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DRAINAGE PUMP STATION OF THE DAM 4-1 – VELIKI KRIVELJ[**]

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Abstract

The paper presents the hydraulic calculation of pipelines and selection the pumping units for hydrotransport of drainage water of the Dam 4-1 from the planned well on the dam to the tailing dump.

Keywords: *hydraulic calculation, pumping station, borehole pump*

1 INTRODUCTION

The Veliki Krivelj tailing dump is a valley-type tailing dump and occupies space in the former bed of the Kriveljska river. The village Oštrelj is downstream from the tailing dump, and upstream is a conveyor system for waste transport from the Krivelj mine to the old open pit Bor and Veliki Krivelj open pit mine.

From the beginning of its work in 1982 until 1989, the Veliki Krivelj Flotation Plant disposed tailings in the old tailing dump - Field 1. The Field 1 was created by closing the valley of the Kriveljska river with two barrier sand dams, upstream the Dam 1 and downstream the Dam 2. In order to evacuate the water of the Kriveljske river, a tunnel was constructed through the original terrain, from the left bank of the river. The length of the Ø3 m diameter tunnel is 1414 m.

In 1990, the tailing dump was expanded downstream, occupying the additional space in the bed of the Kriveljska river – the new tailing dump or Field 2. To contour the new tailing dump, it was enough to build only one dam – the Dam 3. A collector with a diameter of 3 m and length of 2075 m was constructed at the bottom of the Kriveljska river bed for water drainage waters of the Kriveljska river, which is a continuation of the existing tunnel. Due to the problems with the collector itself, its rehabilitation was carried out on a length of 621 m initia-

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lly, which was extended to a total of 700 m during 2010 and 2011. The repaired part of the collector is located under the body of the Dam 3 and starts about 200 m from the outlet of the collector. The rehabilitation was carried out by installing a reinforced concrete ring with a thickness of 40 cm. The light opening on the repaired part of the collector has been reduced to 2.2 m. The other main facilities of the tailing dump are: Dam 1, Dam 2, Dam 3, Dam 4-1, facilities for diversion of the Kriveljska river, safety overflow body in the Field 2, Revision Well in the Field 0, tailings supply system to the tailing dump and return water system from the tailing dump to the pool above the Old Flotation Plant and pool above the New Flotation Plant.

Figure 1 *Layout of the tailing dump of the Flotation Plant Veliki Krivelj*

Due to a lack of free storage space in the Field 1 and its filling over the designed height by more than 3 m, the exploitation of the new Field 0 began in the spring of 2021 and then the drainage system of the Dam 4-1 begins to function in full with the well with borehole pumps.

In order to drain the Dam 4-1, the construction of a drainage system is planned, which includes the construction of a well in which two borehole pumps will be installed, one as the working pump and the other as a reserve. The pumping station is designed for a flow of 30 l/s. A steel pipeline with flanges is placed inside the well, and connection with the plastic HDPE pipeline is made outside the well, after the steel pipe joint, as shown in Figure 1.

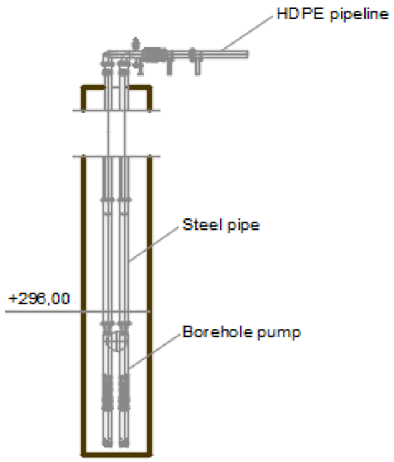

Figure 2 *Cross section of the well*

The pipeline is laid along the edge of the dam, then over the crown of the dam to the place where it flows into the lake at a distance from the dam. It is planned to lay the pipeline in a trench measuring 400x600 mm and then cover with material to protect it from the external effects. In this way, the water will be prevented from freezing in the pipes in case the pumps are out of operation in a period of extremely low temperatures. In the Phase I, the HDPE pipeline crosses the dam at an elevation of +340 and is 900 m long and, in the Phase II, it should cross the dam at an elevation of +393 and is 950 m long.

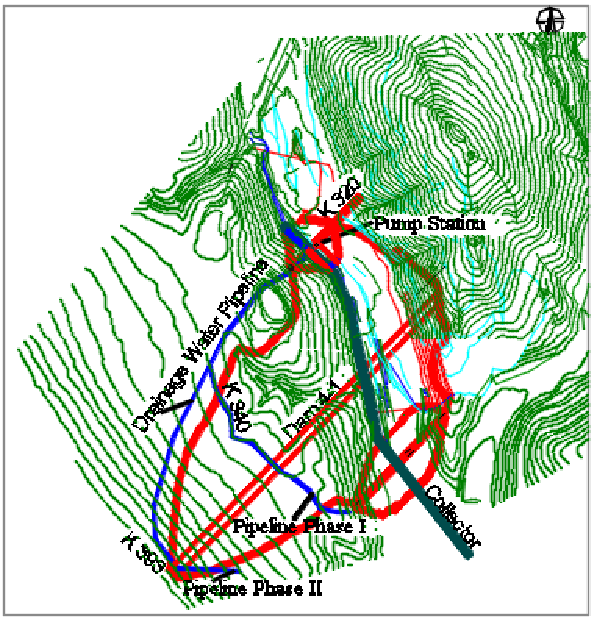

Figure 3 *Layout of the Dam 4-1*

2 CALCULATION

Dam drainage water pump in the station 4-1 (elevation of the pipeline crossing over the crown of the dam + 393)

Initial data:

- Amount of drainage water:
- Q_v=108 [m^3/h]
- Elevation of water level in the drainage well K+296 [m]
- Elevation of outflow of drainage water into tailings: K+393 [m]
- Pipeline length in the Phase II: L2=950 [m]

HDPE pipeline DN 180 (L=950m):

Fluid transport speed:

- $Q_v = 108$ [m^3/h] Fluid flow
- D=0.1472 [m] Internal diameter of the pipeline
- $\upsilon = \frac{4 \cdot Q_v}{3600 \cdot D^2 \cdot \pi} = 1.763\ [\frac{m}{s}]$ Fluid speed
- $L = 950$ [m] Pipeline length
- $C = 130$ Coef. of conditions of the inner surface of pipe
- $i_f = (\frac{Q_v}{3600 \cdot 0.27854 \cdot C \cdot D^{2.63}})^{\frac{1}{0.54}} = 0.02\ [\frac{m}{m}]$ Hazen-Wiliams [3]
- $\sum h_i$ =19.2 [m] Line losses

Total head loss:

H_1=393 Elevation of the dam pass

H2=296 Elevation of the water level in the drainage well

$H_{g=}393 – 296=97$ [m]

$H_{man} = H_g + \sum hi = 116.2$ [m]

The total pressure [2] drop is:

ρ =1000 [kg/m^3] Water density

g= 9.81 [m/s^2] Gravitational acceleration

$\Delta P_= \rho \cdot g \cdot H_{man}$=11,4 $\cdot 10^5$ [Pa]

The total power of the motor to drive the pump: [2]

$$P_{em} = \frac{Q_v \cdot \Delta P_2}{1000 \cdot \mu_p \cdot \mu_m \cdot 3600} = 45.4\ [kW]$$

$\mu p = 0.81$ Efficiency of the pump

$\mu m = 0.93$ Efficiency of the electric-motor

Borehole pump with 52 kW electric-motor (similar to LOWARA Z8 125 7- L8W)

Water Hammer [1]:

- Fluid flow Qv=108 [m^3/h]
- Static head Hg=97 [m]
- Internal diameter of pipe Dn=147.2 [mm]
- Wall thickness of pipe δ=16.4 [mm]
- Elasticity modulus of water E_w=20700 [daN/cm^2]
- Elasticity mo0dulus of pipe Ep=$11\cdot 10^3$ [daN/cm^2]

Fluid density: $\rho = \frac{\gamma}{g} = \frac{0{,}001}{9{,}81}$ dN/ s^2/ cm^4

Celerity of pressure wave: [1]

$$a = \sqrt{\frac{Ew}{\rho\cdot(\frac{Dn}{\delta}\cdot\frac{Ew}{E\check{c}}+1)}} = \sqrt{\frac{20700}{\frac{0{,}001}{981}\cdot(\frac{147.2}{16.4}\cdot\frac{20700}{11\cdot10^3}+1)}} = 336.9 \text{ [m/s]}$$

The propagation time of water hammer:

$$T = \frac{2\cdot L}{a} = \frac{2\cdot 950}{336{,}9} = 5.64 \text{ [s]}$$

When stopping the pump, there is a change in speed from v_1 = 1.76 [m/s] to v_0 = 0 [m/s], so $\Delta v =$ 1.76 [m/s] which creates the water hammer:

$$\max P_1 = \pm (v_1 - v_0)\cdot\frac{\gamma\cdot a_{sr}}{g} = \pm 1.76\cdot\frac{0.001\cdot 336.9\cdot 10^5}{9.81} = \pm\ 6.05 \text{ [bar]}$$

The initial hydrostatic pressure is 97 [m], so the pressure at the pumping station is:

$$abs_{max} = \frac{H_g}{10} + maxP_1 = 9.7 + 6.054 = 15.75\ [bar]$$

$$abs_{min} = \frac{H_g}{10} - maxP_1 = 9.7 - 6.054 = 3.65\ [bar]$$

Based on these values, the armature was dimensioned for the nominal pressure value of 16 bar.

Polyethylene pipeline HDPE 100 DN 180 SDR 11 for the working pressure of 16 bar is adopted.

3 CONCLUSION

Based on the proposed solution, a drainage system was built and put into operation in 2019.

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