

ANALYSIS OF THE RISKS ASSOCIATED WITH THE EFFECTS OF A LANDSLIDE IN THE RESERVOIR

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INTRODUCTION

Around the world, reservoirs are important hydraulic structures that play a vital role in hydroelectric power generation, irrigation, drinking water supply, and water resource management. Ensuring the reliability and safety of such structures is a pressing concern, as they are exposed to various natural and human-induced factors. One of these is landslide activity occurring in the vicinity of the reservoir.

Landslides on the dam banks or adjacent mountain slopes cause large quantities of rock material to fall into the reservoir. In such cases, strong waves form in the water, sometimes reaching heights of several dozen meters. As a result, the dam is subjected to excessive hydrodynamic pressure, or a wave may overtop it, jeopardizing its structural stability and, in the event of failure, endangering downstream settlements. Agricultural lands downstream could be flooded on a large scale [4], [5].

Cases are known worldwide where landslides have generated large waves in reservoirs. For example, in 1963, a massive landslide at the Vajont Dam in Italy generated a wave that flooded the dam and caused catastrophic damage. For this reason, the identification, assessment, and prediction of risks associated with landslides at reservoirs is one of the most important scientific challenges in the field of hydraulic engineering [6].

The Impact of Landslide Processes on the Safety of Reservoirs

Landslides are a natural geological process characterized by the downward movement of rock or soil masses along a slope under the influence of their own weight [2]. The main causes of landslides near reservoirs include:

- the geological structure of the rock formations;
- the steepness of the slopes;
- the presence of groundwater;
- the amount of precipitation;
- seismic influences;
- frequent fluctuations in the reservoir water level.

After the construction of the reservoir, the hydrogeological conditions on the slopes may change. Fluctuations in the water level lead to the saturation of the rock and a reduction in its strength properties. This, in turn, triggers landslide processes [4].

The entry of a landslide into a body of water leads to the following dangerous processes:

1. The formation of shock waves. When the landslide mass enters the water at high speed, it generates waves with considerable energy [1]. These waves spread across the reservoir and strike the banks and the dam.

2. Dam overtopping. If the height of the generated wave exceeds the dam's free overflow height, water can flow over the crest. This is extremely dangerous for earthen dams [4].

3. Erosion of the banks. Strong waves intensify erosion processes along the reservoir's banks and can contribute to the formation of new landslides.

4. A sharp rise in water level. Large-scale landslides can cause a rapid rise in water level in a reservoir [6].

For this reason, landslides are considered one of the key risk factors that must be taken into account in the operation of reservoirs.

Characteristics of waves generated by a landslide

When a landslide enters a body of water, its potential and kinetic energy are transferred to the aquatic environment, resulting in high-amplitude shock waves [1].

The waves generated by a landslide depend in many ways on the following parameters:

- the volume of the landslide;
- the velocity of the landslide mass;
- the water depth;
- the angle of the landslide slope;
- the geometric parameters of the body of water.

Shock waves typically have a large amplitude and decay over time.

Studies show that the height of the wave generated by a landslide is directly related to the speed and volume of the landslide. The higher the speed of the landslide, the greater the wave height [1].

In addition, water depth is also an important factor. Waves generated in a deep water basin can propagate over long distances, but their amplitude gradually decreases [3].

A wave striking a dam is carried further up the dam slope by the large volume of water following it, and such processes can lead to a dam breach [4].

Methods for assessing the risks associated with landslides

The assessment of landslides is crucial for ensuring the safety of reservoirs. Various scientific approaches are used for this purpose:

1. Geological-geomorphological analysis. This method examines the composition of rock formations, the joint system, and the stability of slopes in the reservoir area.

2. Mathematical modeling. The movement of the landslide and its interaction with the aquatic environment are assessed using mathematical models [1], [2]. These models account for parameters such as the landslide's velocity, mass, and water depth.

3. Laboratory experiments. The parameters of the waves generated by a landslide are studied using small-scale hydraulic models [1].

4. Numerical modeling. Using modern computational methods, the processes of debris flow and wave propagation are simulated in computer models [6].

These methods are used to determine the probable maximum wave height acting on the dam and to assess the dam's safety.

CONCLUSION

Landslide processes observed near reservoirs are one of the key natural factors affecting the safety of hydraulic structures. The mass movement of rock into the reservoir leads to the formation of high-energy waves in the water that propagate across the reservoir's surface; dams and bank reinforcements may consequently be subjected to additional stresses.

The interaction between the landslide and the water body is characterized by complex hydrodynamic processes. In this context, the movement parameters of the landslide, the water depth, and the geometric properties of the reservoir are decisive for the generation and propagation of waves. Therefore, the scientific investigation and assessment of such processes is one of the key tasks in ensuring the safety of hydraulic structures.

The identification and assessment of landslide hazards are of crucial importance for the planning and operation of reservoirs. Through modern scientific approaches, including mathematical modeling, experimental research, and engineering analyses, it is possible to assess the potential consequences of such hazards and develop measures aimed at mitigating their negative impacts.

To ensure the safety of reservoirs, a thorough investigation of landslide processes is therefore essential. The development of scientific research aimed at a thorough investigation of landslide processes, the identification of their interaction mechanisms with the aquatic environment, and the reliable assessment of wave parameters is of great importance.

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