The use of low-head waterpower developments in making cargo passages through lowland rivers

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Abstract

The article is devoted to the problems of making cargo passages through low-head waterpower developments (those built in XX century in Central Russia). The paper presents an analysis of layout and structural properties of these passages which go through phreatic and concrete dams and through river-run power plants. The paper stresses the importance of these cargo passages for transport connection both at the time when hydraulic engineering structures were being built and nowadays. The research also points out the problems in cargo passages operation and explains why these problems occur. Motor highways through the biggest hydroelectric power stations of the Volga are taken as an example. The author offers some efficient technical solutions for making cargo passages through lowland rivers more effective.

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1. Introduction

The Volga river basin is the largest and the most important in the central region of the Russian Federation (see Fig. 1). It occupies approximately one third of the European part of Russia [1]. The basin is formed by the Volga which is the longest river in Europe. In the middle of the XX century the largest hydraulic engineering structures in the country were built on the Volga river. They are Cheboksarskaya, Kuibyshevskaya, Saratovskaya and Volgogradskaya hydraulic engineering structures (mentioned in downstream order). These structures have been
effectively used as multipurpose waterworks units for middle and low streamflow control [2-6]. The most important economic value of these hydraulic engineering structures lies in their ability to generate electric power in industrial-scale quantities [7-9]. Particular attention here is paid to reliability of counterfort hydrotechnical structures [10-18].

These complex water power developments were built to solve many problems, to provide cargo passages across the Volga among them. Such counterfort hydrotechnical structures are built to block a river flow, so it was a cost-effective solution to use them as cargo passages. The paper presents an analysis of layout and structural properties of these cargo passages which go through low-head waterpower developments (those built in XX century in Central Russia) both at the time when these hydraulic engineering structures were being built and nowadays.

2. Research

All these low-head water power developments have quite long phreatic dams with cargo passage built right on dam crests. The hydraulic engineering structures under analysis were built in similar conditions and were taken into use chronologically, one after another (see Table 1). However, different methods of building cargo passages on these structures were used.

Kuibyshevskiy water power development was the first to be built. Its phreatic dam was made with the help of hydraulic fill method. So its profile is flat. The M5 federal highway (Moscow – Chelyabinsk) and the railway between Togliatti and Zhigulevsk were built through this low-head waterpower development.

This federal-aid highway starts on the left bank of the river, goes through the downstream end of lock, then through the water front of the phreatic dam, through the supercharger dam (which is approximately 1000 m long),
and through the earth-fill dam (which is about 2800 m long) (see Fig. 2). After that the highway runs down the crest of the earth-fill dam (from 59.5 to 56.5 m level) and goes along the hydraulic engineering structure main building (which is about 700 m long). The highway at this section goes above the box-like tail-water conduit adjoining draft tubes of the hydraulic engineering structure power room (these tubes are used as an erosion protection surcharge) and at last reaches the right bank of the river. The railway is set parallel to the highway along almost the full length of the waterfront. The railway is set on a special bridge near the hydraulic engineering structure main building. The bridge is built on the power room support reinforced-concrete structures close to the switchboard room of the hydraulic engineering structure upstream wall [19].

Table 1. The Volga hydraulic engineering structures construction time.

<table>
<thead>
<tr>
<th>№</th>
<th>Hydraulic engineering structure</th>
<th>Construction works began</th>
<th>Hydropower unit set to work</th>
<th>Design head of turbine, m</th>
<th>Phreatic dam length, m</th>
<th>Phreatic dam max height, m</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Kuibyshevskaya</td>
<td>1950</td>
<td>1955-1957</td>
<td>22.5</td>
<td>2800</td>
<td>52</td>
</tr>
<tr>
<td>2</td>
<td>Volgogradskaya</td>
<td>1952</td>
<td>1958-1961</td>
<td>20.0</td>
<td>3250</td>
<td>47</td>
</tr>
<tr>
<td>3</td>
<td>Saratovskaya</td>
<td>1956</td>
<td>1967-1970</td>
<td>9.7</td>
<td>1260</td>
<td>40</td>
</tr>
<tr>
<td>4</td>
<td>Cheboksarskaya</td>
<td>1968</td>
<td>1980-1986</td>
<td>18.9</td>
<td>3375</td>
<td>42</td>
</tr>
</tbody>
</table>

During the period when this duel highway was being built and in later years the road was extremely important for the national economy as it was the only means of connecting the central part of the country with the Urals region.

The similar cargo passages were built later on Volgogradskaya and Saratovskaya hydraulic engineering structures. On Volgogradskiy water power development the phreatic dam was also made with the help of hydraulic fill method. The R226 motorway (Volgograd – Volzhskiy) going through the dam is also a duel motorway.

On Saratovskiy water power development the duel highway connects Balakovo and Shirokiy Buerak. But as far as this hydraulic engineering structure is situated comparatively far from the city of Saratov, there is also a bridge across the Volga there connecting Saratov and Engels. This three-lane bridge was set to work in 1965 (the same year with the Saratov hydraulic engineering structure).

Nowadays these cargo passages have been in use for many years, and new problems have developed. Three main problems we have to face today are as follows: their undercapacity (according to preset-day requirements),
additional loading negative effect on the phreatic dam, juridical and economic problems connected with the fact that these structures are used both as hydraulic engineering developments and federal-aid highways.

There are different ways now that are used to cope with the growing traffic stream and capacity growth of these structures. Kuibyshevskaya hydraulic engineering structure was reconstructed in 2009, its duel highway being expanded to four-lines both on the phreatic dam itself (see Fig. 2) and on the bridge going through the concrete supercharger dam (see Fig. 3).

Nowadays it is also urgent to provide opportunities for freight traffic growth in Samarskaya region. It might be cost-efficient and effective to build a specially designed 3700 m motorway bridge across the Volga river (across the Kuibyshevskoe water storage basin in particular) 27 km upstream the Kuibyshevskaya hydraulic engineering
structure and the city of Togliatti, near Klimovsk Village. This bridge project design (as well as the 100 km road approaching it) is to be completed in 2015.

There is a different way of dealing with these problems in Volgograd. The first section of the new 7100 m bridge connecting Volgograd with Krasnoslobodskoy and Sredneakhtubinskoy districts has been built downstream the hydraulic engineering structure and has already been set into use. The second section of the bridge with another duel motorway is being built at the moment (see Fig 5).

![New motorway bridge in Volgograd](www.volganet.ru, available on-line, 2015.03.18).

There is a new 2300 m Saratovskiy motorway bridge built in Saratov (15 km upstream the old bridge) with 12700 m approaching roads. The second section of the four-line by-pass belt highway (round Saratov and Engels) was set to use in 2009. It connects Pristannoye Village and Shumeyka Village.

Cheboksarskaya hydraulic engineering structure was built later when the structures mentioned above, so the highway had a new design taking into account traffic prospective development. This is a four-lane highway. It seems that the highway lay-out and design was more important than that of main water-retaining structures, such as the supercharger dam and the power room (see Fig. 6).

Figure 6 shows that the highway runs above all the water-retaining structures being almost straight-line. It also has well-balanced height and width characteristics. This highway has all the necessary qualities required from modern motorways and satisfies the needs of the region.
3. Conclusions

The research yielded the following conclusions:

- The largest hydraulic engineering structures in Russia (Cheboksarskaya, Kuibyshevskaya, Saratovskaya and Volgogradskaya) were built in 1950-1970 of the XX century on the longest and most affluent Volga river. Being multipurpose waterworks units, they also successfully performed the function of cargo passages across the Volga;
- In the later years new approaches and design solutions of building passages which go through phreatic and concrete dams and through river-run power plants appeared. Cheboksarskaya hydraulic engineering structure was built later when the structures mentioned above, so its highway has a new design which takes into account traffic prospective development;
- Nowadays these cargo passages across the Volga river have been in use for many years, and new problems have developed. The main problem we have to face today is the highways traffic undercapacity. The problem can be solved if we take into account regional peculiarities, motorways condition and freight traffic requirements;
- The article takes the Volga river basin as an example and shows that the most effective way of increasing highway traffic capability is to build new modern cargo passages through lowland rivers as well as new roads approaching these passages.

References
