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EVALUATION OF THE ENVIRONMENTAL SAFETY OF SMALL KAZBEGI HPP BY CONSIDERING THE ACTION OF DEVDORAK GLACIER FORMED IN THE BED OF THE RIVER KABAKHI (GEORGIA)

Aiming at assessing the environmental safety of small Kazbegi HPP, we have described the catastrophic-scale mudflow formed as a result of movement of Devdorak glacier in the Gorge of the river Kabakhi (left tributary of the river Tergi) on May 17, 2014, having inflicted significant damage to the hydraulic works of Kazbegi HPP. With the purpose of securing the environmental safety of small Kazbegi HPP and regulating the erosive-mudflow processes inter alia, the performance reliability and risk of breakdown of a new springboard-type structure by considering the dynamic and static loads of the mudflow were specified.

Keywords: **small HPP, rivers Tergi and Kabakhi, Devdorak glacier, erosion, mudflow**

INTRODUCTION

The world practice has evidenced that using small hydropower plants in the hydraulic power industry is one of the principal alternative and optimal solutions of high dams having less environmental loads on the natural landscape. By considering the above-mentioned, let us consider the evaluation of the environmental safety of small Kazbegi HPP project.

The small Kazbegi HPP project envisages the construction and operation of a 6 MW hydropower plant across the river Brolistskali on the territory of Kazbegi municipality. The duration of construction is approximately 9 months. After putting the HPP into operation, the electrical power generated by the plant will be integrated in the power system of the region and totally realized on the local market what will promote the social-economic development of the region.

The HPP headworks will be located across the river Brolistskali, with the water edge level at 1563.4 m (height difference of 256.6 m).

The headworks is a low-head concrete dam with a submerged grate water-intake gallery (of a Tyrol type) with the estimated water intake of 2.9 m^3/sec.

The water from the water-intake gallery flows into a single-chamber discontinuous-flow settling basin with the length of 43.2 m and width of 7.4 m. A steel main HPP penstock with the total length of 1108 m starts from the settling basin laid in a closed trench branching as two 25-metre-long turbine pipelines in the immediate vicinity of the HPP. The water treated in the HPP turbines will flow into the river Brolistskali through a closed conductive channel. Figure 1 shows the plan of the territories of the HPP structure and open electricity-generating sub-station.

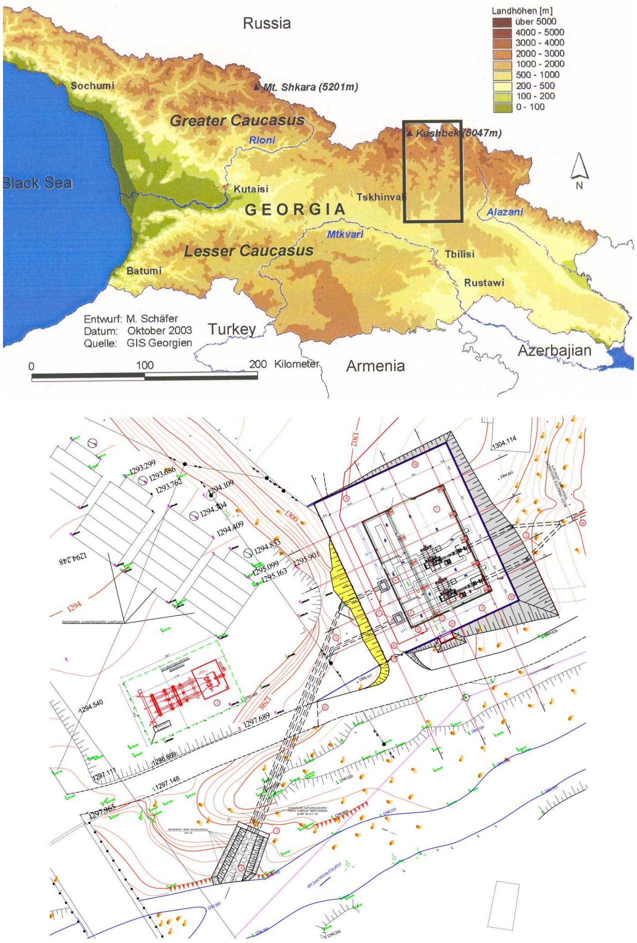

Fig. 1. HPP plan (Scale 1:200)

1. DESCRIPTION OF GEOLOGICAL HAZARDS

The major hazard in the study field (Stepanstminda, former Kazbegi) municipality) is mudflows common in the whole area of the municipality. Formation of the mudflows in the area is promoted by great inclination of the relief and large amounts of weathered and talus material accumulated at the tops of the gorges.

The mudflows pose a danger to the settled areas and military road, main gas pipeline and local village roads. Activation of mudflow processes is expected in the gorges of Devdorak-Amali, Kistinka, Kuro, Kabarjina, Bidara and Truso. The landslide processes are of a limited distribution.

The corridor of Kazbegi HPP has a complex relief and it crosses erosive, periodically active gullies. Development of clear landslide processes along the route is not expected. Mostly, gravitational and collapse-and-demolition processes, linear erosion due to the water currents along the slope and structural mudflows with the periodically active gullies crossing the route are expected. Demolitions over the terrace running in the vicinity of the riverbed due to water impact are likely [1].

2. EVALUATION OF ENVIRONMENTAL SAFETY

Due to the recent global warming on the Earth, the climate on some continents has drastically changed, marked with more frequent freshets and floods caused by intense rains, activated glacier thawing process, etc. Following the above-mentioned climatic changes, the frequency of erosive-landslide and mudflow processes of a glacial genesis has increased what poses a significant threat to the population, while the safe operation of transport and power corridors and power facilities are also at risk and the country economy suffers a certain loss. Figure 2 shows the catastrophic-scale mudflow formed as a result of movement of Devdorak glacier in the gorge of the river Kabakhi (left tributary of the river Tergi) on May 17, 2014, having inflicted significant damage to the hydraulic works of Kazbegi HPP. 7 people perished and 7÷10 mln m^3 of the drifted mudflow mass blocked the Tergi riverbed, thus forming so called natural barrier with the height of 20÷30 m, and the length of the artificial pond reached 200 to 300 m.

Fig. 2. General view of the hydrotehcnical structure of Kazbegi HPP being constructed in the Gorge of river Tergi as a result of the mudflow formation (17.05.2014)

Following the established surroundings, it is without a doubt that the ecological balance in the water catch basin of the river Tergi is disturbed and in case of deteriorated climatic conditions (as a result of intense rains), a new strong mudflow may form at any time.

We think that by considering the above-mentioned, an urgent detailed study of the reasons for the mudflow in the water catch basin of the mudflow-prone river Kabakhi, assessment and forecasting of the risk-factors in the basin and development of the efficient and resource-saving anti-mudflow measures is necessary to protect the environmental safety of the population, power facilities, and transport and power corridors of the trans-border countries (Russia, Georgia, Armenia, Azerbaijan) [3].

Aiming at securing the environmental safety of small Kazbegi HPP, including regulating the erosive-mudflow processes, the new springboard-type structures with their know-how approved by relevant copyrights are highly advisable. Under the influence of the maximum parameters of a mudflow, the new anti-mudflow springboard-type structures are subject to both, current dynamic load and static load of the mudflow mass [2].

Proceeding from the design scheme of the structure, the value of the force (F_d) of the dynamic impact acting on the structure and the statical load (W_s) caused by the weight of debris flow fractions accumulated in its headrace should be determined in the first place; then, using this value, the value of the summary force (F_s) acting on the structure is calculated [2].

The value of the dynamic force of the impact F_d acting on the anti- debris flow structure is calculated with the following dependence [2, 4]:

$$F_d = 4.5\rho\omega V_{max}^2 \sin\alpha \quad [\text{N/m}^2] \tag{1}$$

where: ρ - the debris flow density, ω - the area of action on the structure, V_{max} - the maximum velocity of the debris flow, $\sin\alpha$ - is the angle between the slopes and anti-debris flow structure.

The static load caused by the weight of sediments acting on the anti- debris flow structure is equal to [2]:

$$W_s = 0.5\gamma B\left[H_1\left(l_{st}^2 - H_1^2\right) + 2 l_{st} h\right] \quad [\text{N/m}^2] \tag{2}$$

The sum of formulas (1) and (2) is the value of the maximum force (F_s) of the impact of the debris flow on the structure [2]:

$$F_s = 4.5\rho\varpi V^2 \cdot \sin\alpha + 0.5\gamma B\left[H_1\left(l_{st}^2 - H_1^2\right) + 2 l_{st} h\right] \quad [\text{N/m}^2] \tag{3}$$

where: ρ - the density of debris flow mass [n/m^3]: ω - the area of the structure, which is under load; V - average velocity of debris flow (m/s); α - the bending angle of the structure; γ - the specific weight of the structure, l_{st} - the length of the structure [m], H_1 - the height of the debris flow mass on the surface of the structure [m], h - the depth of the debris flow (m), B - the width of the debris flow [m].

Reliability of springboard type of anti-debris flow before filling up of debris flow mass (W_p - statical load) of head water of construction was [5]:

$$P_1(W_p) = \int_0^1 f(W_p)dW_p = \int_0^{0.61} 2.857e^{-2.857W_p} dW_p = 0.825 \tag{4}$$

The risk of construction fail (R_1) in case of weight load of debris flow mass equal:

$$R_1 = 1 - P_1(W_p) = 1 - 0.825 = 0.175 \tag{5}$$

The dynamic force (F_i) shock dissemination of debris flow in springboard-type of anti-debris flow is:

$$f(F_i) = 0.0023_{exp}(-0.0023F_i) \tag{6}$$

Reliability of anti-debris flow construction in consideration of dynamic force equal:

$$P_2(F_i) = \int_0^1 f(F_i)dF_i = \int_0^{0.61} 0.0023e - 0.0023dF_i = 0.928 \tag{7}$$

The fail risk of type of springboard form of arched and stepped anti-debris flow' buildings, in consideration of on construction force of dynamic shock of debris flow equal:

$$R_2 = 1 - P_2(F_i) = 1 - 0.928 = 0.072 \tag{8}$$

In nature, in case of influence debris flow on building, parallel pass as well dynamic as operation of static force, the refore in case of simultaneously events total reliability of building (P_0) equal:

$$P_0 = P_1(W_p) \cdot P_2(F_i) = 0.825 \cdot 0.928 = 0.766 \tag{9}$$

But risk of building fail (R_0) in case of simultaneously events equal:

$$R_0 = 1 - P_0 = 1 - 0.766 = 0.234 \tag{10}$$

CONCLUSION

- Aiming at assessing the environmental safety of small Kazbegi HPP, we have considered the catastrophic-scale mudflow formed as a result of movement of Devdorak glacier in the gorge of the river Kabakhi (left tributary of the river Tergi) on May 17, 2014.

- Aiming at securing the environmental safety of small Kazbegi HPP, the scales of geological hazards were assessed in the bed of the river Kabakhi and the relevant preventive measures were identified.
- Aiming at efficiently regulating the erosive-mudflow processes formed in the bed of the river Kabakhi, the performance reliability and risk of breakdown of a new springboard-type facilities by considering the dynamic and static loads of the mudflow is identified.

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OCENA BEZPIECZEŃSTWA ŚRODOWISKOWEGO ELEKTROWNI WODNEJ KAZBEGI BIORĄC POD UWAGĘ DZIAŁANIE LAWINY MIESZANEJ POWSTAŁEJ NA RZECE KABAKHI (GRUZJA) SPŁYWAJĄCEJ Z LODOWCA DEVDORAK

Mające na uwadze ocenę bezpieczeństwa środowiskowego małej elektrowni wodnej Kazbegi opisano katastroficzną skalę lawiny mieszanej utworzonej w wyniku przemieszczania się lodowca Devdorak w Gruzji w wąwozie rzeki Kabakhi (lewy dopływ rzeki Tergi) 17 maja 2014, która spowodowała znaczne uszkodzenia w elektrowni Kazbegi. W celu zapewnienia bezpieczeństwa środowiskowego elektrowni Kazbegi i regulacji procesu powstawania lawin między innymi określono niezawodność i ryzyko wystąpienia awarii nowego typu konstrukcji przy uwzględnieniu dynamicznych i statycznych obciążeń od lawiny mieszanej.

Słowa kluczowe: **małe elektrownie wodne, rzeka Tergi i Kabakhi, lodowiec Devdorak, erozja, lawina mieszana**