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SUDOP1 SOFTWARE PACKAGE IMPLEMENTATION IN THE DESIGN OF DEWATERING OBJECTS AT THE OPEN LIMESTONE PIT MUTALJ NEAR BEOČIN

Abstract

The open limestone pit Mutalj is located on the southern slopes of Fruška Gora in the northern part of Serbia. Immediately beside the open pit, the Grabovački stream flows which has in its upper flow two artificial accumulations built to protect the settlements located downstream from floods. In relation to the "Lajtovački Limestone" that is in exploitation, a unique karst aquifer was formed and is hydraulically connected with the Grabovac stream and the artificial accumulations. Successful protection of the open pit of Mutalj from being flooded by surface and underground water was accomplished through designing the drainage facilities of proper dimensions that encompasses the floor canals, sumps, pumping station and a settling pond for which the SUDOP1 software package was used. The aforementioned program enables not only better designed objects of surface dewatering, but also provides a checkup of hydraulic functionality the existing drainage objects at the open pit.

Keywords: open pit, surface dewatering, software package, sump, canal

INTRODUCTION

At the open pit "Mutalj" which is a part of the Lafarge company - cement factory of Beočin (LBFC), limestone is exploited which together with the marl from the open pit "Filijala" makes the basis of mixture for cement clinker production.

In the area of the open pit "Mutalj, the limestone is exploited that has a high content of CaCO_3 which is over 96% and known in literature as the "Lajtovacki" limestone". Limestone thickness increases from the north to the south part of the basin. From a hydro-geological aspect these limestones present the largest collectors of underground water in the basin. A karst aquifer was formed in them which is fed from the atmospheric showers that infiltrate through the overlying permeable sediments, made out of loess and clayed graveled

sands, as well as by the flow of temporary and constant surface waters which pour from northwest down the southern slopes of Fruška Gora, forming the Grabovac stream. This stream flows along the west ridge of the open pit "Mutalj" that was regulated by two dams in the mid XX century due to its flooding tendency.

At a part of the stream which passes near the open pit "Mutalj", the stream bed was buried until May 2014 and did not provide efficient and timely dewatering of the excess atmospheric water. Only after the catastrophic rain falls and flooding in May 2014 was the stream bed of the Grabovac stream near the open pit "Mutalj" finally dug up and cleaned.

The karst aquifer that was formed in the reef limestones is drained in the southwest

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DEWATERING CONCEPT

direction, i.e. in the direction that the floor sediments made out of bentonite clay, basalt conglomerates and lake sediments drop and along with some presentations of coal make up the "Vrdnička serija".

The exploitation of limestone has in the past couple of years dropped beneath the level of ground water that was determined through hydro-geological exploration conducted in 2004 and was at the level of around 175 meters altitude. The present lowest level of limestone exploitation in the pit is around 157 meters altitude which is followed by the lowering the level of ground water as a consequence of continuous pumping of water from the floor canals and the main sump and are directed downstream in the Grabovac stream.

Dewatering of the OP Mutalj is continuously done from June 2008 until today. The current dewatering is done through a system of deep drainage canals out of which one is the main water collector into which four transverse drainage canals lead. The canal depth goes from 3-5 m, width is 1.7 m, and total length is 756 m. The main water collection canal goes into a sump that is 20 x 10 m and 4 m deep which is located at the level of 157 meters altitude. Two submersible pumps are placed in the sump: Flygt 2670.180 18 KW and Flygt 2640.180 5.6 KW. The gathered water from the open pit Mutalj are then pumped via thrust pipelines Ø 105 mm into the Grabovac stream. The equipment required for dewatering consists of: pumps, pipelines, distribution boxes, pump powering cables, level-regulators, pump holder, etc.

Figure 1 Situation map of designed dewatering system at the OP Mutalj

The adopted concept of dewatering and protection of the open pit Mutalj from water to the end of designed period of limestone exploitation consists of the following (Figure 1):

- Dewatering will be done through a system of floor canals which are designed to take the maximum influx of surface and outpoured underground water. This water will be gravitationally directed to the main sump which is always located at the lowest point of the pit. At the main sump on a pontoon, a pump will be installed of appropriate characteristics which will pump the gathered water to the settling tank located outside of the pit contour from where the water will be poured in the Grabovac stream.
- It is necessary to conduct a hydro-construction regulation of the

Grabovac stream and build two ridge canals from the east and north side of the pit.

DESIGNING THE DEWATERING FACILITIES

SUDOP1 (Surface Dewatering of Open Pit) software was used to design the facilities of surface dewatering at the OP Mutalj. This program package contains modules for designing of canal, sumps, pumping stations, gravity pipelines and settling tanks and can be used for designing on the new or existing open pits of coal, metallic or non-metallic mineral ore. At the open pits that are exploited, as is the case with OP Mutalj, this program package offers the possibility of verification the existing facilities of dewatering or design the new ones in a function of development the mining operations. The program SUDOP1 was written in the program language Visual Basic 6.0.

Figure 2 Dependence the water influx, drainage capacity and sump volume

The main sump and drainage pump are designed as a single system at the open pit Mutalj. The volume of the main sump is directly dependent on the characteristics of drainage pump. The design of entire system was done based on a rational method, using the methodology of Z. Ljubić, whose basics are given in the book “Dewatering Facilities at the Open Pits” by Prof. Dr Radomir Simić and M.Sc. Vladislav Kecojević (Faculty of Mining and Geology Belgrade, 1997). This methodology of calculation was applied in constructing the SUDOP1 program. Based on the formulae for calculating the maximum sump volume $V_{\max}$, it can be concluded that the volume of sump as well as the time it takes to empty it depend on the capacity of drainage pump, the pump delay time and the rainfall intensity. Dimensions of the main sump and the drainage pump at the OP Mutalj are determined by taking into consideration the influx of surface and underground water and the time it

takes to empty it (Figure 2). For the purpose of designing the bench channels, the sump and drainage pump, precipitation of 50 year return period were considered with 1 h of lasting intensity, i.e. $i = 51.9 \text{ mm/h}$. This information was obtained from the Republic Hydro Meteorological Department of the Republic of Serbia and originates from the main meteorological station of Sremska Mitrovica which is closest to the OP Mutalj. In order to design the dewatering facilities, the entrance data about the influx of underground water into the pit of $\sim 30 \text{ l/s}$ was used. This data was obtained based on the hydro-geological exploration realized in the zone of OP Mutalj in the period from January 2012 to November 2013.

Table 1 displays the program calculated values of maximum volumes of the sump ($V_{\max}$) and the drainage pump capacity (Q_p) for determined emptying time of 120 h for each designed year of exploitation.

Table 1

Year of exploitation	I	II	III	IV	V	Final
Max. sump volume $V_{\max} \text{ (m}^3\text{)}$	6697	6983	6983	7000	7080	7459
Drainage pump capacity $Q_p \text{ (l/s)}$	53.0	55.3	55.3	55.4	56.0	59.0

Hydraulic calculation the permeability of floor and ridge canals of a trapezoid cross section at the OP Mutalj was conducted based on the Chezy-Manning equation which was applied in writing the SUDOP1 program. The program module for canal design which enables determination the optimal canal dimensions depending on hydrological and hydraulic parameters input consists out of five interconnected parts. In the first part of the program module, hydrological data is input, the second part of the program calculates the optimal proportions between the width of canal bottom, the height of canal and the surface of cross section of the canal. In the third part of the program, the material for

canal construction is chosen, and the fourth part of the program enables the parameters of the canal lane to be defined, and the fifth and final part of the program conducts a graphic interpretation, i.e. determines the dependence of canal depth and throughput at certain sections of the canal lane. This paper displays only the calculation for the ridge canal RC-2. Input parameters for design of the ridge canal RC-2 at the OP Mutalj are shown in Table 2.

Calculated dimensions of the ridge canal RC-2 are shown in Table 3, where J- is the drop of canal lane (%), L-is the length of canal lane (m), H-is the depth of canal (m), B-is the width of canal bottom (m), R-is the hydraulic radius (m), U-is the wet

circumference (m), C-is the coefficient which depends on material that insulates the canal, F-is the surface of canal cross section (m^2), V-is the speed at which water runs in the canal (m/s), V_k -volume of the material that is excavated (m^3). Calculated maximum throughput of the ridge canal RC-2 of the full profile is $Q_k = 2.4 m^3/s$ and was

increased by 20% for security reasons. Figure 3 shows a curve which depicts the dependence of depth change (H) and throughput of the canal (Q_k) while the blue lines on abscissa and ordinate of diagram mark the calculated values of the aforementioned parameters for the input ridge canal RC-2 lane drop.

Table 2

Parameter	Unit	Value
Runoff coefficient	-	0.35
Rainfall height	(mm)	58.2
Rainfall duration	(min)	60
Value of flank angle of canal slope	($^{\circ}$)	40
The roughness coefficient according to Basin	-	1.75
Mid drop of canal floor	(%)	0.48
Influx of underground and infiltration water	(l/s)	30
Size of drainage area	(m^2)	350000
Canal length	(m)	176

Figure 3 Dependence diagram of throughput (Q_k) and depth (H) of the ridge canal RC-2

Table 3

Lane number	J (%)	L (m)	H (m)	B (m)	R (m)	U (m)	C (-)	F (m ²)	V (m/s)	Vk (m ³)
1	0.2	53	1.18	0.86	0.59	4.52	26.51	2.65	0.91	141
2	0.8	12	0.92	0.67	0.46	3.54	24.33	1.64	1.48	20
3	0.2	79	1.18	0.86	0.59	4.52	26.51	2.65	0.91	210
4	0.7	14	0.95	0.69	0.47	3.63	24.54	1.71	1.41	24
5	0.5	18	1.0	0.73	0.50	3.85	25.05	1.93	1.25	35

CONCLUSION

Protection of open pits from water influx in the mining industry becomes a great problem in the designing and exploitation stage. The successful designing of drainage systems at the open pits depends on the knowledge about the hydrological, hydro-geological and geomechanical characteristics of immediate and extended zone of the basin. The open pit Mutalj is mostly compromised by the influx of surface water from alluvium of the Grabovac stream and influx of ground water from the "Lajtovacki Limestone" that is in exploitation. The project solution predicts the hydro-construction regulation of the stream bed of the Grabovac stream and construction the ridge and floor canals, sumps, a pumping station and a water tank as the main protection facilities of the OP Mutalj from water. For designing the aforementioned drainage facilities, the software SUDOP1 was used. It consists of programs for designing the gravitational pipelines, canals, sumps and water tanks and pumping station calculations. The SUDOP1 program can also be used for verifying the hydraulic functionality of existing facilities for dewatering and equipment requisition planning.

REFERENCES

- [1] R. Simić, V. Kecojević, Dewatering Facilities at the Open Pits, Mining and Geology Faculty Belgrade, 1997 (in Serbian)
- [2] R. Simić, V. Kecojević, Z. Teodorović, Introduction to Information Systems for the Purpose of Dewatering the Open Coal Pits, Mining and Geology Faculty Belgrade, 1998 (in Serbian)
- [3] M. Ignjatović, M. Miljković, Mining Hydro-Technics, Copper Institute Bor, 2004 (in Serbian)
- [4] V. Čanović, B. Jovanović, B. Babović, Technical Dewatering Project of the Open Pit Mutalj - I Stage (Book IV DMP for the Open Pit Mutalj), Mining Institute Belgrade, 2015 (in Serbian)