PROCEDURE FOR DETERMINING THE CAUSE OF RIVERBANK PROTECTION INCIDENTS IN VIETNAM

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(Received: September 04, 2024; Revised: September 24, 2024; Accepted: October 15, 2024)

DOI: 10.31130/ud-jst.2024.530E

Abstract - The main goal of this research is to describe the scientific process for identifying the causes of incidents in riverbank protection works in Vietnam. The process is carried out in main steps, including establishing an investigation team with appropriate expertise, conducting field surveys, collecting documents related to design and construction, and performing technical analysis experiments. Each stage in the process plays an essential role in clarifying the factors leading to incidents, from direct causes such as excessive currents, to indirect causes such as design errors or incorrect construction. The research proposes solutions to enhance the works' quality and longevity based on the data gathered and analyzed, which helps to minimize the risk of damage and prevent such occurrences in the future.

Key words - Investigation procedure; Riverbank protection incident; Site survey; Data collection; Assessing the causes

1. Introduction

The importance of riverbank protection works is more emphasized than ever because of Vietnam's intricate and diverse river system. These works play an essential role in maintaining stability and ensuring the safety of riverside areas against negative impacts from nature and humans. These works not only contribute to preventing erosion and landslides but also protect infrastructure, agriculture, and people's lives from threats from natural disasters such as floods and changes in water flows. In fact, the construction of riverbank protection projects is a crucial preventative measure to reduce monetary and social losses in the face of more complicated and unexpected climate change.

Although riverbank protection works are built to protect riverside areas, many of them have encountered serious incidents. In Vietnam, riverbank erosion is becoming an increasingly worrying problem, especially in the Mekong Delta. These incidents not only cause significant property damage and reduce agricultural land area but also directly threaten the lives of millions of people living along the riverbanks. A typical example is the Tien River embankment project at Binh Thanh market, Thanh Binh district, Dong Thap province, with a total investment of more than 90 billion VND, which has experienced three serious landslides since 2016 [1]. Similarly, the Can Tho river embankment project under the climate change response program, with a total length of nearly 52 km and an investment of approximately 11 trillion VND, has also faced serious problems with subsidence and cracking [2]. In addition, the anti-erosion embankment project at Phu Da islet, in Cho Lach district, Ben Tre province, which started construction in November 2019, also encountered landslides on the southern bank when the project was about to be completed for handover. [3]. Similarly, the embankment project in the Resettlement Area - Long Hau Residential Area, along the right bank of Rach Doi River, Long Hau Commune, Can Giuoc District, Long An Province, had cracks appearing on the pile system after only about 6 months of construction (Figure 1a, b, c, d).

Figure 1. *Some typical images of embankment incidents*

It is extremely necessary to investigate and determine the reasons of riverbank protection incidents due to their growing frequency and severe repercussions. Understanding the causes not only helps to solve the problems that have occurred but also has important implications for preventing and improving the quality of future works. This paper aims to propose a scientific and comprehensive process for identifying the causes of incidents in riverbank protection works. This process is built on advanced approaches, including investigation, field surveys, document collection, and analytical experiments. Thereby, the paper will provide a strong theoretical and practical foundation, which managers and engineers can apply to improve the quality and durability of riverbank protection works in the future.

2. Overview of riverbank protection works incident

Riverbank protection structure failure is a phenomenon in which part or all of a structure built to protect riverbanks from natural or human impacts is damaged, destroyed, or loses its original function [4]. Failure can occur suddenly or develop gradually over time, causing serious impacts on human safety as well as damage to property and the environment. Riverbank protection structures often include structures such as embankments, levees, and erosion control systems. When failure occurs, not only does it cause direct property damage, but it also causes environmental consequences, such as land loss, water quality degradation, and the collapse of riverine ecosystems.

2.1. Incident Classification

Riverbank protection engineering failures can be classified into four main groups based on their characteristics and consequences:

2.1.1. Destruction

When all or a significant portion of the riverbank protection structure fails, rendering it incapable of providing protection, this is the most dangerous type of incident. Common causes of collapse are often related to factors such as strong currents, water pressure, and sudden changes in geological or hydrological conditions.

2.1.2. Deformation

Deformation occurs when a structure bends, tilts, or changes shape from its original design, resulting in reduced protective performance. Deformation is often the result of uneven water pressure, subsidence of the ground, or poor-quality materials.

2.1.3. Displacement

This is a phenomenon when a part of a structure is moved from its original position due to the impact of water flow or earthquake. Dislocation can cause the structure to lose its stability and lead to more serious problems if not promptly corrected.

2.1.4. Functional Failure

The structure is structurally sound but does not perform its intended protective function. For example, the drainage system may not function properly, leading to flooding, or the structure may lack the expected resistance to erosion. This may be due to inappropriate design for the conditions or deterioration of materials over time.

2.2. Some reasons

Riverbank protection engineering failures can be caused by many different factors, but can be divided into three main groups:

2.2.1. Natural causes

Natural conditions such as flooding, strong currents, natural erosion, climate change, and sudden geological changes can place great stress on riverbank protection structures. These factors are often uncontrollable and require structures to be designed with a high level of safety to withstand these impacts.

2.2.2. Causes from design and construction

Incidents can arise from errors in the design and construction process. Designs that do not match actual geological conditions, errors in load calculations, or the use of poor - quality materials are common causes. In addition, improper construction and lack of close supervision also contribute to incidents.

2.2.3. Causes from human factors

Incidents can occur due to human intervention, including illegal exploitation of resources, changes in river flows, or uncontrolled construction activities in riverside areas. These actions can weaken the structure of the structure or create unfavorable conditions, leading to incidents:

3. Proposed content to determine the cause of the incident

When a construction incident occurs, the relevant parties are responsible for implementing the procedures according to the provisions of law. Specifically, according to Article 47 of Decree 06/2021/ND-CP [5], the investor, owner or manager, user must prepare an incident record. At the same time, Clause 9, Article 2 of this Decree stipulates the conduct of construction inspection. This inspection process aims to assess the following factors: (1) cause of damage; (2) value of the construction; (3) duration of use; and (4) other technical parameters. Inspection methods include monitoring, testing, combined with calculation and analysis. This process applies to construction products, construction parts, or the entire construction project.

To determine the cause of incidents in riverbank protection works accurately and scientifically, it is necessary to detail the implementation steps [6]. This process includes organizing an investigation team, surveying the scene, collecting relevant documents, conducting additional surveys, and analyzing the cause of the incident. Each stage plays an essential role in identifying the factors that led to the incident and providing appropriate and effective solutions.

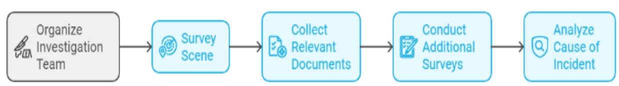

***Figure 2.** The sequence of determining the cause of the incident*

3.1. Investigation organization work

The first step in the incident investigation process is the establishment of a specialized investigation team. This team will include experts from various fields such as civil engineering, geology, hydrology, and building materials. A clear division of labor is important to ensure that all aspects of the incident are fully and comprehensively considered. Investigation team members will be assigned tasks based on their expertise, from data collection, and technical analysis, to final conclusions.

To ensure accuracy and reliability during the investigation, it is necessary to mobilize experienced experts and use advanced technical equipment. Tools such as geological survey equipment, thermal imaging cameras and material testing instruments should be deployed to collect and analyze detailed and accurate data. In addition, cooperation between domestic and foreign experts can provide diverse perspectives and bring innovative approaches throughout the investigation process.

3.2. Site survey

Site investigation is the next step in the incident investigation process. This involves careful observation and detailed recording of the current condition of the riverbank protection structure. Important information to be recorded includes the physical condition of the structure, signs of damage or deformation, especially the main load-bearing structure.

To get an overall and detailed view of the current status of the project, taking photos, filming, and creating a current status diagram is extremely necessary. These documents not only help to store information visually but also serve as a basis for comparison and analysis in the next steps. Creating a detailed current status diagram with full elements such as location, size, and condition of the project components contributes significantly to the process of analyzing the cause of the incident.

Table 1. *Some contents of the field survey*

No.	Survey content
1	Survey of the main load-bearing structure of the project
2	Determine the structural load-bearing surface of the project
3	Survey of cracks and damage to existing structures
4	Local survey of the quality of each type of load-bearing structure of the project
4.1	Typical concrete strength measurement
4.2	Typical steel survey
4.3	Measurement of tilt and settlement displacement

3.3. Collect documents

Collecting documents related to design and construction quality management is an important and indispensable step in the investigation process. These documents include design drawings, construction documents, acceptance reports, and other related documents. This helps to check the accuracy and reliability of the steps from design to construction, and detect errors or differences from the current status. Details for the content of structural survey and construction quality management are presented in Table 2.

Table 2. *Some documents to collect*

No.	Content
I	**Construction structure design documents**
1	Approved construction design documents
2	Structural design calculation explanation
3	Design review report
4	Appraisal report (if any)
5	Design adjustment documents (if any)
6	Geological and hydrogeological survey records
7	Pile profile: Static pile test (if any)
II	**Construction quality management records**
1	Design changes during construction
2	As-built drawing
3	Quality control plan
4	Certificate of origin, product labels
5	Certificate of conformity, declaration of conformity
6	Results of observation, measurement, experiment (if any)
7	Minutes of acceptance of construction work
8	Results of control experiment (if any)
9	Construction equipment quality management records
10	Construction operation and maintenance process
11	Agreement document of competent authority
12	Construction incident resolution file
13	Existing appendix needs correction
14	Minutes of completion acceptance
15	Construction diary

In addition to technical documentation, it is also important to gather information from stakeholders such as contractors, supervisors, and residents living near the construction site. Testimonies from those who directly participated in or witnessed the incident can provide additional perspectives and data to support the analysis.

3.4. Additional Survey

It is necessary to conduct additional surveys and measurements to document topography, geology, and hydrology.

Additional geological surveys are carried out through the method of rotary drilling with a water pump using a terrestrial sample tube, with the depth of the borehole equal to or deeper than the boreholes stated in the design documents. It is recommended that two boreholes be set up so that they may be compared to the old survey documents and provide new, more precise geological characteristics that are not available in the old geological documents. This will serve as the foundation for calculations, inspections, and verifications [7].

Table 3. *Some contents of geological survey work*

No.	Job Description
1	SPT Experiment
2	Experiment on 9 soil physical parameters
3	CV Consolidation Test
4	Uniaxial compression test
5	UU triaxial compression test
6	CU triaxial compression test
7	Prepare report

Conduct additional topographical [8] and hydrological surveys to assess the level of change in the current status compared to previous design survey records.

Table 4. *Some contents of topographic and hydrological survey work*

No.	Job Description
1	Measure the map at scale 1/200, contour lines 0.5m
2	Survey the riverbed cross-section within 100m for each cross-section
3	Collect regional hydrological data (if available)
4	Elevation survey and Max, Min water level investigation

3.5. Root cause analysis

Following the collection of all survey and testing data, the data must be analyzed to identify the reason for the failure. This process involves identifying the immediate causes (the factors that led to the failure immediately) and the root causes (the latent, long-term factors that caused the failure). The immediate cause may be a strong current that caused the collapse, while the root cause may be a design or construction defect.

During the analysis, methods such as elimination and comparison are applied to determine the cause of the problem. The elimination method helps to eliminate factors that are irrelevant or unlikely to cause the problem, while the comparison method focuses on comparing the actual condition with design and construction standards to detect differences that may cause the problem. The results from this process will form the basis for accurately determining the cause and proposing appropriate remedial measures.

4. Some common causes of problems

Riverbank protection structure failures often originate from a variety of causes, which may be related to different stages of the construction and operation process, including survey, design, and construction. Each stage has its own risks that can lead to failures if not performed properly and strictly controlled.

4.1. Survey phase

The main cause of failures in riverbank protection projects is errors in geological assessment of the construction site. Inaccurate geological assessment can lead to incorrect site selection, application of technical solutions that are not suitable for the ground conditions, or ignoring potential risks such as landslides, erosion or subsidence. These factors can potentially reduce the stability of the project, leading to serious incidents such as collapse or deformation.

In addition to geological factors, other factors such as flow, water level, climate conditions, and human impact also need to be carefully surveyed. Failure to assess these environmental factors can lead to inappropriate design and construction of structures for actual conditions, thereby increasing the risk of incidents. For example, failure to properly assess the level of erosion caused by flow can cause structures to succumb to the force of water, leading to collapse or rapid erosion.

4.2. Design phase

The design of riverbank protection structures must be based on the actual data collected from the survey process. However, if the design does not accurately reflect the actual conditions on the ground, such as by using an incorrect computational model or not taking into account the full range of risk scenarios, the structure will not ensure the necessary durability and safety. An inappropriate design can leave the structure unable to withstand natural forces, such as strong currents or changes in water levels, leading to the risk of failure.

In addition, load calculations are a crucial part of building design. If there are errors in this process, the building may be overloaded and lead to deformation or collapse. For example, failure to properly calculate the forces from water flow, groundwater pressure, or loads from external influences such as traffic and adjacent structures can cause serious problems during the operation of the building. These errors often lead to failures within the first years of the building being put into use.

4.3. Construction phase

Construction quality is a key factor affecting the durability and safety of a project. When the construction process does not comply with technical standards and design requirements, problems can easily arise. Using poor- quality materials, not ensuring the compactness of the ground, or violating the concrete pouring process can all reduce the load-bearing capacity of the project. Problems arising from poor construction are often difficult to fix and require high repair costs.

In many situations, construction may need to be modified from the original plan due to unforeseen factors such as weather conditions or new geological discoveries. If these changes are not updated and adjusted in the design in a timely manner, or without close monitoring, they may cause problems in the future. Substitution of materials or modification of construction methods without a full impact assessment can lead to deterioration of the quality and stability of the structure.

Details of some common causes are listed in Table 5.

Table 5. *Some common causes of problems*

No.	Some common causes
1	Because the topographic, hydrological and geological data used for design work is too different from reality (based on re-measured topographic, hydrological and geological survey data).
2	In cases where the terrain, geology, and hydrology do not change significantly, it may be due to the design consultant entering incorrect input parameters during design calculations or creating an inaccurate calculation model, causing erroneous calculation results.
3	Due to construction methods with many additional live loads compared to construction methods and calculations of design consultants.
4	Due to inaccurate measurement, positioning, sequence and detailed construction methods, not ensuring safety according to current regulations and procedures.
5	Because input materials and construction quality do not meet the required quality.
6	Due to ships, barges or equipment with large external forces impacting the embankment
7	Due to heavy rain, floods, unexpected natural disasters

5. Conclusion

The paper presents a scientific and systematic process to identify the causes of failures in riverbank protection works in Vietnam, based on current regulations. Through the study, the main causes such as changes in flow, water pressure, errors in the design and construction process, along with human impacts have been identified as the main factors causing the failures. The proposed process, including the steps of field survey, collection of documents related to design and construction, and conducting analytical experiments, has shown to be effective in identifying the root causes of the failures. The research results not only provide a solid theoretical foundation for failure analysis but also propose useful solutions to improve the quality and durability of riverbank protection works in the future. Implementing these solutions will help reduce risks and ensure safety for riverside areas, especially in the context of increasingly complex climate change.

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