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Risk Management in Rubber Dam Construction Projects: A Case Study in Galeshklam Rubber Dam, Guilan

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Abstract

Risk management in construction projects, particularly in dam construction, has gained increasing global importance due to the significant impact of risks on project time, cost, and quality. This study employed a questionnaire-based survey targeting project managers, engineers from contracting companies, and specialists from client organizations to identify and analyze 37 potential risks associated with rubber dam construction projects. Using probability (P) and impact (I) values to calculate the dimensionless P×I metric, 11 major risks with P×I ≥ 0.28 were highlighted, with financial issues such as inflation, price increases, and lack of continuous funding being the most critical. Risk response strategies, including acceptance, transfer, avoidance, and mitigation, were applied, and continuous monitoring and control provided positive feedback, helping to minimize negative impacts. The study concludes that effective planning, stakeholder coordination, and proactive risk management during implementation are essential for supporting project managers in addressing critical areas and ensuring the successful delivery of rubber dam projects.

Keywords: Galeshklam rubber dam, Risk identification, Risk management.

1 | Introduction

Risk is inevitable in any project. Risk can be manageable, transferable, or acceptable [1]. Still, it cannot be ignored because the consequences of risk directly affect the approved time, cost, and quality of the project and can lead to failure to implement it properly and on time, as well as excessive losses for one of the stakeholders [2]. No project is risk-free [3]. The earlier risks are identified in the project life cycle, the more

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realistic the project plans and expectations for outcomes will be [4]. Dam construction and operation projects always face a set of technical, economic, environmental, and social risks [5].

In general, research on risk management in construction projects has widely accepted standard frameworks such as ISO 31000 and risk management models based on the identification, assessment, response, and monitoring cycle [6]. At the level of construction projects, qualitative (risk matrix, SWOT analysis, expert groups) and quantitative (decision tree analysis, Monte Carlo simulation, network/Bayesian models) approaches each have advantages and limitations;

Therefore, recent research recommends using hybrid approaches to cover multidimensional risks. Rubber dams, due to their structural characteristics—the flexibility of the rubber membrane, the high-performance dependence on installation and sealing quality, and sensitivity to material wear and aging—pose specific risks that distinguish them from concrete and earth dams [7].

The most important associated risks include: membrane failure (rupture, fatigue), leakage and scour in foundations and connections, improper operation of valves and hydraulic systems, effects of flooding and collisions with floating objects, and risks associated with the supply and maintenance of external materials and equipment (such as pumps, wind systems, and pressure control). In addition, environmental risks (impacts on river ecosystems and aquatic animal migration) and social risks (resistance from local communities, compensation issues) have been repeatedly reported in rubber dam case studies. Risk assessment methods that have been used in dam and water project studies include FMEA/FMECA for failure mode analysis, probability-consequence analysis (risk matrix), probabilistic modeling (Monte Carlo), Bayesian networks for integrating uncertainty and dependencies, and data-driven methods for periodic performance monitoring (condition monitoring + structural health indicators).

Recent research emphasizes the importance of knowledge transfer from contractors, the development of preventive maintenance programs, and the use of online monitoring systems to reduce performance risk [8]. Despite the available resources, there are a few specific gaps that are notable for the Galeshklam rubber dam case study:

I. Lack of regional studies that incorporate Gilan-specific climatic, hydrological, and geotechnical factors into risk models;

II. Lack of long-term monitoring data on membrane and rubber dam joint performance in humid climate conditions.

III. Need for integrated frameworks that model technical risks along with environmental and social consequences; and

IV. The need to examine economic-technical control strategies (e.g., cost-benefit analysis for preventive maintenance versus repair after failure [9].

Therefore, a case study in Galeshklam can both fill scientific gaps and provide practical guidance for risk management in similar rubber dams by collecting local data, employing quantitative methods (e.g., Monte Carlo or Bayesian networks), and conducting FMEA analysis and field monitoring [10].

2 | Construction of Rubber Dams

Construction and civil engineering work are generally carried out in the dry season. The conditions prevailing in the wet season are not suitable for carrying out these works. To facilitate excavation, foundation construction, and river diversion, it is best to carefully plan the sequence and flow of the work. An ideal approach is to use the existing channel to divert river water to the lake and adjacent ponds. If such ideal conditions do not exist, a temporary cofferdam is constructed to divert the water downstream of the dam. River diversion is also accomplished by constructing an embankment upstream of the dam and installing a water pipe beneath it. The river water at the dam site is directed downstream through the water pipe.

Additionally, on a wide river, dam construction can begin by diverting water from one side to the other. Once the dam foundation is complete on one side, a portion of the dam body can be placed on it. The river water is then diverted to this side so that construction of the dam foundation can begin on the other side. Where river water flows over the dam body, to rest on the completed dam foundation on the other side of the river (while foundation construction is underway on the other side).

Before placing the dam foundation, it is better to remove excess material so that the foundation is placed on sound material. The foundation settlement affects the height of the rubber dam crest, which is also an important parameter for the dam's proper functioning. In addition, reinforced concrete is used to prevent various possible leaks that could cause the dam body to rupture. It is best to use a loading test or other test methods to assess the foundation's resistance to applied forces. A smooth foundation surface helps reduce wear on the dam body during vibration. The retaining screws should be properly positioned to ensure the dam body surface is seated properly. Otherwise, improperly positioned screws may have catastrophic effects on the entire rubber dam project (*Fig. 1*).

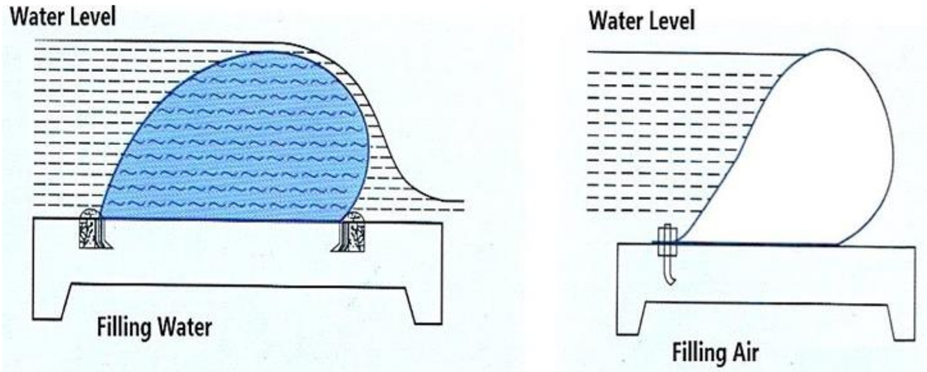

Fig. 1. Location of rubber bolts in rubber dams in two states filled with water and air.

The high-strength concrete floor and bedplate are installed to prevent damage from water washing the riverbed and the embankments. In addition, sediment accumulation on or near the dam, which adversely affects the dam during swelling, causes damage to it. Sediment traps are therefore essential for the proper functioning of the dam. To facilitate regular de-sedimentation, vehicle access from the riverbed to the bottom of the sediment trap should be provided. The body of the rubber dam is a membrane of rubber fibers, consisting of a combination of synthetic layers and layers of reinforced synthetic fibers, firmly bonded together by welding.

When a rubber bag is made, quality control must be carried out throughout the coating, assembly, and gluing processes. Unevenness and local defects can lead to bag failure. If the bag is to be transported to the dam site after completion, there is no truck or container suitable for the dimensions of a large bag, so the bag must be glued on site. Special attention should be paid to the quality of management, as unfavorable conditions (humidity and dust) at the dam site can adversely affect adhesion.

Before being transported from the factory to the dam site, the rubber bag should be carefully wrapped around a pipe and packaged to prevent any damage or deformation. It is best to protect the bag and its associated parts from corrosion, mechanical damage, and deterioration during transportation and in the workshop warehouse before construction. Installing a rubber dam is simple and can be done quickly. Easy, fast installation is one of the advantages of a rubber dam compared to other hydraulic structures, such as steel gates, concrete dams, and rock and earth dams. With an experienced team, its installation can be completed in one day. As mentioned, the inflation and deflation of rubber dams is done by electronic devices in the control room. An air blower or water pump and auxiliary devices, such as a valve, are used to fill the dam with air or water in their own order.

There are three types of emptying systems: bucket, float, and electric. For the bucket type, when the downstream water reaches the desired height to empty the dam, the water flow falls into the bucket. As soon as the water collapses, the outlet pipe opens, and the dam body is emptied. For the electric type, a sensor detects the water level. When the upstream water level reaches the desired emptying height, the outlet pipe opens automatically (*Fig. 2*).

For the floating type, a floating body oscillates up and down on the water surface. When the upstream height reaches the desired emptying height, the outlet pipe opens automatically. An air outlet tank can be used as a safety device for the air-filled dam. When the dam's emptying mechanism malfunctions or the internal air pressure exceeds the maximum design pressure, air is released from the dam body. For a water-filled dam, a siphon pipe can be used for safety when the emptying mechanism malfunctions or when the internal water pressure exceeds the maximum design pressure.

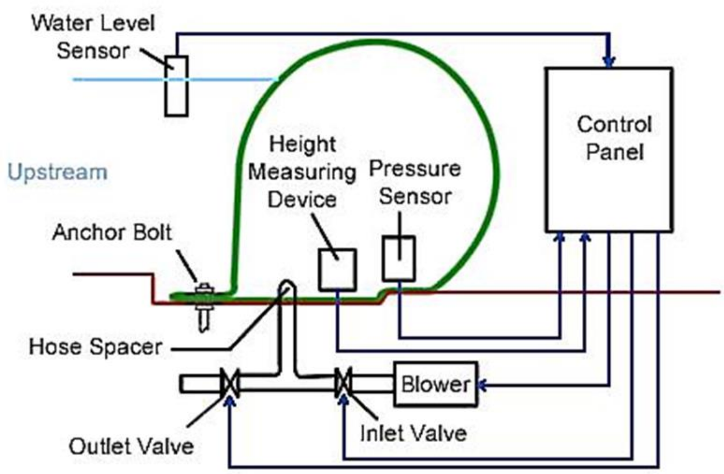

Fig. 2. General diagram of the electrical control device in rubber dams.

Air is often used more than water to fill a dam for the following reasons:

I. Water, trash, and debris carried by water can cause pipes to rust and clog.

II. Dams filled with air are easier to design and build.

III. Water-filled dams require a more complex piping system and often require a reservoir to store water for filling the dams when the river level is low.

IV. The inflation and deflation time of an air-filled dam is much shorter than that of a water-filled dam.

V. Due to the weight of the water, a dam filled with water has a hunched, squat shape and requires more rubber than an air-filled dam of the same height.

VI. 6. The perimeter of a water-filled dam is about 4.8 times its height, compared to 3.5 times for an air-filled dam.

VII. To coordinate the dam body, the foundation of a water-filled dam must be wider than an air-filled dam of the same height.

Although air-filled dams are less stable and vibrate more than water-filled dams, they are preferred in many hydraulic situations.

3 | Applications, Advantages, and Disadvantages of Rubber Dams

Access to hydraulic structures is important for the development of water resources technology from an environmental and economic perspective. Continued advances in technology enable rubber dams to be used in a wide range of water resources management applications.

3.1 | Dam Security and Flood Control

A major advantage of a rubber dam is that it can be lowered quickly to prevent flooding in nearby areas once the water level rises above a predetermined level. The rubber dam, when in the lying position, does not obstruct the free flow of water and allows flood flow to pass without raising the water level upstream. itprevents damage to upstream properties. It is also an effective method for dam security and flood control, without sacrificing water storage, and can be used for multiple purposes.

3.2 | Increase Water Storage Capacity and Electricity Output

In concrete dams or steel gates, there is a trade-off between the appropriate spillway capacity and the required water storage. Rubber dams can also increase water storage capacity by using existing or new reservoirs without reducing spillway capacity. For example, in a hydroelectric power station, the height of a rubber dam installed on a spillway can be continuously adjusted to maintain the maximum allowable water head for generating electricity without causing flooding upstream. In contrast, a flashboard can be raised as soon as the flow recedes. It increases the power output by retaining more water. The rubber dam can also reduce downstream water levels and increase power output by capturing overflow directly from the power station. In addition, debris and ice can pass over the spillway without adversely affecting the power generation equipment. Rubber dams can also maintain a stable water level, allowing ice to form and preventing the formation of brittle ice that could block the debris trap at the reservoir inlet.

3.3 | Reducing River Sediment Problems

The increase in riverbed height due to high sedimentation capacity significantly increases the risk of flooding. For example, in the lower reaches of the Yellow River in China, the riverbed rises by an average of 50-100 mm per year. Frequent floods in this region have caused millions of deaths and significant financial losses. Heavy sedimentation rapidly reduces the river's reservoir storage capacity. The average annual sediment accumulation rate (the volume of accumulation above the reservoir storage capacity) for large and medium-sized reservoirs is 2% to 3%.

Canal systems in the lower reaches of the river, used for irrigation and urban and industrial water supply, are affected by severe sedimentation, reducing their water supply.

Rubber dams can help address some of the problems mentioned regarding sedimentation. On the one hand, when rubber dams are partially or completely emptied, they allow water to pass through. On the other hand, the sedimentary deposits behind the dam are removed as they empty. By constructing channels upstream of the rubber dam, the sedimentary deposits are directed to the calm pond. In addition, rubber dams can be installed at the channel entrance. Dams can be emptied regularly to allow sediment accumulations to pass from above the dam into the channel, thereby directing the accumulations directly into the stilling ponds.

Like wide-crowned weirs, rubber dams can be much more efficient than concrete dams and steel gates. They do not suffer from the many sedimentation problems that plague steel gates and other hydraulic structures. Rubber dams can also be used for siltation. Rigid dams, such as rock and earth dams, prevent the movement of aquatic plants and mosses, bran, and floating woody plants along the flood path, which require a large number of workers and a lot of time to remove, which can be easily solved by emptying the rubber dam.

In 1985, two rubber dams were installed at both ends of a sedimentation pond in Henan Province, China. Each dam has three openings, each 1.5 m high and 10 m long, which can operate independently. Sediment and debris are carried into the sedimentation ponds through partial subsidence. The sediments in the pond are then pumped to nearby areas by a high-pressure pumping system for permanent desalination. These sediments can be used as fertilizer to fertilize nearby agricultural lands.

3.4 | Galeshklam Rubber Dam on the Shalmanroud River

Considering the negative effects of water withdrawal from the Shalmanroud River during the agricultural seasons on the water level of this river and the return of sea water to the Shalmanroud River, as well as considering the characteristics stated for rubber dams, the construction of the Galeshklam rubber dam was underway in the village of Galeshklam, 2 kilometers from the river's confluence with the sea (*Table 1*).

Table 1. Water levels before and after the construction of the rubber dam.

Level Surface	Desired Location
-28	Sea level
-27.5	The level of the Shalmanroud River before the construction of the dam
-30	River bed level at the construction site
-27.5	Level surface on the dam platform
-25	Flat surface on the tire
-26.5	The level of the Shalmanroud River after the construction of the dam

By operating this project, the need for farmers in 9 downstream villages for agricultural water will be fully met, and the return of seawater to the Shalmanroud River will also be prevented. Below are pictures of this dam under construction. (*Fig. 3* and *4*)

Fig. 3. Dam under construction.

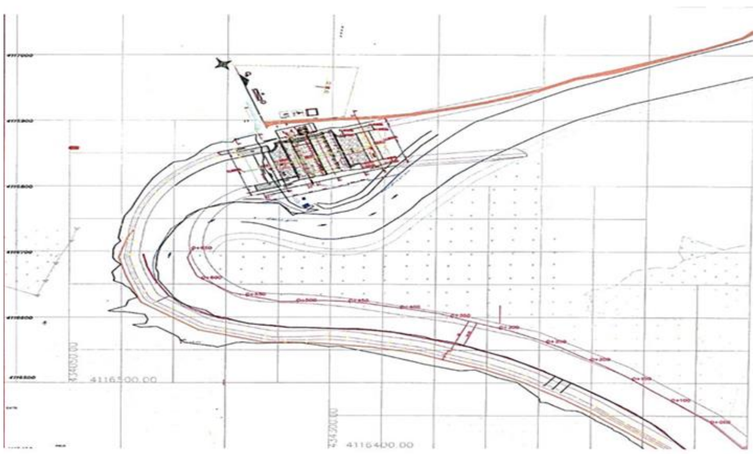

Fig. 4. Dam under construction.

4 | Conclusion

In the present study, all risk management steps were implemented and executed in accordance with the PMBOK standard, using the rubber dam method. Given the importance of the issue of risk, identifying risks and managing them, these studies can be considered a suitable guide for other construction projects, and all stages of risk management can be implemented on other construction projects, such as bridge construction, tunnel construction, etc., that will be carried out in the future. Considering the importance of risk, the following research can be considered in the future:

I. Implementing risk management based on other risk management models in these types of projects.

II. Comparing the results obtained from other models with the PMBOK model in rubber dam construction projects.

III. Case study on other rubber dams and implementation of risk management models, which will lead to better and more theoretical results in the field of construction of these dams.

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