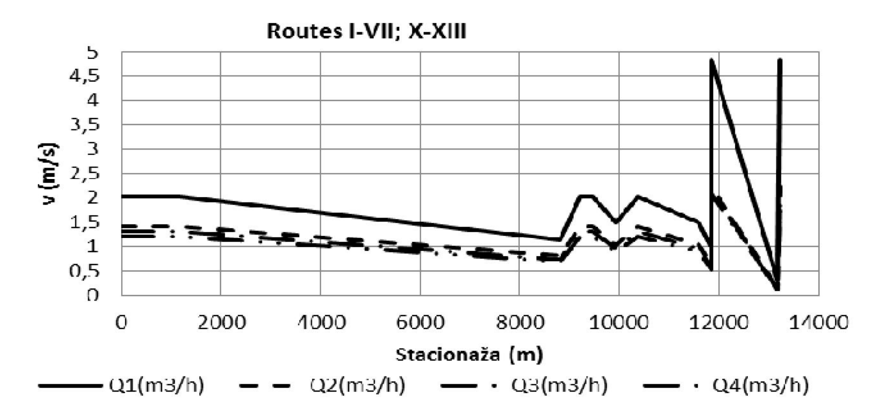

Figure 11 *Change in flow speed in pipeline on the routes I-VII, X-XIII depending to the flow size*

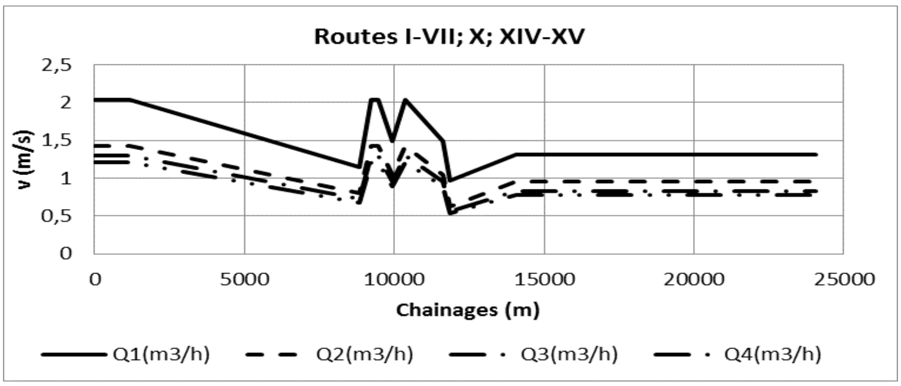

Figure 12 *Change in flow speed in pipeline on the routes I-VII, X, XIV-XV depending to the flow size*

3 DISCUSSION

Based on the conducted research and analysis, the following can be concluded:

- With increase of brine flow "Q", the speed in pipeline "v" increases (at D=const.).
- With increase of flow, the values v, i, Δh, Δp increase, the Re (at D=const. L=const.) increases, but the abrasion coefficient λ slightly reduces and vice versa.
- At D=const. by reduction the flow, the value of speed "vi" of the number Re on the route reduces, and the value of abrasion coefficient λ rises.
- Length of the route does not affect the value of abrasion coefficient.
- With increase in the flow Q, the piesometric elevation reduces.
- Change in brine density for 2 kg/m^3 influences the change in brine mass in pipeline on some routes.
- If pipe length and diameter are larger, the mass change is more significant.
- Length of pipeline influences the overall increase in brine mass in pipeline by increase in density.

CONCLUSION

In conclusion, based on the analysis provided in this work it is possible to mathematically calculate the gravitational transport of brine through pipeline, and hence, it can be used to calculate the gravitational transport of colloid hydro – mixtures.

Upon calculations based on this model, the entry data must be accurately defined. Therefore, the analysis of obtained data for a specific instance leads to a conclusion that by increasing the flow, the vales v, i, Δh, Δp and Re are increased, and the abrasion coefficient L_i, $D_{i,}$ decreases for the exact same value.

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CHARACTERISTICS OF THE PROJECT FINANCE IN THE REPUBLIC OF SERBIA

Abstract

Nowadays, the project finance is applied both in undeveloped and highly developed economies, including Serbia. In the current practice of the project finance in Serbia and Europe, the project finance has usually been used for intensive capital activities, therefore the aim of this study is to apply all experiences gained on those projects, not only in our country. It is pointed out hereby to superiority of this kind of finances together with all risks it takes, and what is needed to make it more attractive under the current economic conditions and circumstances. Moreover, the effectiveness and efficiency of using this model of finances requires the economic sustainability of concrete projects through the positive impacts on entire social and economic development, especially of Serbia. The analytic and synthetic methods, as well as the classification method were used in this research as the fundamental scientific methods, whereas the methods of analytic-deductive and comparative methods were used as the general scientific methods.

Keywords: *project, investments, economic development, energy*

INTRODUCTION

Project finance is also known as the structured finance, since it requires such structure of debt and shareholders' equity enabling the cash flow of the project to be adequate to the service of debt.

In practice, the project finance is usually used for capital intensive activities when the ones responsible for a project are the loan insolvent for traditional forms of financing or are not ready to take risks and loan commitments. In the project finance model, total risks of the project are distributed to several partners, and thus risks are decreased to the level acceptable to each partner. [1].

Quantitative methodologies support project finance and include simulation and techniques of finance engineering. They optimize the structure of capital and evaluate financial variability of projects, under risky circumstances, especially when the project implementation is associated to the constructive risk, risk of potential bankruptcy, economic crisis, as well as the other limitations created as a result of lack of capital.

Project finance is such a model of project financing based on the analysis of project justification, since only the projects generating income during the project enabling service of invested funds are regarded acceptable. Therefore, negotiations which follow the project finance should meet the common interests of various parties, thus the anticipated economic profit of each participant is proportional to the risk associated to the project implementation.

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Nelge Switala (2010) points out that establishment of a special project company and predictability of future cash flows are the most prominent characteristics of the project finance. According to this author, there is a serial of other characteristics, such as: conceding all rights of debtors to creditors regarding the project which is being funded; inclusion of so-called "partner" with interest; contract distributes structure of risk among all parties; ban of additional debts; commercial value of project may outlive downfall of one sponsor, supplier, contactor. [2].

Gatti Stefano points out in this regard that the most important characteristics of the project finance are: supervision and money investment with interest and repayment. It seems that the project finance may be defined in the best manner as a method of financing where, when it comes to service of debt and investment profit, the "creditors" investors are exclusively or predominantly focused on cash flows created by the funded project. Essentially, the project finance is based on transfer of risk regarding certain funded project at the expense of the financier [3].

GENESIS OF THEORETICAL FINDINGS OF THE PROJECT FINANCE

With regards to genesis of theoretical findings of the project finance, the financial literature about this issue is still in the initial phase of formation. Analyses of the project finance (assumptions and justifications) are also in the initial phase. Nowadays, the project finance has become a big business in the world. It is also important as a manner of financing economic development in entire world; however, there are very few researches within academic theory and researches of project finance itself. *Worenklen* is one of the theoreticians who left a mark on definition the project finance. This author deems that the project demand, with sources of credit support, has to be put in form of a contract. In more details, *Worenklen* (1981) underlines that in order to attract investors for the new capacities needed in the future, the regulations are to help and to create stability in which the investor expectations will be met. The author proposes a new model of public-private partnership for the poorest countries. Such model, according to this author, will encourage the initiative and creativity of the private sector. [4]. According to *Dasu (Das*, 2006), most of infrastructural projects may be regarded as the greenfield projects [5], since they started as a public-private partnership.

According to *Nevitu* and *Fabozziu*, the term project finance is defined as the project financing where a creditor will be satisfied that service of debt is initially done from cash flows, and later from profit produced by the project [6]. Project finance may be sometimes used to increase invested capital as optimal as possible adjusting the investment and expenditures ensuing from the project itself. They are, in a way, opponents to the concept of project finance, since, according to them, the project finance foresees greater shareholder risks and does not provide convincing reason to use such model of financing. [7]. Under those circumstances, *Smith and Warner*, propose some kind of monitoring for the project finance, since it allows more detailed control to leaders over company management. For Smith and Warnera *(1979) and* Rajan and Wint*er* (1995), monitoring at project finance is very important, since it includes and enables detailed control to leaders over management [3]. *Smith* and *Warner* concretely suggest that by defining hypothesis of shareholders control in a contract may increase value of a company. Hypothesis in the contract should contain prohibitions for companies that have a role of debtors in loan agreements. *Smith* and *Warner* (1979) underline that the public debt is present at project finance, *Berdli* and *Roberts* (2003) say that the project finance contains a private debt, *Kaplan* and *Stromberg* (2003) say that the private capital is essence of the project finance [8].

Shah and *Thakor* (1987) are the first authors who analyzed the project finance for large and highly risky projects. Those two authors claim that the project companies may work in scope of good economic institutions. On the other hand, in the unstable environments, the project companies need to refer not only to the agencies, but also to the other institutions in order to protect their rights. So, according to these authors, the basic motivation is to empirically study potential impact of factors that contribute to efficient management of debt capacity in project companies under circumstances where there is poor institutional environment. [8].

In the world, the project finance is a fast growing field of large capital investments for large and other infrastructural projects. If trends of the project finance growth are followed, it has tendency of growing according to all indicators. That growth is manifested in such a way that there were 541 projects financed with 180 billion USA dollars in total in the world in 2006. This trend was significantly higher in 2010 with 58 projects financed with total 206 billion USA dollars, despite deterioration of economic crisis in that moment. *Vepjatin E*sty was very concrete when indicated that the growth of project finance went from less than 10 billion USA dollars annually in the world during 1980's to almost 220 billion USA dollars in 2001[9]. Contrary to previous theoreticians, *Shep, Kepsinger* and *Martin* (1989) prefer thesis that the project finance is widely used for the low risk projects of medium size [3].

It seems that the fastest growing filed through the project finance model is an investment into energy. Other models that show a growth tendency are the infrastructural projects, not only in developed, but also in developing economies. All of these is aimed to creating the necessary infrastructure to generally improvement the lives of citizens. In the world, the project finance has been successfully implemented in the following sectors: infrastructure, water pipe lines with factories for waste water processing, roads, railways, ports and airports, energy, telecommunications, mining, industry, tourism, public services (schools, hospitals, public lightening, etc.).

Table 1 *Trend of the project finance growth in the world in 2010 (in USA dollars) [10]*

State	Project value	Number of loans
Spain	174 billion of dollars	67
India	52 billion of dollars	131
Australia	14.6 billion of dollars	32

STRUCTURE AND DYNAMICS OF THE PROJECT FINANCE

Structure of project finance represents a combination of debts, investment and loans, where service of debt primarily depends on profit created by the project itself. Project sponsors establish a project company in form of joint venture that will be the owner of funds and manage the project. Project company, not sponsors, borrow the financial funds from banks, needed for the project implementation. Project does not have direct impact on balance of sponsors or their loan credibility. Project finance demands creation of complex framework of internally connected contracts.

Project finance mechanism according to the Bassel regulations in Serbia foresees: financing of power plants, mines, processing industry, oil sources, telecommunications, media and technology; IPRE (Income Producing Real Estate) – refers to loans for construction or purchase of: business and office space, residential buildings, hotels, hypermarkets and shopping malls, complexes of cinemas, technological parks; financing of buildings - includes financing the purchase of movable assets, such as: airplanes, ships, trains, vehicle fleet, satellites; financing of goods - refers to financing the stocks, spare goods in trade, oil, metals, wheat, etc.

Project finance of money is a long term financing of large infrastructural and industrial projects based on the projected cash flow. Project finance structure usually includes a serial of shareholder investors and banks that will provide loans for the project. Very descriptive structure and dynamics of project finance was given by the General Director of Princepation Pacific Group and lecturer at the Euro money institute of Finance *Thomas H. Pule,* who defines a concept of project finance as follows: sponsor is a head, contractors and operators are wings, project company is a body, suppliers and buyers are weapons, and banks are legs. [11].

When the project finance is analyzed, it is significantly different than classic loaning. The main characteristic is that return of invested funds is expected from money profit made by project itself, not by debtor. Success of project depends on success of investment. Classic assessment of debtor's solvency, based on his financial report, does not contribute much when decision is made whether to finance the project or not. In that context, for the sake of project implementation, a new company is established for special purposes, which often does not have any balance or have them insufficiently.

Structure of specific investment project foresees that return is to be made from cash flow created by the project. Examples for such projects are: construction of buildings, mines, factories, roads, gas pipelines, water pipelines, ships, hospitals, schools, etc. Project finance is different than traditional form of financing, because creditors see the funds and cash flows of the project as source for return the inve-sted funds. At the project finance, return of invested funds most frequently does not depend on other property and income of debtors or project sponsors. Risk of debtor oneself is not so relevant as it is at regular loan. Loan analysis is composed of the project effectiveness assessment and project risk identification and management. Center of analysis is a project, not a debtor. A debtor is often a company for special purposes whose exclusive property is a project, and the only source of funds is a loan taken for the project funding. In case of large value projects, the role of creditor is often taken by several banks, so-called syndicated financing. At the project finance, the most important is an investment return period which defines a number of years needed to return the initial investments into project.

CHARACTERISTICS OF THE PROJECT FINANCE IN THE REPUBLIC OF SERBIA

Project finance all over the world, especially with regards to the infrastructural projects, represents large financial investments followed by high level of commercial, political and financial risks. Serbia started its transitional process in economy in 2000. Up to date, the economic, financial and political problems have been reality of the Serbian economy. Under circumstances of modest domestic accumulation, the significant foreign funds were needed for implementation of large investment projects throughout Serbia, as well as high foreign debt which limits the possibilities of direct loan indebtedness of our state that was practically the only source of international financing for these projects so far. On the other hand, the international funding of certain number of priority infrastructural and other investment buildings, with necessary level of commercial profitability, on principles of project finance and various types of partnership between the private and public sector, concessions and other types, would enable their construction without the new loans taken by the state, since the project itself would be indebted, and its property would be a guarantor for the debt. Anyway, an overview of the direct foreign investments in Serbia in the period from 2007 to 2014 indicate that arrival of foreign direct investments may play a key role in economic recovery of the Republic of Serbia, where a significant place may be taken by the model of project finance through concessions, public and private partnership, etc., Table 2.

Table 2 *Direct foreign investments in Serbia 2007 – 2014 (in millions of euros) [15]:*

Year	2007	2008	2009	2010	2011	2012	2013	2014
Direct foreign investments	3,219	2,711	2,100	1,278	3,544	1,009	1,548	1,500

Regarding to the concept of project finance in the Republic of Serbia, it is followed by various types of risks that accompany character of the economy of Serbia. Various techniques of the project finance in the countries of the South-Eastern Europe, with the special emphasis on Serbia, have been applied mainly in the sectors of traffic and energetic. These projects rely on financing in foreign currency and they use technique of project finance, since their outputs are intended for the global market and they make profit in foreign currency. In our country, there are certain market risks that impact the outcome of most of the projects, therefore, the investors decide on the project finance in the sectors where profit may be defined and guaranteed in most of the cases. One of such investments, which is the focus of attention, is construction of the second phase of gas warehouse in Banatski dvor and Srpski Itebej, capacity of billions of cubes of gas. Srbija Gas and Gasprom also consider the construction of co-generative gas plants in Belgrade, Novi Sad, Paracin and Nis.

Serbia started to apply the project finance at the end of 2004, and during 2010 there were less than ten banks that offered such service on the Serbian market. [12]. With regards to this model and manner of servicing, the project finance through loans, banks should be primarily interested in value of the project and whether it is reasonable. When it comes to perspective of the project finance, it may be anticipated that in the incoming period, the domestic banks will start to follow construction and renting of small hotels of middle category in Belgrade, run by the experienced domestic or international management, whose business will service the debt in as short period as possible. One more interesting model or, better to say, future of the project finance are media in Serbia. According to our opinion, the most successful financial institution that was the first one to actively apply the model of project finance in Serbia is the Unicredit Bank. This bank approved a long-term investment loan of 12.7 million euros to the company HVAC Retail d.o.o., for construction the outlet center in Indjija and thus, confirmed that it remains devoted to the Serbian market and development of the local economy despite conditions of changeable economic environment and unstable market circumstances.

Table 3 *The largest projects in Serbia implemented through the project finance in Serbia from 2010 – 2012 [13]*

Project	Investor	Type of project	Year	Value of investment
Zeland, Dedinje	Koling AD	Residential complex, 23000 m^2	2010	35 millions of euros
Stepa Stepanović	Government of the Republic of Serbia	Construction of apartment building complex	2012	112 millions of euros
Outlet Center Indjija	HVAC Indjija	Construction of shopping mall, surface 30000 m^2	2012	24 millions of euros

Nowadays, China is very interesting investor for our country, and it has already started to invest at special targets through several projects. When it comes to potential endeavors in scope of the project finance by the Chinese companies, they will probably be candidates for cooperation with Serbia, being a Balkans country that plans to construct a navigable canal Belgrade - Thessaloniki. Future project sponsors in Serbia are very significant from aspect of economy such is Serbia. Therefore, there is a proposal that if we want to have greater inflow of funds for projects in the future, we need to be more oriented towards banks and sponsors coming from China, India and other countries, since their economic growth in 2014 was 8.2 % in China, and 6.2 % in India [14].

CONCLUSION

Unfortunately, the project finance in Serbia is still in its initial phase, even though we officially started with the project finance in 2005, because we have not reached the standards that would enable a successful implementation. Serbia nowadays lacks those standards, mixture of legal and economic components, which are: upgrading or, better to say, creation of our legal and institutional frameworks with special emphasis on utilization the competences and financial possibilities of our public and private sector, as well as attraction of foreign investments, which were very few since the beginning of 2016. So, the legal, economic and political aspects have a key impact on efficient use the project finance in the Republic of Serbia.

There are a lot of successful examples of the project finance in Europe, and all we need to do is to learn positive lessons from those projects and to understand what their impact on development of those economies was. The basic motive for potential investors in Serbia primarily should be that the capital investment has to be made into those fields where it is certain that profit and income exceed the price of investment. In fact, those are projects associated with the smallest risks, and in our country those are infrastructural projects, as well as investments into renewable energy resources.

Models of project finance with all its shortcomings and advantages should stand behind initiation of investment cycle in Serbia nowadays. Moreover, the economic literature about this filed teach us that utilization of the project finance and its development has an extraordinary importance for economy. What has to be realized about project finance is that we have to approach it with a syntagm that the price of the project is not a market price, but it is always a realistic price and thus, under given circumstances, risks have to be distributed to two, three or more participants, even to the state that should provide the additional guarantees in order to attract serious investors in the future.

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MINING AND METALLURGY INSTITUTE BOR LABORATORY INFORMATION SYSTEM

Abstract

Dozens of samples are analyzed daily in the Sector for Laboratories of the Mining and Metallurgy Institute, based on which the reports of analyses are formed. Former approach to creating of these reports included a manual report design, sample marking and template preparation with Microsoft office tools, which can be time consuming and error prone. Automating these tasks through a software solution became a necessity in order to optimize the reporting process. System includes the automatic report creation, analysis result entry, standard and method record and its assignment to a specific employee. Regular updates would improve the overall picture of a complete laboratory as well as for every individual employee. System uses the "Oracle 11g XE" database, "iReport" ("Jaspersoft Studio) for report design and "Oracle APEX" application design tool, while the application is deployed on the "Glassfish" application server. Necessary hardware consists of quad core processor, 4 GB memory and 500 GB HDD.

***Keywords**: laboratory analysis, Oracle 11g XE, Oracle APEX, iReport, Jaspersoft Studio, Glassfish*

INTRODUCTION

In order to round and complete its activities, the Mining and Metallurgy Institute Bor has owned for many years the modern and accredited laboratories for:

1. Laboratory for Chemical Testing, CTC,
2. Laboratory for Mineral Processing, PMR,
3. Laboratory for Geomechanics and Soil Testing and
4. Laboratory for Electrical Measurements [1].

Every material needs to be analyzed since the useful or harmful trace elements can appear. Analyses are performed using various methods that are defined by specific accredited or non-accredited standards.

Generally speaking, the system that provides such service consists of several tiers:

1. Presentation (client) tier,
2. Logic (application) tier and
3. Database (persistence) tier.

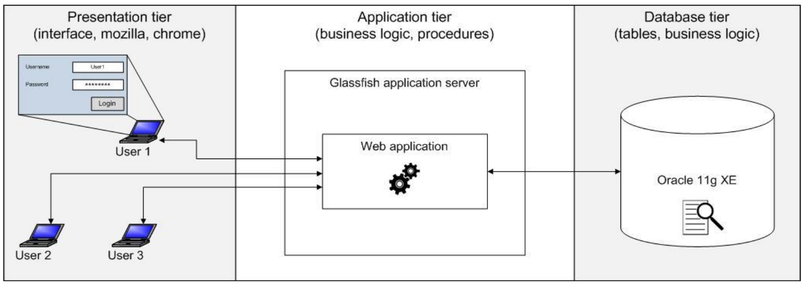

Figure 1 *Multitier architecture*

* *Mining and Metallurgy Institute Bor, IT Department*

Every tier (Figure 1) has its own purpose, but some tasks can be performed on different tiers simultaneously. Presentation tier involves the user interaction with an application using tools like the web browser. Interaction includes the communication establishment with an application and sending it user commands [2].

Logic tier represents an application that is deployed to an application server, in this case the Glassfish. Application processes received data and decides how it will interpret them *(Business logic)* [3]. Communication can be established with database if it's necessary. Let's say that the user enters his password. Application establishes communication with a database where passwords are stored and depending on the interpretation, the user gets an appropriate feedback. Application can perform some of its own checks like number of failed login attempts, or an IP address from which the user is connecting.

Database tier represents the data storage in separate tables which are connected in a meaningful way. Data is extracted from tables and sent back to application. Database, just like an application, can also implement some sort of data checks and constraints. Storage is provided by the Oracle 11g XE database.

PROBLEM OVERVIEW

Current report processing includes the unique sample identification, their analysis, result entry, report printing, archiving in hard copy and sending reports to the clients. This task gets complicated as the amount of job increases. In cases where calculations are needed, Microsoft Excel Macros would be required and after that, a report would be created using Microsoft Word. Standard and method maintenance also requires a special attention since non-accredited standards are maintained separately by every department. It is not uncommon for one standard to be mistakenly defined differently by two or more departments.

SOLUTION

Application can be divided into four logical sections:

1. Reception,
2. Result entry,
3. Administration and
4. Printing.

At the moment, not all features are available since application is still in its test phase. Every employee has its own role and privileges with specific responsibilities. Reception group create templates while technicians enter analysis results based on these templates. Template is first prepared through the sample identification, then forwarded to the technicians for result entry and finally, the chief engineer checks and confirms those results. Idea is that every employee sees standards and reports he is in charge of.

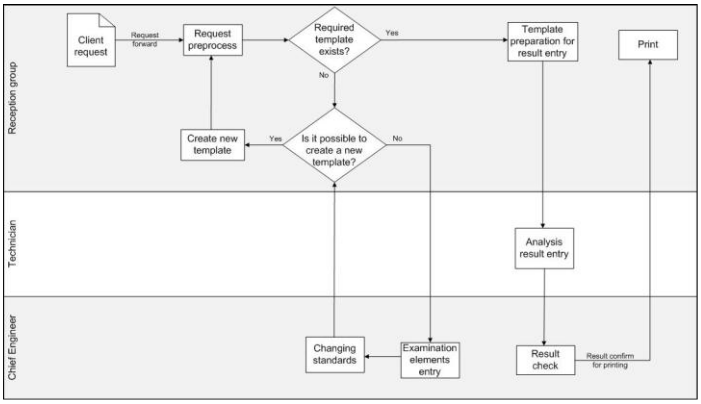

Figure 2 *Simplified report creation process*

1 Data Entry

In order to insert results, the technician needs to wait for necessary template preparation by the receptionist. All requests are forwarded to the reception group for its preprocess which includes the report header definition like the client name, report ID and deadline among other things that should appears on the front page, as shown in Figure 3.


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ПИБ: 100627146 * МБ: 07130279 * Жиро рачун: 150-453-40

РТБ Бор Група
ТИР
Електролиза
Р.Ј. за производњу бакар-сулфата

Датум:
Date: 07.02.2016

ИЗВЕШТАЈ О ИСПИТИВАЊУ бр.195130-544/2016

1. Датум пријема узорка: 04.02.2016
2. Врста / шифра / порекло узорка: Бакар-сулфат -/ Р.Ј. за производњу бакар-сулфата/
3. Посебни услови / допуна / одступања везана за узорковање:
4. Допуне, изузимања, или одступања везана за испитивања: ISS је тренутно у фази промена стандарда за плави камен.

Метода:

EG	електрогравиметрија	СРПС Х.П8.110:1989
G	гравиметрија	СРПС Х.П8.112:1989
G	гравиметрија	СРПС Х.П8.115:1989
V	волуметрија	СРПС Х.П8.113:1989
G	гравиметрија	СРПС Х.П8.114:1989

Извештај припремио:

Управник Лабораторије
за хемијска испитивања

Број јединица:

Достављено:
1 x Архиви Лабораторије за хемијска испитивања
1 x Координатору Лаборатије за хемијска испитивања
1 x Партнер

- Дати резултати се односе само на испитане узорке
- Извештај се не може умножавати без одобрења управника Лаб. за хем. испитивања
- Жалбе и рекламације на наш рад можете упутити директору Института за рударство и металургију
- Број јединица одређивања дефинисан је по важећем ценовнику Лаб. за хем. испити.

Стр 1 од 2

QF-957.104 Насловна страна - Извештај о испитивању Издање обр: 2
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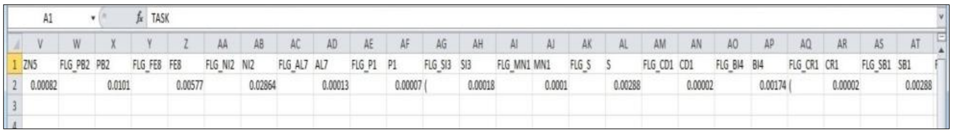
Figure 3 *Front page*

Reports are usually formed in same way, but there are some exceptions like the Geological Reports. Because every client usually requests the same kind of reports, term “*group*” (*template*) is introduced to simplify the reception task. Groups are formed only once and choosing one of them defines a sample with all elements from that group. Samples are labeled and finally forwarded to the technicians for result entry. Elements can be added afterwards if client request differs from predefined group.

Sometimes even technicians do not know how analysis will be performed. In that case, the multiple standards are used and one chosen by the chief engineer can be joined to a specific group. Usually, the results are entered manually in appropriate fields, but in some cases data can be imported from an external source like CSV file (Figure 4). Technician uploads that kind of file for further processing and after that, database enters correct data in the appropriate fields. Elements can be added to the current report by technician, but that element will not appear in any of the predefined group.



A1 TASK

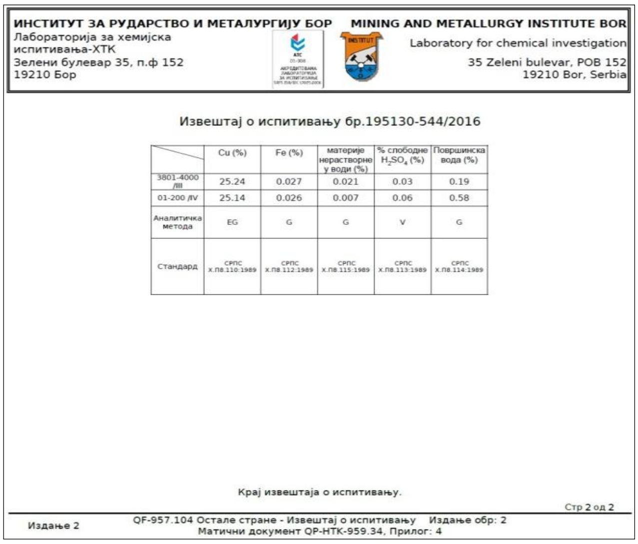
	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN	AO	AP	AQ	AR	AS	AT
1	ZN5	FLG_PB2	PB2	FLG_FE8	FE8	FLG_NI2	NI2	FLG_AL7	AL7	FLG_P1	P1	FLG_SI3	SI3	FLG_MN1	MN1	FLG_S	S	FLG_CD1	CD1	FLG_BI4	BI4	FLG_CR1	CR1	FLG_SB1	SB1
2	0.00082		0.0101		0.00577		0.02864		0.00013		0.00007 (		0.00018		0.0001		0.00288		0.00002		0.00174 (		0.00002		0.00288
3																									

Figure 4 *CSV file*

Chief engineer checks and confirms entered results and signals recipient that report is ready for printing. He also must ensure regular standard updates because they define the analysis method. If any standard needs some sort of modification, like label, element or compound, then chief engineer must carry out that task also. Regular standard updates reduce confusion and conflicts_among other employees since groups are defined using those standards.

2 Results

As stated, the chief engineer signals that reports are ready for printing, while recipient prints and, for the sake of simplicity, marks them as "*printed*". Reports are printed in PDF or RTF format and, if needed, type of reports can be changed since horizontally ordered elements (Figure 5) are sometimes more readable than vertical ones (Figure 6). Unfortunately that is not always the case, and special report design was needed for some reports like geological, as shown in Figure 7. Reports are archived in the paper format, but the recipient can print any report at any time since all data is kept in database. Database backup means a complete database copy, but that is part of the database administrator's job. Backups should be saved on different medium due to the unpredictable server failures.



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	Cu (%)	Fe (%)	материје нерастворне у води (%)	% слободне H_2SO_4 (%)	Површинска вода (%)
3801-4000 /III	25.24	0.027	0.021	0.03	0.19
01-200 /IV	25.14	0.026	0.007	0.06	0.58
Аналитичка метода	EG	G	G	V	G
Стандард	СРПС Х.П8.110:1989	СРПС Х.П8.112:1989	СРПС Х.П8.115:1989	СРПС Х.П8.113:1989	СРПС Х.П8.114:1989

Крај извештаја о испитивању.

Стр 2 од 2

Издање 2 QF-957.104 Остале стране - Извештај о испитивању Издање обр: 2
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Figure 5 *Horizontal result report*

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Извештај о испитивању бр.195130-544/2016

Елементи	3801-4000 /III	01-200 /IV	Метод	Стандард
Cu (%)	25.24	25.14	EG	СРПС Х.П8.110:1989
Fe (%)	0.027	0.026	G	СРПС Х.П8.112:1989
материје нерастворне у води (%)	0.021	0.007	G	СРПС Х.П8.115:1989
% слободне H_2SO_4 (%)	0.03	0.06	V	СРПС Х.П8.113:1989
Површинска вода (%)	0.19	0.58	G	СРПС Х.П8.114:1989

Крај извештаја о испитивању.

Стр 2 од 2

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Figure 6 *Vertical result report*

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Извештај о испитивању бр.195100-31/2015

PB19/14					Анализа	Композит		
Р. бр.	Од	До	Интервал	Број пробе	Cu%	S%	Ag%	Au%
1	158	161.1	3.1		0.65			
2	161.1	162.7	1.6		0.42			
3	162.7	164	1.3		1.03			
4	164	166	2		0.49			
5	166	168	2		0.67			
K	158	168	10			2.23	1.80	0.70
6	168	170	2		0.79			
7	170	171	1		1.01			
8	171	173	2		0.86			
9	173	175	2		0.83			
10	175	177	2		0.55			
K	168	177	9			5.09	3.10	0.40
Аналитичка метода					AAS	S	FA	FA
Стандард					ВМК Е.х.1:1994	*ВМК Е.д.1:	СРПС Б.Г8.473:1981	СРПС Б.Г8.473:1981

Крај извештаја о испитивању.

Стр 2 од 2

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Figure 7 *Geological report*

CONCLUSION

Data centralization makes it suitable for further analysis, but to achieve this, system needs to be maintained constantly. Report backup, part of the system maintenance, is simpler than copying every report in the paper format, which is one of the database advantages. Current system state provides the basic functionality but unfortunately lacks some authorization mechanisms due to the frequent laboratory organizational structure change. It should be noted that beside the Institute, this system can be used in other laboratories as well.

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Journal **MINING AND METALLURGY ENGINEERING BOR** is published four times per a year and publishes the scientific, technical and review paper works. Only original works, not previously published and not simultaneously submitted for publication elsewhere, are accepted for publication in the journal. The papers should be submitted in both, Serbian and English language. The papers are anonymously reviewed by the reviewers after that the editors decided to publish. The submitted work for publication should be prepared according to the instructions below as to be included in the procedure of reviewing. Inadequate prepared manuscripts will be returned to the author for finishing.

Volume and Font size. The work needs to be written on A4 paper (210x297 mm), margins (left, right, upper and bottom) with each 25 mm, in the Microsoft Word later version, font Times New Roman, size 12, with 1.5 line spacing, justified to the left and right margins. It is recommended that the entire manuscript cannot be less than 5 pages and not exceed 10 pages.

Title of Work should be written in capital letters, bold, in Serbian and English. Under the title, the names of authors and institutions where they work are written under the title. The author of work, responsible for correspondence with the editorial staff, must provide his/her e-mail address for contact in a footnote.

Abstract is at the beginning of work and should be up to 200 words, include the aim of the work, the applied methods, the main results and conclusions. The font size is 10, italic.

Key words are listed below abstract. They should be minimum 3 and maximum of 6. The font size is 10, italic.

Basic text. The papers should be written concisely, in understandable style and logical order that, as a rule, including the introductory section with a definition of the aim or problem, a description of the methodology, presentation of the results as well as a discussion of the results with conclusions and implications.

Main titles should be done with the font size 12, bold, all capital letters and aligned with the left margin.

Subtitles are written with the font size 12, bold, aligned to the left margin, large and small letters.

Figure and Tables. Each figure and table must be understandable without reading the text, i.e., must have a serial number, title and legend (explanation of marks, codes, abbreviations, etc.). The text is stated below the figure and above the table. Serial numbers of figures and tables are given in Arabic numbers.

References in the text are referred to in angle brackets, exp. [1, 3]. References are enclosed at the end in the following way:

[1] Willis B. A., Mineral Procesing Technology, Oxford, Pergamon Press, 1979, pg. 35. (for the chapter in a book)

[2] Ernst H., Research Policy, 30 (2001) 143–157. (for the article in a journal)

[3] www: http://www.vanguard.edu/psychology/apa.pdf (for web document)

Specifying the unpublished works is not desirable and, if it is necessary, as much as possible data on the source should be listed.

Acknowledgement is given where appropriate, at the end of the work and should include the name of institution that funded the given results in the work, with the name and number of project, or if the work is derived from the master theses or doctoral dissertation, it should give the name of thesis / dissertation, place, year and faculty where it was defended. Font size is 10, italic.

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