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Professional paper

DETERMINATION OF THE CROSS SECTION OF NEW KRIVELJ'S RIVER TUNNEL

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Abstract: New Krivelj's river tunnel will be made through very bad surrounding for production and stability of the premises, both, during development and for the period of use.
During the construction of underground objects in weak environment, in this case the future tunnel (collector), it is necessary to pay attention to the process of creating and supporting. Shape of hydraulic tunnel cross section depends on several factors, among which are: the static condition of tunnelling linings, hydraulic working conditions of the tunnel and conditions under which will be constructed
Criteria for defining the final cross section of the tunnel, which will meet all requirements, will be presented in this paper.

Key words: Krivelj's river tunnel, cross section of the object

1. INTRODUCTION

Necessity for creation a new Krivelj's river tunnel was caused by poor condition of the existing Krivelj's river collector. Its construction would be partly through the flotation tailing dump, and partly through rock massif (Figure 1). The new tunnel will regulate the flow of the Krivelj's river, because today's flow may be interrupted by breach of the old Krivelj's river collector.

Along the tunnel route, Figure 1, field investigation drilling was carried out with the aim of determination rock material.

The following works have been done:

- Research drilling with coring;
- Detailed engineering-geological core mapping;
- Selection of representative samples of each isolated lithological unit, marking, conservation and delivering samples to the Mining and Metallurgy Institute laboratory;
- Determination of rock mass cracking and dividing of received core (RQD).

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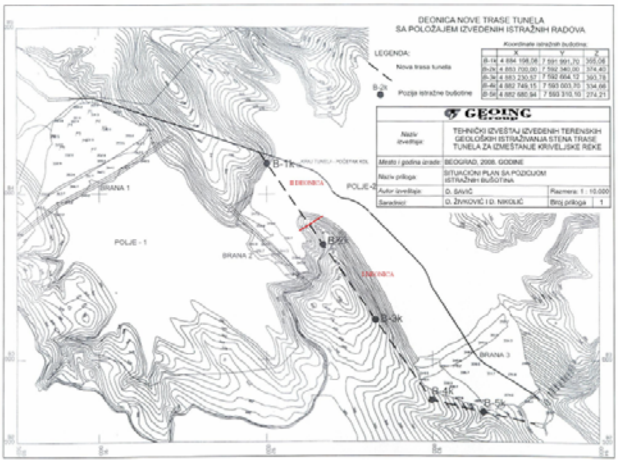

Figure 1 – New Krivelj's river tunnel route

2. NEW KRIVELJ'S RIVER TUNNEL CREATING

Proposed new route for Krivelj's river tunnel (Figure 1) would be in the length of about 2530 m. Tunnel would be made from altitude K+246 (in contact with the Krivelj's river, out of tailing dump) to K+272, with ascent of 1% (to the circuit with the old tunnel).

Making of the tunnel would be done by ascent, because of the excavation works drainage, and it will be divided into two parts:

1. **I phase -** making would be from its future out, along the Krivelj's river, with ascent of 1%, to K+267, in the total length of about 2000 m (Figure 1). Making of the tunnel would be through the weak rock environment, with a constant inflow of water.
2. **II phase -** will be from the end of the first phase to the circuit section of the old tunnel. The length of these shares would be around 500 m, and from K+267, to K+272. Make these shares would be through flotation tailing dump, Field 2, and partly by former river's alluvium.

For creating tunnel on this part, due to very weak environment, it is necessary to apply special methods to obtain adequate durability and safety

3. HYDROTECHNICAL TUNNELS

Depending on the water pressure in the tunnel, these tunnels may be ***tunnel under pressure*** or ***gravitational tunnel.***

If in storage basin comes to significant changes in the amount of water, which may be caused by different factors, for example, occasionally filling the reservoir, then taking the water should be from greater depths. In such cases, derivative tunnels carried out the water under increased pressure. This kind of tunnel calls ***tunnel under pressure.***

It is possible to make a capture of water from the upper layers, if the reservoir level is constant, or with some fluctuations. In such cases, the water in the tunnel is not under pressure and the tunnel is called the gravitational tunnel (the new Krivelj's river tunnel).

Besides those derivative hydrotechnical tunnels, tunnels for streams and river implementations are also of great importance. Those tunnels are made as a gravitational tunnels

3.1. Cross-section forms of hydrotechnical tunnel

A cross-section form of hydrotechnical tunnel depends on several factors, among which are:

- Static conditions of the cover;
- Hydraulic conditions of the tunnel and
- Conditions of the tunnel production.

Hydrotechnical cover of the tunnel has to be so dimensioned that has the smallest volume, and at the same time has ability to support internal and external pressures without deformations. Besides all this, it has to be waterproof.

According to the hydraulic work, the form of cross section should provide the greatest flow in a certain fall and the lowest cross section. High camera shape, circular and horse–shoe shape are the best shapes that satisfied these conditions (Figure 2).

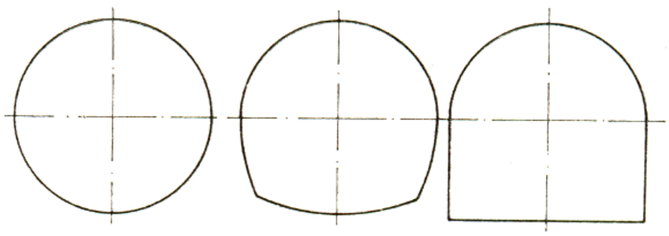

Figure 2 - Types of free section of the hydrotechnical tunnel

Taking care of all influential factors, the forms choice of tunnel cross-section still prevails hydrotechnical condition related to lining static work. Given the priority that has a circular form, the static and hydraulic conditions, the disadvantages related to compensate for the advantages of the previous two conditions.

3.2. The size of the free cross section

The size of the free cross section of the hydrotechnical tunnel determined on the basis of conditions (gravitational regime or a regime under pressure), cross-section shape and quantity of water that should be free to provide a profile. In determining the size of the free cross section, it is necessary to comply with a request to which a tunnel must be so dimensioned that has required pass, in particular the fall and the smallest surface cross-section.

For these reasons, as the different working conditions, it is necessary to specifically consider the problem of dimensioning of the system under pressure and in particular for gravitational system

3.3. Dimensioning gravitational tunnel

Previously, it has been emphasized that the best forms of cross-section of the hydrotechnical tunnel are the forms that have the smallest hydraulic resistance, such as circular, high camera shape and horse–shoe shape.

Roughness coefficient values η for gravitational tunnels, will be shown in Table 1..

According to Pernat, for gravitational tunnels, it is necessary that the water level in the tunnel is something less than the height of the tunnel, considering the formation of waves, and should be within the range of:

$$1.7 \cdot r \leq t \leq 1.85 \cdot r \tag{1}$$

Where:
r – half of the maximum width;
t – high of the tunnel filling.

Figure 3 shows high camera and horse–shoe shape form with the dimensions of which fulfill all the necessary hydraulic requirements, according to Pernat

Gap power of hydrotechnical tunnel can be calculated by the pattern of Forhaymer:

$$Q = 1/n \cdot \omega \cdot R^{0.7} \cdot I^{0.5} \tag{2}$$

Where:
n – roughness coefficient according to Gangy-Kutter, (Table 1);
ω – cross-section free area, under the water [m^2];
R – hydraulic radius;
I – tunnel bottom decrease.

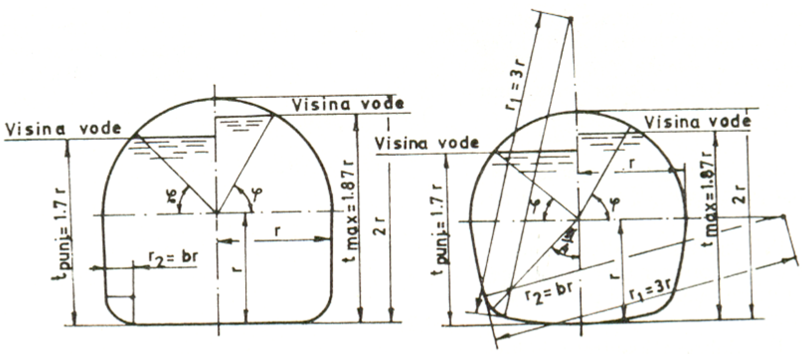

Figure 3 – Optimal forms of hydrotechnical tunnel (according to Pernat)

This general form for the transference of hydrotechnical tunnel (2) has refined by Pernat specifically for the calculation capacity of the gravitational tunnel:

Table 1 - Values of the roughness coefficient η for gravitational tunnels

<table>
<tr><th rowspan="2">Type num.</th><th rowspan="2">Characteristics of lead</th><th colspan="3">Value for η</th><th rowspan="2">Note</th></tr>
<tr><th>secondary</th><th>largest</th><th>smallest</th></tr>
<tr><td rowspan="3">1.</td><td colspan="5">Gravitational tunnels in unmarked rock</td></tr>
<tr><td>a) Gravitational tunnels under conditions of medium-leveled walls with persistent removal of rocks</td><td>0.030</td><td>0.038</td><td>0.038</td><td rowspan="2">1) Conditions are given individual because the values are given only for orientation

2) Reduce sediment deposition of roughness coefficients</td></tr>
<tr><td>b) Gravitational tunnels under unfavorable conditions; very uneven surface of the rock, a little more outbreak from projected profile</td><td>0.040</td><td>0.045</td><td>-</td></tr>
<tr><td rowspan="3">2.</td><td colspan="5">Gravitational tunnels in the partially mortared rock</td></tr>
<tr><td>a) During gunite or mortaring of rock, without making groove in the bottom of the section</td><td>0.030</td><td>0.022</td><td>-</td><td rowspan="2"></td></tr>
<tr><td>b) During groove creating in the bottom of the section and partial rendering</td><td>0.023</td><td>-</td><td>0.019</td></tr>
<tr><td rowspan="3">3.</td><td colspan="5">Gravitational tunnels fitted with plain concrete coverings without rendering and ironing</td></tr>
<tr><td>a) Smooth concrete that comes with good planning of shuttering, without the persistent and hole</td><td>0.014</td><td>0.015</td><td>0.013</td><td rowspan="2">1) Conditions are given individual because the values are given only for orientation

2) If there is moss (no drift) roughness coefficient increase for 0.002</td></tr>
<tr><td>b) Roughness concrete that bears the traces of self shuttering (recess, trace fiber) due to poor shuttering contact boards, and type 3-a when sand and gravel are settling on the bottom of the shuttering</td><td>0.016</td><td>0.018</td><td>0.015</td></tr>
<tr><td rowspan="3">4.</td><td colspan="5">Gravitational tunnel with the process, plastered or polished concrete surface</td></tr>
<tr><td>a) By high quality works from the surface of plastered cement mortar and polished</td><td>0.011</td><td>-</td><td>0.010</td><td rowspan="2"></td></tr>
<tr><td>b) When good quality work surface is mirror and flattened, connectors are polished</td><td>0.012</td><td>0.013</td><td>0.011</td></tr>
<tr><td rowspan="4">5.</td><td colspan="5">Gravitational tunnels with concrete lining area</td></tr>
<tr><td>a) During the careful cleaning with steel wire brush and careful polishing</td><td>0.013</td><td>0.015</td><td>0.012</td><td rowspan="3"></td></tr>
<tr><td>b) During cleaning with steel wire brush and prevention for creating "edges" between the concrete and gunite-mortaring surface</td><td>0.018</td><td>-</td><td>0.016</td></tr>
<tr><td>c) Gunite-plain concrete without any special measures</td><td>0.019</td><td>0.023</td><td>-</td></tr>
</table>

$$Q = P \cdot 1/n \cdot r^{2.7} \cdot I^{0.5} \tag{3}$$

Where:

P - coefficient, which depends on the values of *t*/*r* (ratio of charge and half width of the tunnel) - (Figure 3).

This form allows determine the half width of the tunnel *r*, on the basis of which can make the dimensioning of the profile. This is possible only with knowing the other values in the form.

For the purpose of calculation simplification, nomogram was made, where is possible to calculate a pure cross-section and half width of the tunnel *r*.

This nomogram is made only for high camera and horse–shoe shape of tunnel.

In Figure 4 is shown a key for the nomogram with two examples.

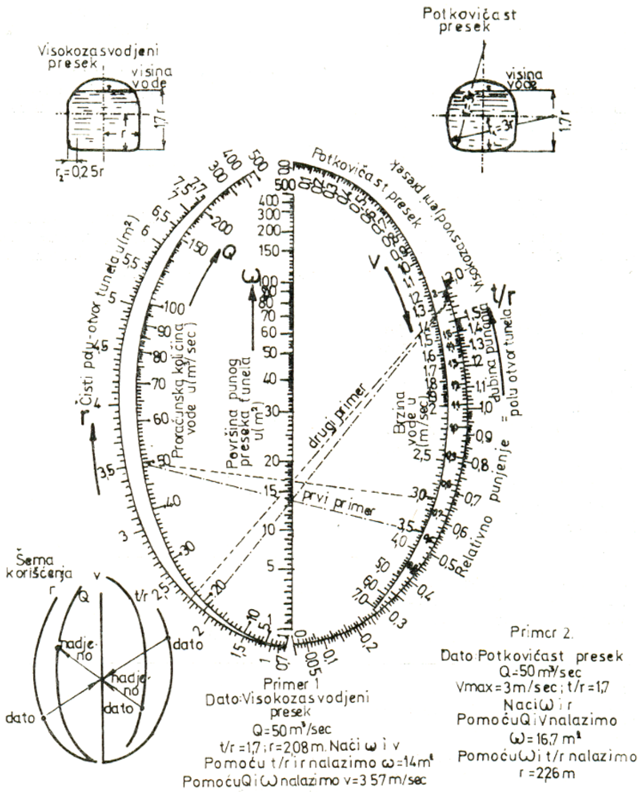

Figure 4 - Nomogram for determining the half-section hydrotechnical gravitational tunnels

4. CONCLUSION

Pursuant to the foregoing paragraphs it can be said that the choice of cross-section forms for the Krivelj's river tunnel need more detailed analysis, which will resulted with the optimal existence of this corridor.

Circular cross section has been adopted as the most adequate solution. Its diameter is 3 m, as the diameter of an existing Krivelj's river tunnel.

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